The financial inputs required to appropriately adjust domestic and international spectrum prices and benchmarks

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Executive summary

The ACMA intends to undertake a benchmarking exercise to inform the future value of expiring spectrum licences (ESLs) that may be renewed in future. The ACMA has sought advice on the methodologies and financial inputs required to adjust spectrum licence price benchmarks. We expect the ACMA will obtain domestic and international price benchmarks in a raw form that will most likely be time inconsistent and incomparable to each other and the future value of ESLs. Therefore, a key issue will be how to best convert historical benchmark licence prices with different licence periods, to ensure they are consistent and comparable to the characteristics of ESLs, given changes in fundamental value that occur over time, including changes in the market circumstances that influence value.

We break down the process of converting historical observed prices into time-consistent and comparable benchmarks for ESLs into the following steps:

- Step 1: Determines an annual price benchmark by allocating the observed prices for benchmark spectrum licences (including upfront and ongoing price components) over the benchmark licence durations. We propose using a simple present value/annuity with payments discounted by an appropriate weighted average cost of capital (WACC).
- Step 2: Carries forward the annual price benchmark determined in step 1 to a contemporary benchmark year (for example, FY2026). We propose using an index that reflects changes in the value of spectrum over time.
- Step 3: Carries forward annual price benchmark to the start dates for the potentially renewed ESLs. We propose beginning with the median of the annual price benchmarks and carry forward that value using the same approach in Step 2.
- Step 4: Determine an ESL benchmark price by calculating a present value of the annual price benchmarks applied for the duration of the ESL. We propose using a simple present value using an appropriate WACC.

Summary of advice: indexing spectrum value

For the purpose of informing the future value of ESLs that might be renewed we propose an index based on Mobile Service Revenue (MSR) adjusted for mobile spectrum in megahertz (MHz) held by Mobile Network Operators (MNOs) and population. We have proposed such an index for the period from 2005 to 2025 based on best estimates of MHz held, as well as an index weighted for different values of low band, lower mid band and upper mid band spectrum held.

There are a number of factors that likely affect the valuation relationship between MHz held and MSR generated by MNOs including the changing value-in-use of spectrum over time (particularly for upper mid band spectrum through a twenty year benchmark period), metro v regional spectrum holdings, the lumpiness of spectrum allocations at a point in time relative to continuous change in data usage and related revenue, and different outcomes across the three (or more in some years) MNOs. There is also a related issue of matching the wireless revenue generated with the relevant spectrum held by MNOs.

A key issue is the impact of mobile termination access services (MTAS) on MSR, particularly with changes in the regulated rate over the twenty year period. The change in the regulated rate in January 2016 had a significant negative effect on MSR. To the extent MTAS reflects balanced payments between MNOs, the reduction had a limited effect on value derived from spectrum. However, a material proportion of MTAS, and probably an increasing proportion,

is derived from other service providers and represents a valuable contribution to MNOs. We have not made any adjustments to the MSR index for MTAS on the basis that MSR as reported is a ready proxy for spectrum value, ad hoc adjustments to it undermine that utility and, we consider, have little impact on the index outcome over time.

These issues are manageable in our view, based on our initial work on such an index. And worth pursuing given that, MSR and MSR/MHz/pop are readily available, reported and audited regularly by MNOs and is the key driver of MNO assessments of future expected cashflow from wireless services (along with MSR drivers such as subscribers, data usage and ARPU).

Against that, to be reliable from an investment viewpoint such an index should be: (i) a reasonably reliable indicator of valuation; (ii) relatively simple to model and replicate; and (iii) consistent over time subject to considered policy development. Such an index would be reliable both for short term wireless service decisions as well as long term network investment decisions, and so consistent with the objectives of the Act.

International benchmarks may also inform the future value of ESLs in Australia although the underlying relationship between expected cashflow, MSR and MSR/MHz/pop may play out differently in different market settings including differences in end user demand, MNO competition and other supply side differences including the scale of operations as well as policy and regulatory differences. We note the government's stated concern about the significant challenges of Australia's particular geography.

There are several other valuation indexes that are available to the ACMA including production and consumption indexes. However, these typically appreciate value within some defined process and don't appear to accommodate significant changes and possible reductions in asset values that may occur for a period when expectations adjust.

Summary of advice: allocation of a given value of spectrum over a licence period

For the purpose of duration adjustments and/or allocating a given spectrum value over the duration of a licence, there are a number of approaches we consider including: a straight-line depreciation; a discounting of value through the life of the licence using a WACC value; and a tilted annuity approach to discounting.

The allocation process we propose involves converting benchmark prices into annual amounts using an annuity calculation, and then reconverting into upfront prices for ESLs. This would allow for a comparable valuation of licences of different duration, assuming the same start date and expectations at that date. The variation in value through the licence period is then a matter of the choice of allocation approach. There are alternative approaches to the conversion into annual prices, which would lead to the same outcome. However, we consider an annuity is a relatively straightforward and readily understood.

In considering these alternative approaches, particularly in the case of duration adjustments there is an important distinction between allocating an established value through the spectrum licence period and redetermining value at a point during the licence period. The value of a twenty-year licence for spectrum made in 2021 would have been based on expectations at that time, of which 15 years will remain in 2026. The value of a 15 year licence for the same spectrum in 2026 will depend on whether the 'depreciated' 2021 value is applied, with 15 years remaining, or whether a new valuation is determined in 2026 based on expectations then of the next 15 years.

In economic theory the two fifteen-year valuations in 2026 will be equal if economic depreciation is used to adjust the value of the 2021 licence in 2026. However, that can only

be done *ex post*, based on all the new information learned over the five-year period that feeds into new expectations in 2026.

In practice, the holder of a 2021 twenty-year licence has carried (and managed) the risk of expectations between 2021 and 2026. Whether a 15-year licence for the same spectrum in 2026 should be set based on the remaining value of a 2021 twenty-year licence or a reset in 2026 based on revised expectations depends on when the transactions were considered and committed, that is when expectations were set, risk was accepted, and the spectrum licence was contracted.

The same distinction will also apply to licences issued, say, in 2028 versus 2033. Even though both dates are well into the future, expectations of future cashflow that determines value in 2033 may be very different to those of 2028.

In either case, once valuation is established, the allocation of value through the licence period will depend on which of the options best allocates the given value through the licence period. This is unlikely, in our view, to be a tilted annuity which pre-supposes some constant variation in valuation through the licence period.

It may be that discounting using an appropriate WACC best replicates the discounting of expected cashflow (that may be generated by the spectrum licence) through a given licence period. However, given the uncertainties about the future and realisation of expectations, a straight-line approach may provide a more conservative view. We note the MNOs and NBN Co use a straight-line approach to amortise spectrum over the relevant licence period based on the conservatism principle in financial reporting.[1]

The ACMA's specific questions

Is the tilted annuity formula we use for duration adjustments still fit for purpose? Or are there other appropriate methods to adjust/standardise spectrum values / benchmarks?

The titled annuity approach is not an appropriate approach for duration adjustments of a given licence value. Its fitness for purpose depends on whether a path of variation in value through the licence period can be predetermined at the beginning of the period and held constant over that period.

Such a presupposition may have seemed appropriate 10-20 years ago when the mobile market was growing consistently, and expectations were for good ongoing growth. However, as it turned out, valuation wasn't tilted in any predetermined way and value in use clearly declined for a period after 2015, and expectations have since been reset. The outlook for the mobile sector over a ten year forecast period, much less twenty years, suggests such an approach is fraught with uncertainty.

A simple WACC approach may best replicate discounting (including risk) built into expectations about the long-term value of spectrum. A more conservative approach would simply amortise the value, once set, on a straight-line basis over the life of the licence.

Indexing ESL prices using titled annuities may not offer an appropriate matching of the (indexed) price over the life of a renewed licence because the value in use is likely to vary considerable through the licence period. Indications from MSR and mobile EBITDA suggest

[1] The conservatism principle is well-established in generally agreed accounting principles (gaap). It guides that in the context of uncertainty a company should always err in favour of the most conservative estimate of costs and losses in reporting financial outcomes and position. For spectrum that typically means straight-line amortisation. Spectrum value is reviewed regularly by the MNOs and NBN Co and, if circumstances warrant, carrying value may be written down to a recoverable value where this is less than the carrying value. We note, financial reporting has a different purpose to that of informing economic decision making.

that there are periods, sometimes of several years' duration, when value in use is above average and periods when it is below average. Indeed, the value in use may fall from one year to the next, or over several years depending both on events beyond the control of licence holders (eg Covid-19 lockdowns) and events which reflect poor investment or strategic decisions and poor operational outcomes.

What type of WACC (e.g., pre-tax, post-tax, vanilla WACC) and what rate of WACC and projected cashflow growth should we be using for duration adjustments and why? We note that we have most recently used a 5.5% post-tax WACC and 2.5% cashflow growth those inputs have not been updated for several years.

The choice of WACC (pre- or post-tax, and real or nominal) should be matched to the type of cashflows the WACC is being applied to. For example, a nominal pre-tax WACC should be applied to nominal pre-tax cashflows, and a real post-tax WACC should be applied to real post-tax cashflows.

We propose using a value-in-use index, which measures cashflows before tax and in nominal terms. Therefore, we would recommend a nominal pre-tax WACC.

If the ACMA adopts the most recent ACCC methodology for determining WACC, and using contemporary inputs, the nominal pre-tax WACC would be 8.9% to 9.8%, depending on low or higher equity risk assumptions.

When analysing prices for older licences used as benchmarks, should we be using historic or current WACC and cashflow growth inputs for duration adjustments? We expect that updated inputs will be needed compared with what we currently use in our tilted annuity formula for duration adjustments.

When allocating upfront licence prices into annual prices, or aggregating annual prices into an upfront price, the ACMA should use a WACC that is appropriate for the date at which the licence price was paid. We provide a model for estimating historical WACCs to use for historical price benchmarks, using the most recent ACCC methodologies, but with historical input values.

We do not recommend using a WACC as an index to carry prices forward to contemporary dates. The WACC reflects a licensee's cost of obtaining funds to pay for a licence, but it is a poor proxy for the future expected value the licensee might obtain from the licence. A new spectrum valuation will depend on current expectations which may not closely resemble previous expectations, and the difference can't be reconciled with a WACC.

We recommend using a MSR/MHz/pop index to carry spectrum licence benchmark prices through time, as that best reflects changes in the value of spectrum over time.

What options should we consider in determining prices for ESLs that reflect the timing of the new licence commencement dates? For example, how do we set a nominal price for a new licence starting in 2028 versus 2032?

Licence prices set in 2028 should be based on valuations driven by expectations in 2028.

Licence prices set in 2032 should be based on valuations driven by expectations in 2032.

Auctions for the same spectrum in each of these two years would likely reflect different valuation expectations in each of the two years, informed by the market developments in each of the two years.

Absent an auction or similar form of contested and informed consideration, the most readily available indicator of changes in expectations for mobile spectrum is mobile service revenue, or mobile service revenue adjusted for the spectrum (in MHz) held by MNOs required to generate MSR and population. We note the revenue generating capacity of different bands

of spectrum may vary over the intervening period which may require [adjustments] to an MSR/MHz/pop index.

The only exception to using expectations at each time period would be if the 2032 licence is valued, considered and transacted in 2028, ie that is based on expectations made in 2028.

Are there other considerations that we should be mindful of when adjusting and comparing international benchmarks for estimating the value of particular spectrum licences/bands?

Market circumstances that determine valuations may be quite different across different countries.

- Potential or expected wireless service revenue which may vary due to country specific factors such as relative GDP and usage.
- The extent of competition for service revenue, including from fixed services.
- Rivalry and bid tension at auction.
- Differences in population density noting Australia has large areas of network and spectrum coverage with sparse population that would tend to dilute the average value of national spectrum.

1 Introduction

The ACMA intends to undertake a benchmarking exercise to inform the future value of ESLs that may be renewed in future. There is a substantial amount of spectrum previously allocated by ESLs, in high value bands. For example, ESLs cover 65% of the total licenced spectrum in the 700/850/900 MHz range and 100% in the 1.8-2.5 GHz range.[2] Therefore, its valuation will have a material impact on the operation of businesses and other organisations that hold ESLs.

The ACMA has sought advice on the methodologies and financial inputs required to adjust spectrum licence price benchmarks to ensure they are appropriately comparable with each other and with potentially renewed ESLs. In particular, it seeks advice about appropriate use of WACC and cash flow growth assumptions when standardising licences of different durations, and discounting or inflating historic values to common and contemporaneous timeframes.

We expect that the benchmarking exercise will include international and domestic prices for similar spectrum licenses that were purchased some time ago, that begin at different dates, that might have upfront and ongoing price components, and that are for different durations. To account for these differences, we expect the ACMA will need to make a number of adjustments to ensure comparability and time-consistency between each of the benchmarks and with potentially renewed ESLs.

Any adjustments will need to be consistent with the ACMA's general approach to valuing spectrum, the objectives of the *Radiocommunications Act 1992* (the Act) and the Ministerial Policy Statement (the MPS) issued on 7 May 2024.

This report provides advice on alternative adjustments, and the key inputs for those adjustments, that would help ensure the ACMA's price benchmarking will inform the future value of ESLs in a way that promotes the long-term public benefit.

The rest of this report is structured as follows:

- Section 2 discusses the general principles for valuing spectrum licences that we refer to in our analysis.
- Section 3 discusses alternative methodologies that can be considered by the ACMA to help ensure comparability and time-consistency between the price benchmarks and potentially renewed ESLs.
- Section 4 sets out an approach to measure the WACC, which is a key input into the discussed methodologies.
- Section 5 sets out an approach to estimate a value index, a key input into the discussed methodologies.
- Section 6 summarises ITU spectrum valuation methodologies.

2 General principles for valuing spectrum licences

Spectrum is a scarce natural resource and a key input into communications and other services. It is finite in available bandwidths although technology developments have

[2] See ACMA, *Approach to Expiring Spectrum licences: Consultation Paper*, May 2023, Tables 1 and 2.

expanded the useful range of bandwidth for communications services. It is limited by geographical range although varying transmission power may expand coverage. Unlike many other natural resources, electromagnetic spectrum cannot be depleted. As well, use by some users can cause interference that impacts the usefulness of spectrum to other possible users.

Owing to limits on the useful range of spectrum and propagation and data carriage differences across different bandwidths, the need for its licensing and efficient allocation of licences is appreciated by regulators, service providers and investors. The ACMA is given the role of licensing spectrum to ensure there is a sole right of use to avoid interference and congestion, and to price that spectrum to help ensure it is allocated to the user that values it the most.[3] In undertaking its role, the ACMA is governed by legislative, regulatory and policy instruments, and subject to the economic principles of valuation.

Before discussing the legislative and economic frameworks governing the ACMA's role, it is worth drawing a distinction between the following measures or indicators of spectrum value:

- Fundamental value: A value that is defined by general (and market) equilibrium and disclosed in a transaction such as a spectrum auction. We consider this fundamental because it is based on a 'consideration' where parties have weighed up their willingness to pay against expected outcomes and have made a transaction priced against this consideration.[4]
- Value-in-use: From a final consumer perspective, it is the amount of utility gained by end users in their use of wireless services and reflected in their willingness to pay for such services. From a licensee perspective, it is the discounted future net cashflows that licensees expect to earn from final consumers purchasing their wireless services (noting wireless services are supplied jointly by network infrastructure and spectrum).
- Benchmark value: A value disclosed in a comparable transaction, say for similar spectrum in comparable markets and/or subject to adjustment for any quantifiable differences.
- Value indices: Are a means of interpolating or extrapolating the above valuation measures that are provided periodically through transactions or benchmarks. For example, value-in-use indicators such as MSR or EBITDA might provide a basis for calculating a value index. While indices might guide valuations, they aren't themselves valuations, at least not until there is a transaction based on them.

The rest of this section summarises the ACMA's governing instruments (Section 2.1), use of general equilibrium asset pricing to determine fundamental value (Section 2.2), distinctions between benchmarking prices and fundamental value (Section 2.3), and the principles for measuring change in fundamental value over time (Section 2.4). The discussion in this section is intended to inform the ACMA's benchmarking exercise generally, and the adjustment of benchmarks for time consistency and comparability, specifically.

3 ITU, *Methodologies for valuation of spectrum*, 2017, p. 3. See also our summary in Section 6.

4 Much the same as 'consideration' in the legal contract sense where there is an expectation of an exchange of value.

2.1 Governing legislative, regulatory and policy instruments

In considering whether or not to renew ESLs, and in undertaking benchmarking to support such decisions, the ACMA is principally governed by the Act.[5] The object of the Act is to promote the long-term public interest derived from the use of the spectrum by providing for the management of the spectrum in a manner that:

- facilitates the efficient planning, allocation and use of the spectrum; and
- facilitates the use of the spectrum for commercial purposes and defence purposes, national security purposes and other non-commercial purposes (including public safety and community purposes); and
- supports the communications policy objectives of the Commonwealth Government.[6]

The ACMA has confirmed the role of the public interest framework in its consideration of ESL renewal applications, and identifies five public interest criteria that it proposes underpin the ESL process:

- facilitates efficiency;
- promotes investment and innovation;
- enhances competition;
- balances public benefits and impacts; and
- supports relevant policy objectives and priorities.[7]

On 7 May 2024, the Minister for Communications, the Hon Michelle Rowland MP (the Minister), issued an MPS in relation to ESLs.[8] The MPS sets out five key communications policy objectives that the ACMA must have regard to, including:

- supporting service continuity for end users, particularly where no alternative service is available;
- facilitating opportunities for new entrants and use cases, including for low earth orbit satellites;
- connectivity and investment in regional and remote areas to deliver improved services to end users;
- promote competition; and
- capacity for sustained investment and innovation.

The MPS followed a letter from the Minister to the ACMA in December 2023 “to indicate my support for the comprehensive approach proposed by the ACMA, to set out some of my

5 The ACMA is also subject to the *ACMA Statement of Expectations*, 7 December 2022.
6 S.3 of the Act.
7 ACMA, *Approach to Expiring Spectrum Licences: Consultation Paper*, May 2023, p. 2.
8 Minister for Communications, Ministerial Policy Statement Instrument, 7 May 2024, Federal Register of Legislation.

policy objectives for the ESL process, and to request that, as part of its process, the ACMA explore and advise on the merits of alternative licensing conditions."[9]

In that letter the Minister proposed policy priorities that the MPS could specify, and these were consulted with stakeholders in the following period. The Minister noted that "finding a balance between these priorities will be challenging", but asked the ACMA to actively consider these as it takes this work forward.

The Minister also noted the following:

- Some submissions to the ACMA's ESL consultation process "raised alternative licensing conditions that have not previously been used in Australia. Such licence conditions have been adopted in overseas jurisdictions, with the aim of improving, for example, coverage or service choice for consumers."
- The House of Representatives Standing Committee on Communications and the Arts recently tabled its report on co-investment in multi-carrier regional mobile infrastructure. The Committee identified access to spectrum as a barrier for connectivity in regional, remote and First Nations Australian communities, and included recommendations regarding the consideration of licensing conditions.

The Minister noted the unique challenges faced in Australia because of "our vast land mass and dispersed population may mean that these alternative licence conditions may not be the most effective mechanism to deliver broader coverage or choice". However, she considered that the ESL process offers an opportunity to comprehensively consider different licensing arrangements.

The Minister asked that the ACMA develop a considered view on the use of alternative licensing conditions in the Australian context including, but not limited to:

- roll-out obligations and their effectiveness in achieving broader coverage; and
- use-it-or-lose-it and use-it-or-share-it provisions and their effectiveness in achieving more efficient spectrum use.

The Minister also asked if the ACMA could seek feedback from stakeholders on any issues around resilience and temporary disaster responses that arise in the context of spectrum licenses and their renewal.

The policies outlined in the MPS, and the other matters raised by the Minister, may have implications for the value of spectrum, both to existing licence holders, and prospective and possibly new licence holders as well as the wider community in terms noted by the objects of the Act.

While it is beyond the scope of this report to balance the objectives of the instruments governing the ACMA's role, we assume that the ACMA will meet those objectives by, among other things, (1) allocating all ESL spectrum (either by ESL renewal or a subsequent allocation procedure) to ensure no spectrum is left fallow, and (2) that the allocations are to those who can use the spectrum to generate the highest social and economic value.

In this case, the purpose of the ACMA's benchmarking exercise should be to help understand the long-term future value that potential licensees have for ESL spectrum licences and their willingness to pay for them.

[9] Minister for Communications, letter to the ACMA, 14 Dec 2023. ACMA website.

2.2 General equilibrium asset pricing and fundamental value

Spectrum licenses of 15 or 20 years are long-term assets and licence holders, notably network operators, consider them as a long-term investments. They are much the same as network infrastructure, with which the two assets together provide a wireless communications network.

Without over-complicating this exercise, valuation of such assets is well established in financial economics in the related pricing principles of general equilibrium asset pricing and rational (or risk-adjusted) asset pricing. The general equilibrium pricing principles relates to prices set by demand and supply, typically in a market context such as the ACMA's spectrum auctions.

For long term spectrum licences, the supply side is, as noted, a function of technology and regulated spectrum allocation processes including international agreements and standards.

The demand side requires a financial forecast for the value-in-use of the relevant wireless services market, discounted at an appropriate rate including the riskiness of the related cashflow, and noting the interrelated role of spectrum and network investment to provide the targeted capacity required to achieve the expected cashflow. Licensees' cashflow is derived from the downstream demand for wireless services that licensees supply. End consumers in aggregate have a willingness to pay for downstream services that declines with the more services they consume. Operators can charge consumers prices for mobile and wireless services no higher than their willingness to pay and typically less than this in a competitive and/or regulated market. But licensees must incur the costs of network investment and operating and other costs required to supply downstream services. Licensees, at least at the margin, also have alternative options to buying spectrum – they can substitute network investment instead of buying more spectrum if that is a less expensive option.

In a contested market well-informed participants will consider a probability distribution of possible future cashflow outcomes which, when discounted for risk and aggregated, provide a risk neutral outcome. (That is, the aggregate probabilities of all possible outcomes add to one.) They will offer to buy assets based on this information, and if that offer is accepted by a supplier, there will be a market price that defines fundamental value.

The theory has been developed in the context of financial assets which have a secondary market within which asset holders, sellers and potential buyers can trade through the life cycle of the asset. This means that the price of such assets can vary continuously as drivers of value change, rather than periodically as in the case of spectrum. The theory also applies in a context with many informed economic agents, both buyers and sellers.

Is the asset price theory sufficiently relevant in a spectrum market context with few bidders, the key ones already well-established in wireless services and with established networks? The spectrum market may not be as liquid and revealing as markets for financial assets, but the bidders are rational, well informed and (while noting some strategic errors have occurred) are motivated to maximise their value-in-use.

Key points:

- General equilibrium asset pricing is a robust framework for determining the fundamental value of spectrum, as it considers the constraints in the supply of spectrum and the demand for spectrum by potential licensees.

- On the demand side, the value-in-use of spectrum to potential licensees is derived from the discounted future cashflows licensees expect to earn from end customers – their revenues, capital expenditure and operational costs.
- When a licensee buys spectrum from a supplier based on their consideration of value-in-use, this discloses a fundamental value for that spectrum.

2.3 Distinctions between benchmarking prices and fundamental value

Relatively infrequently, regulatory authorities in many jurisdictions, including the ACMA, have sought to 'discover' the fundamental value of incremental blocks of spectrum by carrying out competitive auctions for spectrum licences. Such spectrum auctions are often designed to allocate spectrum to its highest valued use and for bidders to expose their true value-in-use. Bidders are typically very well informed and bid rationally, with constraints on irregular bidding built into auction processes. Therefore, competitive spectrum auctions are likely to result in observable pricing outcomes that reflect the fundamental value of spectrum at a point in time, consistent with general market equilibrium valuation principles.

Prices previously struck for the purchase of spectrum are frequently benchmarked by market participants to extrapolate fundamental value for another spectrum licence purchase at a different time. There are several distinctions to note between benchmarking prices and fundamental value.

First, fundamental values disclosed through transactions are infrequently observed. While asset prices frequently increase and decrease as new information comes to hand (changing expected cashflows, discount rates and risk), spectrum auctions are held only every so often. This is particularly relevant in the case of spectrum which, as we will show, has seen material change in expectations since a relative high point in 2015.

Therefore, while the ACMA might observe spectrum valuations at points in time (i.e. when competitive auctions are held), the ACMA needs a means of measuring how those spectrum valuations change over time to estimate a value at a current or future date (i.e. when/if ESLs are renewed).

Second, benchmarked prices need to relate to similar blocks of substitutable spectrum sold in similar circumstances. Any benchmarking exercise will need to limit the pool of benchmarks and/or adjust the benchmark prices to ensure comparability.[10]

Third, even with similar spectrum and similar population density, dissimilar factors may influence prices and negate the comparability of benchmarks. These may include the extent of competition, the market power and position of bidders, regulatory arrangements and policy settings.

A good example of the impact that particular regulatory settings and extent of competition can have on benchmark spectrum prices was the outcome of the 3.4-3.8 GHz auctions. These included relatively tight regulated competition limits in some areas which led to limited bid rivalry and saw much of the spectrum sell at reserve price. In other areas where there was increasing network-based rivalry prices were bid up to amounts an order of magnitude

[10] Another approach is to undertake statistical regression analysis on benchmark data to account for differences between the things being benchmarked, as has been undertaken by the ACCC to benchmark some regulated wholesale prices. See ACCC, *Domestic Transmission Capacity Service Final Access Determination Inquiry: Final Report*, October 2020. However, the ACMA is unlikely to have a sufficient sample size of benchmark prices to utilise this approach for benchmarking ESLs.

higher. Adjusting for such differences in reviewing the comparability of benchmark prices may be an arduous if not impossible exercise.

Fourth, some benchmarks might inform how licensees value smaller incremental blocks of spectrum but won't typically correspond to how licensees value larger quantities of spectrum.[11] In the present context, the ESLs represent the majority of spectrum held by wireless operators, and are not incremental as such.

Licensees will value their first usable blocks[12] of substitutable spectrum relatively high. This is because they are needed for the licensee to operate in the market for wireless services. As more and more blocks of spectrum are purchased, the licensee's incremental valuation of that spectrum will decline. This is for a number of reasons – at higher levels of output final consumers' willingness to pay is lower and the licensee has greater opportunity to avoid purchasing incremental spectrum and instead build more radiocommunications infrastructure to provide a similar level of service.

Therefore, caution should be taken when using benchmarks for smaller blocks of spectrum and when existing holdings are high, as the observed prices might be poor indicators of the overall value placed on spectrum.

Fifth, generally, competitive auctions tend to set prices that correspond to the second highest valuation of those bidding. Prior to bidding in a competitive auction, well-informed bidders will typically value the increment of spectrum being auctioned at its opportunity cost, by comparing their future net cashflows with the spectrum and their future net cashflows without the spectrum (but with higher network costs and potentially lower quality of service). The present value of the difference is how much better off a potential licensee would be if they obtained the spectrum licence. Rational bidders who value the spectrum licence the most will bid up to their opportunity cost but will stop bidding and win the auction when the party with the second highest valuation drops out. Thus, bidders reveal, and the auctioneer discovers, an approximation of the second highest value of incremental spectrum, whilst allocating the licence to the bidder with the highest value.[13]

It is worth noting that regulatory authorities responsible for the allocation of spectrum in many international jurisdictions might use other pricing methodologies that have no relation to opportunity cost (e.g. direct allocation or beauty contests). Alternatively, they might use international benchmarks themselves to determine prices. The prices for these cases should be closely scrutinised before including in a benchmarking to inform the economic value of spectrum.

The use of direct allocation should be distinguished from circumstances when spectrum is sold by auction at reserve prices. This reveals that licensees have a fundamental value at or above the reserve price and, depending on the auction format, other competitive bidders did not. In such cases some lots might remain unsold, which signals that no potential licensees had a fundamental value for those unsold lots at or above the reserve.

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11 An exception to this is if there is no discrimination in the pricing for spectrum (for example, if the price is constrained to be equal across the larger quantity of spectrum sold).

12 The very first blocks sold might be unusable on their own, until sufficient spectrum is owned to enable the supply of downstream services. In this case, the value of the very first blocks to an individual licensee might be relatively low.

13 While this outcome is true Vickery (second price) auctions, it is also generally true of ascending auctions. See Vickrey, William (1961) "Counterspeculation, Auctions and Competitive Sealed Tenders," *Journal of Finance*, p. 16; Milgrom, Paul (1989) "Auctions and Bidding: A Primer," *The Journal of Economic Perspectives*, Vol. 3 (3), p. 9.

Notwithstanding the above considerations, the prices paid at auctions previously are a useful starting point as these reflect a disclosed valuation in a market transaction where prospective licensees have given great consideration to expected value when making their bids.

Key points:

- While benchmarking prices can be used to compare prices paid for similar blocks of spectrum sold in similar circumstances, care must be exercised in using benchmarks to inform the long-run future value of spectrum.
- Some international price benchmarks might bear no relation to the value of spectrum.
- While carefully selected historical price benchmarks for spectrum sold at auction are a useful starting point to understand future value, consideration needs to be given to how those observed values have changed over time.

2.4 Principles for measuring changes in fundamental value over time

As explained in the previous section, the fundamental value of spectrum is dependent on the demand and supply of spectrum and observed when licensees trade their spectrum at auction or on secondary markets. However, the fundamental value will change over time, in between auctions and secondary market trades, as licensees' value-in-use for spectrum changes. The ACMA will need to consider changes in value-in-use, to carry forward historical observations of fundamental value.

Care needs to be taken in carrying historical benchmarks forward through time to the present. While measures such as prices paid, service revenue generated and margins earned are more rigorous or truer in disclosing value, they are not always readily available, or only available periodically (say at the date of auction) rather than continuously through the period of the licence.

In proposing approaches to setting reserve prices for spectrum the ITU proposes several methods to assess fundamental value, including a producer surplus approach, a production function approach (accounting for spectrum, network and other inputs), and a revenue surplus approach.[14] However, these are information intensive, laborious and, don't necessarily result in a disclosure of fundamental value.

Well-considered indices applied to historical benchmarks may be more practical if they sufficiently reconcile to, or at least reflect, disclosed fundamental valuations, are reliable for stakeholders and time-consistent.

A notable feature of wireless services is that expectations of both demand and supply have shifted over more than three decades of liberalised or market driven mobile services. Both the demand shifts and supply adjustments have changed the nature of the value-in-use of wireless services, and the part of it attributable to spectrum, or allocated to spectrum by mobile network operators.

Over that timeframe, the value-in-use of wireless services in aggregate has expanded significantly. In some periods growth is high, evidently reflecting the introduction of new uses or devices including wireless broadband, smart phones and IoT as well as expansion of

[14] See Section 6 for further details.

bandwidth as technology development has enabled use of previously unusable spectrum. But at other times it has decreased, perhaps due to increasing capital and operating costs as operators invest in the next technology cycle, the effect of new competition and competitors, or reductions in end customers' willingness to pay.

The future revenue a licensee would expect to earn from holding spectrum, relative to not holding spectrum, would likely be the strongest indicator of these changes. Expectations of future revenue will change as market conditions change – at one point in time a licensees might expect revenue growth due to holding spectrum to be 2% and the following year their expectations might change to be 3% growth due to an unexpected change to willingness to pay for example. Another driver is changes in forecast opex and capex. In the long run, expected opex and capex might change with unexpected inflation in the cost of inputs. It would be reasonable to assume that the long run would encompass a business cycle of introducing new technology so this should not affect a value-in-use index. If the opex and capex that is expected to be spent in that business cycle goes up and down from year to year, then that would feature in the index. Changes in the cost of capital would also change value, by changing the way licensees discount future cashflows, but this would likely have a relatively diluted impact on the overall value.

Ideally, we would create an index for how the value-in-use of spectrum changes over time by estimating for each year, licensees' discounted future cashflows from holding spectrum, including:

- mobile (and other wireless) service revenue;
- operational costs, which are also reported financially with the net amount reported as cash earnings or EBITDA; and,
- capital costs for network investment.

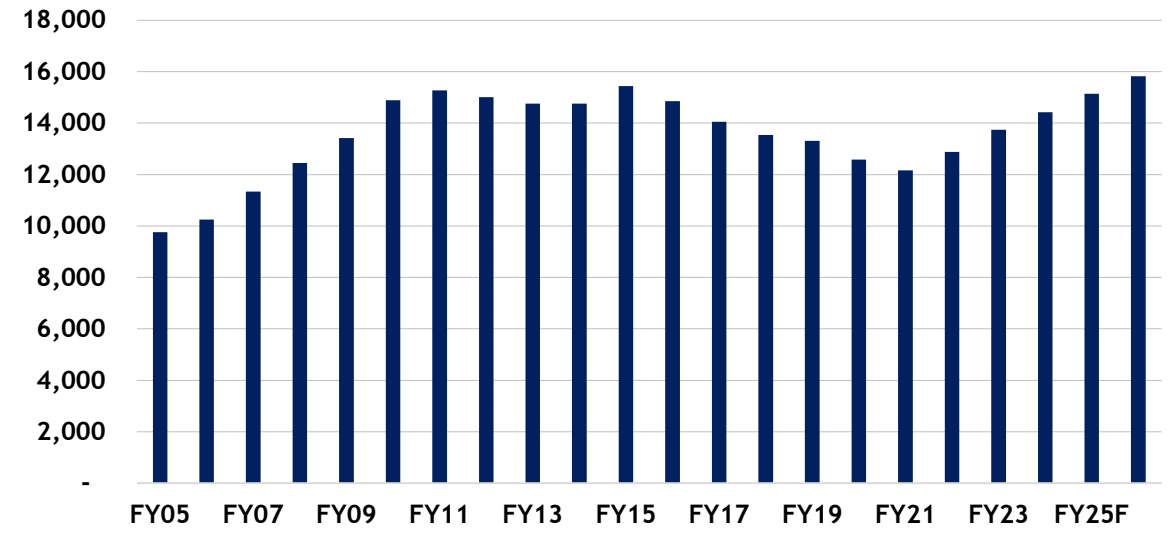
These would be net of the discounted future cashflows the licensee would earn without (or with smaller amounts of) spectrum.

However, this would require a considerable amount of foresight as to the market conditions and market expectations in each year of the index. It is also problematic to do such an exercise independently of the market, that is if the assessor is not actually facing the risk or bearing the consequences of forecasting errors.

Instead, we can observe value-in-use in terms of historical MSR and EBITDA. These figures are reported periodically by the three MNOs, and other wireless operators such as NBN Co. The MSR of MNOs is indicated in the chart below, demonstrating substantial change in value from FY05 to FY23, and across three years of forecasts to FY26.[15]

[15] We should also include fixed wireless revenue of NBN Co and the MNOs as FWA services are supported by the same spectrum. However, FWA revenue is not material over the twenty-year period and reporting arrangements are not well-established across the four companies.

Chart 2.1: Indicative aggregate MNO Mobile Service Revenue (A$m)



Note: Not adjusted for different year end for each of the three MNOs. Includes MNO wholesale revenue but not the retail mark-up of MVNOs. NSR/IMA has made some minor adjustments to some historic MSR items to reflect changes in revenue reporting over time. Notably mobile interconnection has been excluded to avoid double counting across MNOs.

Source: MNO financial reports and NSR/IMA estimates

Although actual or reported outcomes, rather than expected outcomes, the data in the chart above are key inputs to any forecast of future revenue and earnings through a spectrum licence period. The difference between forecasts at any time and what actually eventuated can be material. Notably, in the case of wireless spectrum used to support mobile service, there has been a material change in expected cashflow between the several years to 2015 and the period following, even putting aside the interim impacts of Covid19 on mobile service revenue.

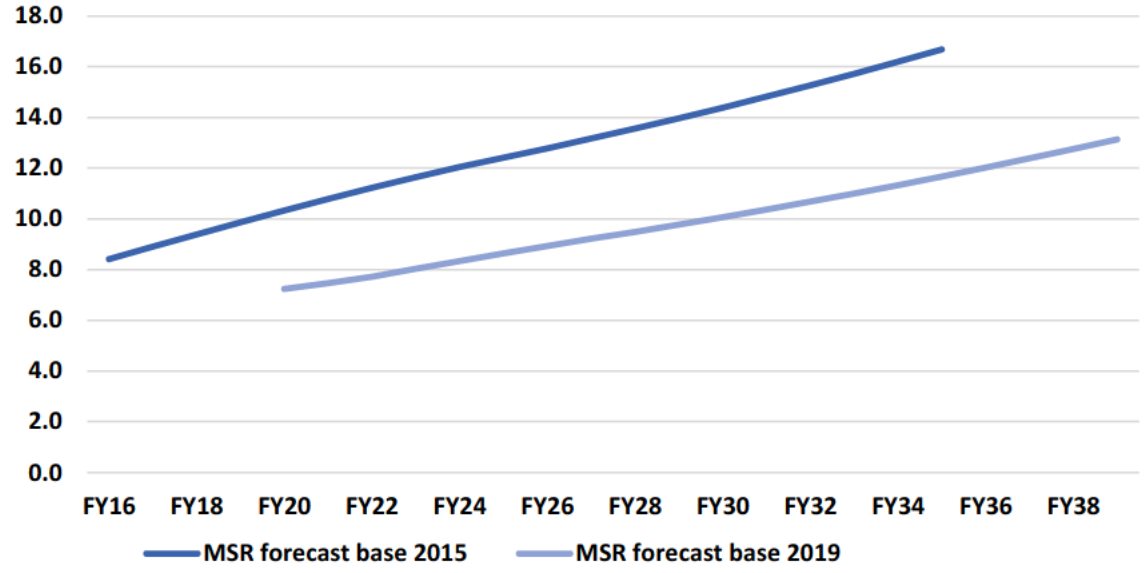
A standard forecast of mobile service revenue in 2016 might follow a typical pattern based on recent trends in subscriber growth and ARPU:

- A three-year specific forecast period based on recent underlying trends at the time would see MSR growth tapering to say 5% by year four.[16]
- A trend period would see MSR growth reducing to 3% pa (i.e. a general long-term growth rate) by year ten.
- And, rather than capitalising growth in year ten, for the purpose of estimating the value of a twenty year spectrum licence, the long-term forecast would continue growth at 3% pa to year twenty.

Discounting the forecast MSR (and adjusted for market share expectations) would inform a bidder's estimate of the capital amount that should be invested to provide capacity and coverage for mobile service, including an optimal mix of network and spectrum. The price at which a bidder may be willing to pay for spectrum to be offered at the next auction would be based on what contribution such spectrum would make to network capacity and coverage including, at the margin, trade-offs between spectrum and network infrastructure.

[16] Market MSR growth mid-decade was dominated by Telstra and, to a lesser extent Optus, although the overall impact over several years was distorted by subscriber loss at VHA. More broadly, the key MSR impact was growth in data usage as 3G services matured and 4G services became well established and expectations about these drove strong MSR forecasts at the time.

Chart 2.2: Indicative twenty-year forecasts of MSR 2016 v 2020 (A$bn)



Note: *2016-35 forecasts based off 2015 MSR and three years average growth to 2015, tapered to 3% pa by year 10. 2020-39 forecast based off 2019 MSR, with recovery from negative MSR over three years to 4% pa, tapered to 3% pa by year 10.*
Source: *IMA/FRC estimates*

A forecast of MSR made in 2020 (pre one-off Covid impacts) based on a similar pattern would provide a much lower twenty year cashflow forecast given the change in recent MSR trends at that time.

The point is expectations of future cashflow change, and with it the price willing to be paid by those that value the asset.

A good analogy is the valuation capital markets apply to companies based on expected future cashflows, or the value of the equity share of such cashflow (i.e. after net debt) in many cases indicated by short term cashflow multiples (such as EV/EBITDA) or price earnings multiples.

An apposite example is Telstra's share price which traded at a high of about $6.00 per share in 2015, due to optimistic forecasts of future cashflow or earnings driven largely by expectations of continued good growth in mobile service revenue at the time.

Telstra now trades at about $3.50, about 42% lower than its 2016 high point with much of the decline a result of lower expectations for its mobile service business (among other things).

Chart 2.3: Telstra share price 2014 to 2024 shows that asset values vary and can decline as expectations change

Note: D represents dividend payments.
Source: ASX.com

Key points:

- Fluctuations in the value-in-use of spectrum make forecasting fundamental value difficult. With different expectations about future innovation in use cases, devices, and radiocommunications technology more generally, the future value-in-use of spectrum might be quite different to the past.
- That said, indicators of changes in value-in-use, such as MSR and EBITDA might be the best of the available and reliable measures.

3 Consistency and comparability of price benchmarks

A key issue in benchmarking historical spectrum prices is how to best apply such prices from previous licence periods to ensure they are consistent and comparable to future licence periods given changes in fundamental value that occur over time, including changes in the market circumstances that influence value. Actual value-in-use realised by licensees might have played out differently to expectations at the time of bidding for a spectrum licence.

Drawing on benchmarks from international spectrum prices carries similar concerns: that actual value realised by those licensees may have played out differently to expectations at the time of the bids; and more, that the market circumstances in those areas were significantly different to circumstances in Australia.

Those differences may extend to revenue expectations including drivers such as the level of service penetration at the time, differences in drivers of end user willingness to pay, competition as well as geographic coverage and regulatory and policy differences. As the Minister noted in her letter to the ACMA of December 2023, Australia faces unique challenges because of "our vast land mass and dispersed population may mean that these alternative licence conditions may not be the most effective mechanism to deliver broader coverage or choice".

Ultimately, benchmarks are only useful in guiding valuation decisions to the extent valuation circumstances underlying them are consistent and comparable, or capable of meaningful adjustment in the case of variations in such circumstances.

The ACMA has sought advice about the financial inputs, including the weighted average cost of capital and cash flow growth assumptions, required to appropriately adjust domestic and international spectrum prices/benchmarks to ensure consistency and comparability.

We expect the ACMA will obtain domestic and international price benchmarks in a raw form that will most likely be time inconsistent and incomparable to each other and the future value of ESLs. The ACMA may need to adjust the benchmarks to ensure they are time consistent and comparable. The ACMA has previously used a tilted annuity approach to adjust price benchmarks for licences with different start dates and durations, however, is considering alternative approaches.

The rest of this section proceeds by:

- Setting out the general steps the ACMA might need to take to adjust price benchmarks for different licence start dates and durations (Section 3.1);
- Discussing the methodological options the ACMA has to carrying out these steps (Section 3.2);
- Discusses the use of the tilted annuity approach previously applied by the ACMA (Section 3.3); and,
- Sets out the impact the different approaches could have on ESL valuations (Section 3.4).

3.1 General steps to account for different licence start dates and durations

The ACMA will observe historical prices paid for spectrum licences purchased at different dates for licences of different durations and will want to compare those to ESL renewal prices on a time consistent basis. For example, a benchmarking exercise might observe a $1/MHz/pop price for a ten-year licence and a $0.50/MHz/pop price for a five-year licence. The ACMA will need to make adjustments to those benchmark prices to ensure they are comparable with each other, and to a renewable ESL with potentially a twenty-year duration and a different start date.

In this section we set out adjustments the ACMA could consider making to ensure historical observed prices can be compared to renewable ESLs on a time consistent basis.

Note that the tilted annuity can be used to carry out Steps 1, 2, 3 and 4, although the particular formula published by the ACMA carries out only steps 1 and 4. To consider alternative approaches, it is helpful to break the steps down into the following separate parts:

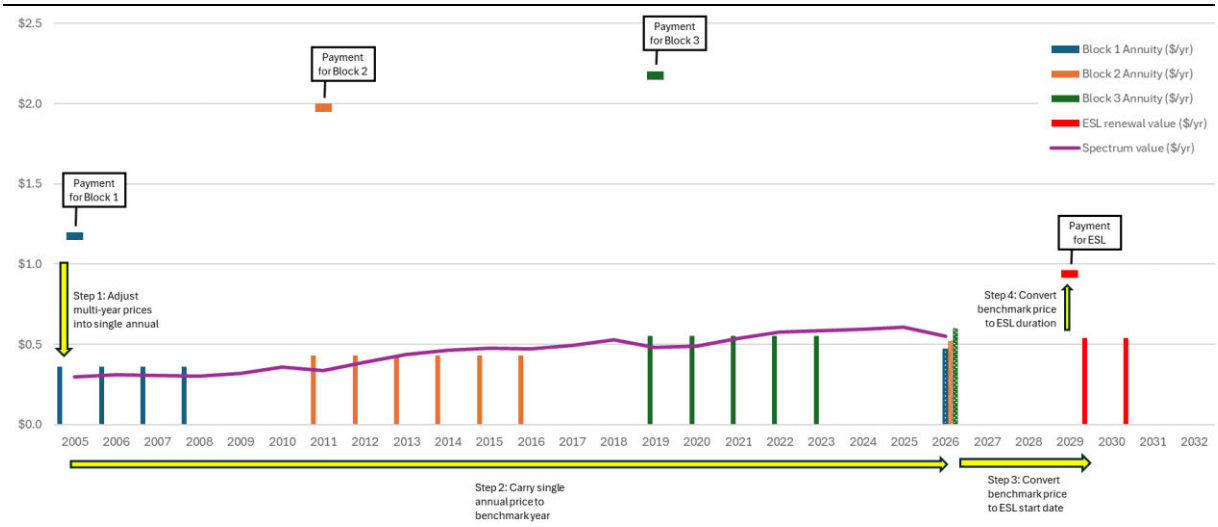
- Step 1: Convert to an annual price: Observed prices for benchmark spectrum licences might be comprised of upfront and ongoing price components, over periods of different durations. The ACMA will need a methodology for consolidating those individual price components into an annual price benchmark that would apply of the duration of the benchmark licence. Using the example above, a $1/MHz/pop price for a ten-year licence and a $0.5/MHz/pop price for a five-year licence might both be converted into a $0.10/MHz/pop/year benchmark price.[17]
- Step 2: Carry forward to benchmark year: The benchmarking will include spectrum allocations that were made at different times, potentially long into the past. The ACMA will need a methodology for adjusting historical single annual price benchmarks to a contemporary benchmark year (for example, FY2026)[18] to ensure time-consistent comparisons.
- Step 3: Carry forward to ESL start date: The ACMA will need to carry the benchmark annual price to the varied start dates for the potentially renewed ESLs.

[17] For this illustrative example, we ignore the WACC, which as discussed below is important for this step.
[18] The earliest potential renewal period for an ESL begins 18 June 2026, in the 2026 financial year.

- Step 4: Convert to single upfront price matching ESL Duration: The benchmark annual price at the proposed renewal start date will need to be converted into an upfront benchmark price that reflects the duration of the ESL, noting that different ESLs might have different renewal periods.

These adjustments are illustrated in the Chart 3.1 below. The illustration begins with three payments for separate blocks of spectrum – a payment for block 1 (blue) which is a four-year licence, a payment for block 2 (orange) which is a six-year licence, and a payment for block 3 (green) which is a five-year licence. Step 1 involves converting each payment (covering licences of different durations) into annual payments for the duration of each licence (the solid blue, orange and green bars). Step 2 involved carrying those annual payment amounts forward through time to a time-consistent annual value in the 2026 benchmark year (the shaded blue, orange and green bars). Step 3 carries forward the median of those benchmark annual prices to the ESL start date and for the ESL duration, which in this example is two years (the red bars). Step 4 involves determining an upfront equivalent payment for the ESL annual benchmark prices.

Chart 3.1: Hypothetical illustration of steps to adjust spectrum price benchmarks



Note: The payment for ESL (red) is the present value of the two annual ESL renewal values, using an 8% WACC index. The two annual ESL renewal values are equal to the median benchmark value in 2026 dollars, carried forward using a 1.25% growth index. The benchmark values in 2026 are equal to the benchmark licence's annual payment amount, carried forward using a 1.25% growth index from the first year of the licence duration to 2026. The annual payment amount is the annuity equivalent of the observed prices paid, calculated using a WACC of 8%.

Source: Flat Rock Consulting

We provide a spreadsheet model in Attachment A, which can be used to input observed prices for benchmark licences and carries out each of the above four steps to determine a time consistent and comparable benchmark for potentially renewed ESLs.

3.2 Different methods for carrying out each step

Each of the four steps can be applied with appropriate indices. The choice of index is particularly important to the benchmarking exercise and whether it is done in a way consistent with the objectives of ACMA's governing instruments and the principles of fundamental valuation.

We next discuss what index options are available to apply to each of the four steps.

3.2.1 Steps 1 and 4: Present values and annuities

Step 1 involves converting a number of price points relating to the same benchmark licence into one annual price that could apply to the duration of the benchmark licence. Step 2 involves converting a benchmark annual price into an upfront price that reflects the duration of the ESL licence.

In both steps the conversion involves determining payments that would be made by the same licensee for a single licence. Because of this it is appropriate that the licensee be no better or worse off depending on whether the payment is annual for each year of the licence duration or upfront covering the duration. It is appropriate in this case to use a WACC to convert between upfront and ongoing payments. The WACC is the market clearing rate at which investors are prepared to provide capital and firms are prepared to borrow in order to fund long term productive capacity. Therefore, a firm (and its investors) will be impartial to borrowing a dollar today so that it can earn a dollar tomorrow indexed at the WACC.

This feature is important in the context of ESLs.

For Step 1, for each benchmark licence, multi-part prices might need to be converted into a single price/year. It is likely that when making the decision to buy that benchmark licence, the buyer compared the prices it paid with its future value for that spectrum discounted with its own WACC. Therefore, the WACC should also be used to discount what was paid into a different time profile.

For Step 4, the benchmark price/year applied to the ESL duration will need to be converted into an upfront payment. The WACC should be used for this step, as it will ensure the potential licensee is impartial between the benchmark prices/year and the upfront price equivalent, and it will not affect their decision about how much spectrum to buy or whether to buy it or not.

This approach is consistently used in other spectrum benchmarking exercises.[19]

Given the potentially large time differences between the dates when Steps 1 and 4 are applied, it would be most accurate to use a WACC applying to each of those dates.

[19] This approach is adopted in Plum, *Benchmarks for Review of Radio Frequency Spectrum Pricing*, 30 May 2014; DotEcon, *International Benchmarking of 900MHz and 1800MHz Spectrum Value*, September 2013; CEG, *Value of the 600 MHz Spectrum Band*, May 2021.

3.2.2 Steps 2 and 3: Carrying value through time

As noted above, fundamental value of spectrum may be observed at auction or through other competitive market transactions, where licensees bid up to their value-in-use derived from supplying downstream services to end-users.

We refer to these as fundamental valuations because they are disclosed by a considered market transaction, or an exchange of values; by end-users paying for services they value, and by MNOs and other licensees paying for spectrum that they value as an input to provide such services.

However, these fundamental valuations are infrequently observed yet change frequently. Therefore, when using the observations that can be made, account needs to be made for how value-in-use changes over time.

Steps 2 and 3 involve carrying a benchmark annual price at one historical date forward to a benchmark year (e.g. 2026) and to the potential ESL renewal date (e.g. 18 June 2028 for 850 MHz spectrum). An index can be used to take into account changes in value-in-use since the fundamental value underlying a price benchmark was observed. The index methodology should be the same for each step, to ensure consistency. Given the long periods of time between the start of the benchmark licences and the start of the potential ESL licence renewals, the choice of index will have a large impact on the results of the ACMA's benchmarking exercise.

The appropriate indexing approach to carry spectrum licence prices forward through time should be guided by the objects of the Act and the five MPS policy objectives. As discussed in Section 2, an index based on changes to value-in-use would ensure price benchmarks are intertemporally consistent with the unobserved changes in fundamental value over time.

While there are numerous measurement challenges, there are alternative indices the ACMA could consider, which are discussed below.

In applying any of these indices, the structure of the index should match the structure of the price to which the index is applied to the greatest degree reasonable. This is because the index is being used to estimate how the price (as it is structured) changes over time. If the benchmark price has a $/MHz/pop structure, then the index should have a $/MHz/pop structure. There might be insufficient information to construct an index in exactly the same structure as the price of spectrum, requiring a degree of caution to construct the index in a way that reasonably resembles the price structure.

MSR index

The most accurately recorded and reliable indicator for changes to value-in-use is mobile service revenue (MSR). This represents that part of end-user's willingness to pay that is monetised by each of the three MNOs. (We exclude MSR from MVNOs not owned and operated by the MNOs but include the wholesale income MNOs earn from MVNOs.)

MSR is just one component of licensees' net cashflows (and value-in-use). EBITDA would consider direct operating costs in addition to MSR. However, reported values and estimates of MNO EBITDA over time are inconsistent and irregular.

Accounting for MNOs' capital expenditure, including on their networks and spectrum, would also be useful to more completely reflect value-in-use. Capex reflects MNOs expectations about the potential future value-in-use that may be realised from services that use spectrum.

However, we don't have this information readily available across the extended time frame of the benchmarking exercise.

The extent to which these variables may inform the use of indexing for spectrum is only indicative given that spectrum valuations at a point in time when licences are to be issued (whether by auction or some renewal process) are forward looking and may be influenced by expectations at the time, while subsequent outcomes may vary from expectations. Similarly, strategic considerations may influence a one-off temporal pricing outcome but have little if any impact on revenue and operating outcomes. Nevertheless, the pattern of outcomes over time may be informative for general views on indexing.

In terms of the structure, it is possible to construct an MSR index on a MSR/MHz/pop basis to match a $/MHz/pop spectrum price. Alternatively, if the benchmark prices have a $/pop structure, for a specific quantity of spectrum, then an MSR index should be constructed to measure the change in the MSR/pop over time for that same specific quantity. This becomes difficult as there is not a simple way of allocating the MSR earned by licensees to particular quantities of spectrum. Hence, a MSR/MHz/pop index structure should be preferred.

We provide more detail on the estimation of an MSR/MHz/pop index in Section 5.

Consumer Price Index (CPI)

CPI is a common index used to carry forward historical values into current currency. The standard measure of CPI published by the Australian Bureau of Statistics measures the change in the weighted average price paid for a basket of goods by a representative metropolitan household in the population, allowing that basket to change in composition annually.

CPI would be used to index spectrum in circumstances where the price of spectrum relative to all other goods in the CPI basket needs to be set at a constant real value over time.[20] If this is the aim, then to be exact, the CPI index could be applied to a spectrum price structure that reflects the average amount of spectrum consumed by a representative household in their consumption of downstream services. Applying CPI to a $/MHz/pop price structure, might be a good, and considerably simpler, proxy for this.

However, it is unlikely that licensees' value-in-use of spectrum changes at the same rate as the price of the CPI basket over time, due to many different factors influencing the prices for each. Therefore, a CPI index might result in price benchmarks over-valuing licences when CPI grows at a faster rate than spectrum value-in-use, and vice versa.

Producer Price Index (PPI)

Like CPI, PPI could be used to index spectrum but to keep the real value of spectrum constant over time relative to the prices of all other goods in the PPI basket. While the CPI basket is comprised of a broad range of consumer goods and services, the PPI basket is comprised of goods and services producers purchase as inputs into their production. Again, it is unlikely that licensees' value-in-use of spectrum changes at the same rate as the prices for inputs Australian businesses buy for their production processes. Therefore, a PPI index might result in price benchmarks under or over-valuing licences.

The ABS produces certain PPI measures but doesn't seem to have one for the telecommunications sector much less mobile services.

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[20] CPI was used to carry spectrum values through time in Analysys Mason, *Key Input Data and Outputs for the MTAS Benchmark*, version 0.7, 15 May 2020. In this context the authors were benchmarking wholesale prices, and adjusting those benchmarks for the amounts paid for spectrum at different dates.

Weighted Average Cost of Capital (WACC)

The weighted average cost of capital provides a basis for discounting expected future cash flows depending on the market value of time preference adjusted for risk, that is the effect of uncertainty on expected outcomes. It is not appropriate to use such a measure to index asset prices based on previous estimates of expected cashflow, where these have changed materially.

As discussed above the WACC is the market clearing rate at which investors are prepared to provide capital and firms are prepared to borrow to fund long-term productive capacity. A WACC index would be used to discount future payments when it is important to ensure an investor is financially impartial between the value if spent today and an alternative value spent later. The WACC index is appropriate for Steps 1 and 4, as it relates to aggregating payments made by a firm for the same asset where that firms needs to be kept whole. In Steps 2 and 3, the benchmarks of value-in-use relating to one licence owner are carried forward through time to estimate the value-in-use of potentially a different owner. There appears to be little need, from the perspective of the objectives of the act, to keep the benchmarked licensee whole in estimating the value-in-use of a future comparable licence.

Further, the value-in-use changes through time likely at a different rate to the cost of capital (although changes in cost of capital is an albeit small determinant of value-in-use).

For these reasons, a WACC-based index is likely to be a poor index to use for Steps 2 and 3.

Social index

A social index is a relatively arbitrary way of carrying value forward through time. For example, if the ACMA wanted to reduce consumer prices for downstream services, it could apply an arbitrarily decreasing index to the value of spectrum.[21] Licensees would face lower costs for spectrum and competition in downstream supply might lead to lower end-user prices.

We don't see indexing, or variations in indexing itself, as the best approach to meet wider policy objectives such as those indicated in the Minister's letter of December 2023. Varying indices to implement policy objectives would introduce complications and may disrupt economic signalling. To the extent such variations add to uncertainty about long term outcomes, by definition they add further risk to long term investment decisions and raise the relevant cost of capital.

This is certainly not to say social policy does not play a role in spectrum allocation, but that implementing social policy through indexation of value can send mixed messages and create distortions. Social policies should be implemented in a transparent and direct way, and if such policies have an impact on the fundamental value of spectrum, then that should be reflected in the index.

[21] An example of this type of index was Telstra's retail price controls. For one period, the price control for a basket of retail telecommunications services was indexed at CPI-5.5%.

3.3 Previous adjustment approaches applied by the ACMA

The ACMA has previously used the tilted annuity methodology to account for licences starting at different times and lasting for different periods.[22] For this use case, the ACMA:

(i) begins with a benchmark value for a spectrum licence (at a certain time for a certain licence period),

(ii) calculates a series of annual tilted annuity payments that would spread that value over the licence period using a price escalator and cost of capital, and

(iii) calculates the present value of a subset of those annual tilted annuities, matching the duration of the licence being valued.

In theory, this methodology determines a time consistent value for a spectrum licence that begins at a different time and/or has a different licence duration, relative to a benchmark spectrum licence. However, it assumes that the value-in-use of the licence changes at a constant compound rate over the period of analysis.

The tilted annuity has a long history in asset valuation in Australia. It has often been used to value physical telecommunications assets for the purposes of asset pricing.[23] In these cases, the tilted annuity methodology was used to determine the return on and return of the value of an asset, that would provide sufficient incentives for investors to invest.[24]

The ACCC's use of titled annuities applied to the supply side of the valuation equation, the return on and return of capital invested in network, with the regulator considering that aspects of input (notably trench costs) would increase disproportionately through the asset's life-cycle. The application of price or revenue control regulation based on the regulated asset base derived by such methodology limits the revenue that can be realised by the regulated (typically fixed network) firm, and so limits its valuation, but (if time-consistent) would allow greater recovery in later years.

In contrast valuations of spectrum disclosed at auction are primarily driven by the demand side, with mobile network operators considering spectrum value as a function of potential mobile service revenue. Post auction they were then motivated to try to maximise the value in use of spectrum and wireless services over time. The logic of the tilted annuity in this case may be that value in use would increase over time as network coverage and capacity expanded and technology brought new services into play.

For these purposes, the tilted annuity was favoured because asset values were changing over time, and the asset base was frequently revalued.[25]

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22 See, for example, Radiocommunications (Spectrum Access Charges – 1800 MHz Band) Determination 2012 (No. 2); and Radiocommunications (Spectrum Access Charges – 1800 MHz Band) Determination 2014. The ACMA also used this approach in to determine starting prices for licences in the "Lower" products of Perth in the 2018 3.6 GHz band auction, and in the "Upper" products of Greater Perth, Hobart, and Margaret River in the 2021 26 GHz band auction.

23 The ACCC first adopted a tilted annuity approach for asset pricing in 2000 – ACCC, A *Report on the Assessment of Telstra's Undertaking for the Domestic PSTN Originating and Terminating Access Services*, July 2000. It moved away from this approach from 2010 – ACCC, *Review of the 1997 Telecommunications Access Pricing Principles for Fixed Line Services: Draft Report*, September 2010, s.6.1.2.

24 Schmalensee's (1989) Invariance Proposition proves that any series of depreciation payments that sum to the actual cost of the asset, when discounted at the cost of capital, will result in a net present value of investment equal to zero.

26 ACCC, *Review of the 1997 Telecommunications Access Pricing Principles for Fixed Line Services: Draft Report*, September 2010, s.6.1.2.

However, the tilted annuity came under criticism.

One criticism of the tilted annuity is that it assumes asset valuations change at a constant compound rate over the asset's life. To accommodate this assumption, a valuer would often estimate the average compound growth of asset prices over the life of the asset.[26] However, when used for long-lived assets, that average compound growth rate can deviate significantly from the actual growth rate from year to year. Indeed, asset values can and do fall as expectations of future value change. In some cases, this has seen network operators write off part of the value of their spectrum holdings.

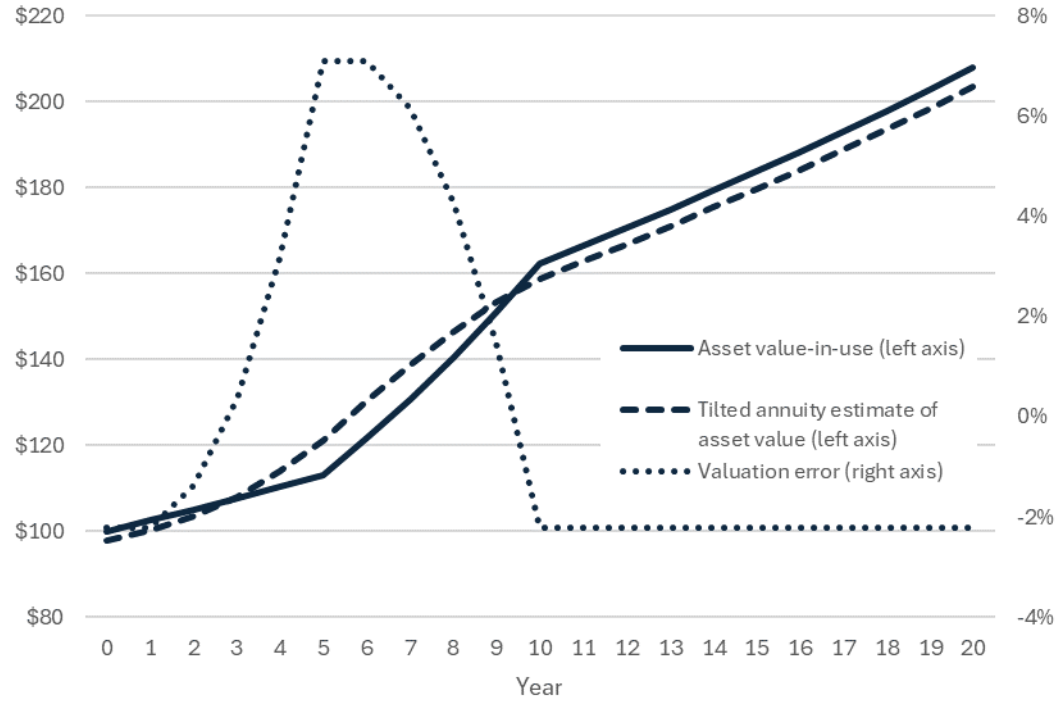
When using the tilted annuity to compare the values of spectrum licences over different time periods, the assumption of a constant price escalator can cause significant deviations between the estimated value and the actual value of spectrum licences even when they increase at the same compound average rate. Chart 3.2 illustrates this. In this stylised example there is a short period of high inflation in the value-in-use of the asset, resulting in the titled annuity over-estimating the asset value during the inflationary period and undervaluing the asset before and after. This is the case, even though the tilted annuity uses a price escalator that accurately reflects the compound growth rate of the asset's value-in-use over its life (i.e. averaging out the variation).

It is worth noting that the tilted annuity has often been used to determine future replacement cost. In these cases, it might be reasonable to forecast future replacement cost grows at a constant rate, and so it might be reasonable to use a tilted annuity with a constant growth rate. In the case of the ACMA's benchmarking exercise, the ACMA will carry forward historical benchmark prices into a current period and will have information on historical changes in value with variable growth rates. Therefore, the constant growth assumption is likely to be problematic for Steps 2 and 3 of the benchmarking exercise, but less problematic for Step 4.

A second concern with the tilted annuity was that it was not applied consistently over time. Historical analysis identified that asset valuations based on asset replacement cost did not change at the same rate that was predicted for the purposes of calculating tilted annuities. Therefore, the annual payments derived from the tilted annuities deviated from the actual payments need to recover the replacement cost of the asset.

[26] It is extremely complex to solve for a tilted annuity formula that allows price growth to change over the life of an asset.

Chart 3.2: Tilted annuity v true asset value over 20 years



Notes: The true asset value grows at a constant 2.5% rate, except for 5 years of growth at 7.5%. The tilted annuity price escalator equals the CAGR of the true asset value growth over 20 years.

Source: Flat Rock Consulting

This posed a further problem. Because the tilted annuity tended to backload the profile of cost recovery, this added to the risk that those backloaded costs would be stranded by technology, competition and changes in regulatory approaches to pricing assets. That risk was observed by investors, thereby reducing their incentives to invest in the asset, or increasing their cost of capital.[27]

While these time consistency problems were realised and discussed in the context of telecommunications asset pricing, they are also relevant to pricing spectrum licences. If a tilted annuity is used to determine the value of different future spectrum licences using different sets of tilted-annuity parameters,[28] then this can lead to inconsistent valuations of spectrum over time and over bands.

A third criticism was that depreciation in the tilted annuity tended to misalign with economic depreciation. With the use of positive price escalators, depreciation is backloaded into the later stages of an asset's life, whereas economic depreciation only leads to backloaded depreciation profiles in unusual instances.[29] In the case of spectrum, economic depreciation of spectrum is likely to follow a straight line profile, at the end of each year there is one year less of the licence left to generate value.[30]

27 Ergas, *Depreciation*, August 2008, p. 12-14.

28 For example, if a tilted annuity with a price growth rate of 1% was used to value a 15-year licence in 2015, then a tilted annuity with a price growth rate of 5% was used to value a licence in 2020.

29 Ergas, *Depreciation*, August 2008, p. 39.

30 Economic depreciation of spectrum might be backloaded for a new entrant that is building market share and revenue over the duration of the spectrum licence.

As a result of this and other factors, the ACCC moved away from using the titled annuity for telecommunications asset pricing and have since favoured indexed historic accounting cost methods.[31]

There is also an additional issue with the use of the tilted annuity in an international benchmarking application, that does not arise in the context of regulated asset pricing in Australia. To carry forward a historical spectrum value from a foreign country using the tilted annuity, an adjustment must be made for a long-term change in the exchange rate. To illustrate this, consider ten years ago that a spectrum lot was worth $100 in both a foreign and domestic country. Assume that the spectrum value-in-use has not changed in the foreign country over ten years but has doubled in the domestic country. Such an outcome may occur due to differences in market circumstances across the two countries including economic growth, competition and other factors that differentially effect the value-in-use of spectrum. Also assume the value of the foreign currency has depreciated by a quarter.

One approach would be to convert the foreign value to domestic currency as it was ten years ago and apply a domestic price escalator (a compounded 100% growth rate over ten years) to the tilted annuity. However, it is likely the foreign spectrum was priced assuming zero growth, but the tilted annuity would use a 100% rate of growth. The foreign spectrum would be overvalued.

There are two approaches to correct for this, each of which requires considerable complexity. One approach would be to approximate the foreign spectrum value-in-use growth using the growth rate of the domestic spectrum value converted into foreign currency. This assumes that the rate of change in currency exchange rates is a good indicator of the difference in rates of change of spectrum values between the two countries. While changes in currency and prices tend to be correlated, the correlation applies at an economy-wide level, rather than for prices for each individual good. Also, spectrum licences are not traded internationally, so currency exchange rates are likely to be poor indicators of relative spectrum values between countries.

Alternatively, a tilted annuity could be constructed for each foreign jurisdiction, using the foreign jurisdiction's value-in-use escalator, and then converted to domestic currency using a contemporary exchange rate. This solution would require understanding the value-in-use growth and cost of capital in each jurisdiction benchmarked.

In any case, applying a tilted annuity to foreign currency and converting to Australia dollars requires considerable complexity in the approach, and could introduce risk of material measurement error.

More generally, notwithstanding the ACCC's movement away from tilted annuities, the ACMA used a tilted annuity in at least four determinations that we are aware of – to set prices for reissued spectrum licences in the 1800 MHz band payable by rail authorities and telecommunications providers.[32] The tilted annuity was applied to a $/MHz/pop price for spectrum with a constant annual price growth rate of 2.5%. We assume that the purpose for using the tilted annuity in this limited case was to determine prices for licences with the same end date but different durations, in the belief that prices for these specific licences grew at a rate of 2.5% per annum. This use of the tilted annuity is equivalent to Steps 1 and 4, defined

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31 See ACCC, *Review of the 1997 Telecommunications Access Pricing Principles for Fixed Line Services: Draft Report*, September 2010, s. 6.1.2.

32 Radiocommunications (Spectrum Access Charges – 1800 MHz Band) Determination 2013 (No. 2): Explanatory Statement. See also Radiocommunications (Spectrum Access Charges – 1800 MHz Band) Determinations 2012 (No. 2), 2013 (No. 1) and 2014.

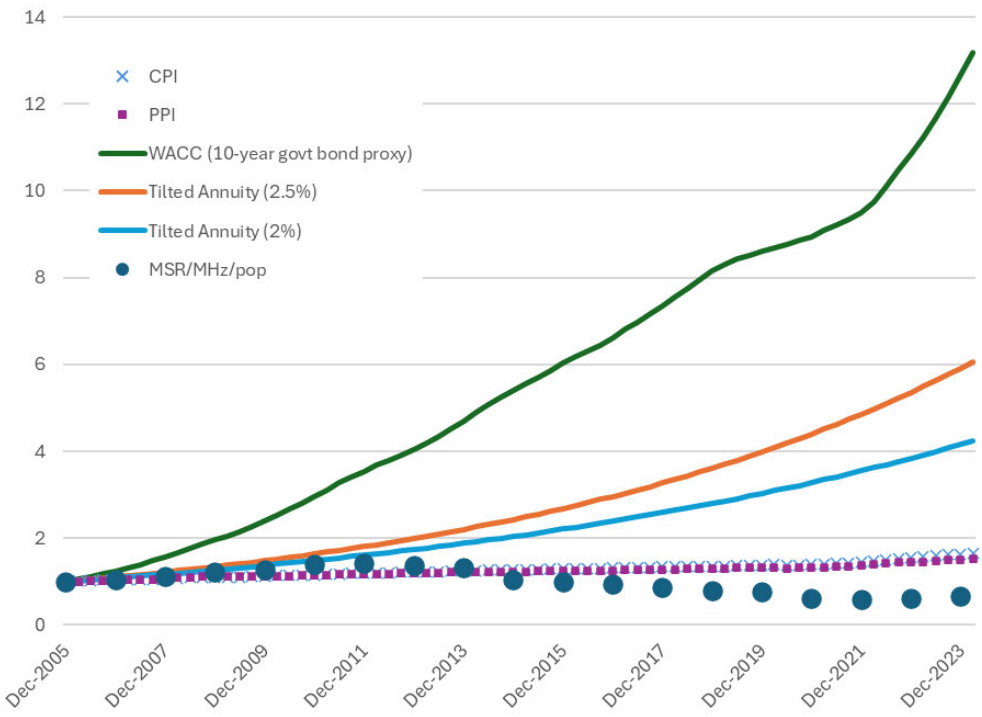
above. In this context, the issues with the tilted annuity we identify above might have little impact on the public interest.

However, for the current purposes, Steps 2 and 3 specifically, the issues with the tilted annuity identified above might be quite material.

3.4 Impact of different adjustment approaches

Carrying values forward over potentially long timeframes, as is needed to be done in Steps 2 and 3, can have a large impact on the final estimate of value. Above we have discussed a number of alternative approaches to carrying values forward: growth in MSR, CPI, PPI, WACC, and the use of the tilted annuity to apply a constant growth rate over time. Chart 3.3 illustrates the outcomes that could arise from use of these different approaches over a twenty-year time period. All approaches begin with an index base of one, at December 2005. As can be seen, the choice of indexation can have a large effect on the carried forward value – ranging from a 22-fold increase using the WACC proxy to a 1.6-fold increase using PPI. The MSR/MHz/pop index is the only index to decline over the period. This reflects a decline in revenue and an increase in spectrum availability (making it less scarce). Importantly, asset values will decline over time if the expected value to be derived from them declines. This variance in potential outcomes would have a large impact on licensees' businesses, their incentives to use spectrum, and the long-term public benefit.

Chart 3.3: Examples of the effect different indices have on final values

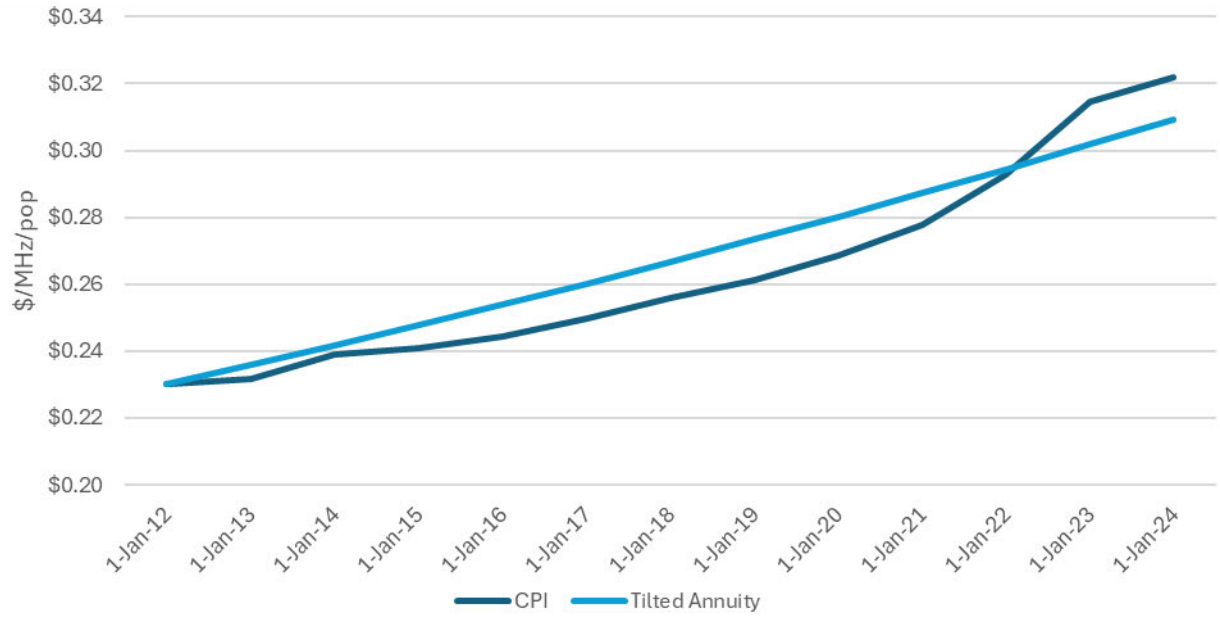


Notes: We have used the 10-year government bond rate growth as a proxy for the growth in the WACC over this period. This is generally a relatively poor proxy for changes in WACC, but suitable for this illustrative purpose.

Source: Flat Rock Consulting, ABS, RBA.

Also of importance is the fact that different approaches introduce different levels of risk that decisions made now will turn out to be incorrect in future. This is particularly pertinent to the tilted annuity, as it assumes a constant growth rate. Chart 3.4 illustrates the value of spectrum as determined by the use of the tilted annuity in the ACMA's 2013 determination for pricing 1800 MHz spectrum.[33] The determination made use of a value for spectrum equal to $0.23/MHz/pop and applied a tilted annuity to that value over a fifteen-year period, assuming a 2.5% inflator, which corresponded to CPI forecasts at the time of the determination.[34] As illustrated, the tilted annuity turned out to over value spectrum relative to CPI in the early years, although CPI has recently caught up. This does not suggest there was an error made, rather it demonstrates that the best forecasts have a degree of uncertainty, and when uncertainty has consequences, it is useful to adopt approaches that minimise its impact.

Chart 3.4: Value of 1800 MHz spectrum, CPI v tilted annuity



Source: Flat Rock Consulting

4 Measuring the weighted average cost of capital (WACC)

The WACC is an important input into any analysis aggregating or dispersing cashflow across time. On the demand side, when firms need capital to support investment, the WACC represents the opportunity cost of investing capital today with the expectation of earning returns in future years. On the supply side, it represents lenders and investors willingness to defer consumption today for a greater outcome in future, adjusted for risk. If an entity cannot earn a real return at least as high as its WACC, then its investors would be better off investing that money elsewhere.

33 Radiocommunications (Spectrum Access Charges – 1800 MHz Band) Determination 2013 (No. 2).
34 Commonwealth of Australia, Budget Strategy and Outlook: 2013-214, 14 May 2013, Table 2.

If the ACMA needs to determine an upfront payment that is equivalent to annual payments and vice versa, to make the licensee no better or worse off, future payments will need to be discounted by an appropriate WACC. This is important for Steps 1 and 4 set out above. For Step 1, the payments a licensee makes for the same benchmark licence need to be discounted by a WACC to convert them into a single annual price.[35] For Step 4, annual benchmark prices over the proposed ESL duration need to be converted into an upfront charge. An appropriate WACC should be used to discount future annual prices.

In Section 3.2.2, we discuss the possibility of using a WACC for Steps 2 and 3, that is, to carry spectrum values forward through time. We don't recommend using the WACC for this purpose, as reasoned above.

The appropriate WACC to use depends on the type of future or expected cashflows that are being considered, and there are generally four types of WACC: pre-tax, post-tax (vanilla), real and nominal. The key difference between each of these four types of WACC is whether the costs of company income tax and inflation are included in the WACC, or they are excluded (and calculated separately).

It is important to recognise the effect of inflation on investors. Inflation has the effect of diminishing the value of money they have previously invested over time. To encourage investment the "cost of inflation" needs to be accounted for.

There are generally two approaches to ensure the cost of inflation is taken into account. The first is to calculate real cash flows for future periods, and discount those with a real WACC. The second, and more common approach in Australian regulatory settings, is to calculate nominal cash flows for future periods, and discount those with a nominal WACC. The two approaches will provide the same outcome.

Similarly, there are two approaches to account for the cost of company income tax. The first approach is to calculate an entity's company income tax as an expense and subtract these tax expenses from future cashflows. These 'post-tax' cashflows should be discounted with a post-tax WACC. This type of WACC is often called a 'vanilla' WACC. The second approach is to convert the post-tax vanilla WACC into a pre-tax WACC, by increasing the cost of equity to account for the cost of company income tax.[36] The pre-tax WACC is then used to discount pre-tax cash flows – those that have not yet had corporate income tax subtracted from them.

The choice to use a post-tax or pre-tax WACC comes down to the ability and level of confidence one has in estimating liabilities to company tax for the company and the diversity of its investors. Theoretically, pre-tax cashflows discounted with a pre-tax WACC will provide the same result as post-tax cashflows discounted with a post-tax WACC. However, the conversion of a post-tax WACC into a pre-tax form might require generalisations (for example, an industry wide gearing might be used, the effective tax rate might differ from the statutory tax rate, and the degree to which franking credits apply might be averaged across a diverse mix of investors). These generalisations might be avoided by modelling tax liabilities as an expense, providing more accurate estimates of the cost of tax. However, that accuracy comes at the expense of simplicity. A pre-tax WACC is relatively simple to estimate using previous regulatory decisions as precedent. Modelling tax expenses accurately requires information on tax accounting asset values and depreciation, which may differ from reported values.

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35 This might involve taking a present value of multiple payments for the licence and converting that into an annuity over the licence duration. Or it might involve converting a single upfront payment into an annuity over the licence duration.

36 The cost of debt is typically tax deductable in Australia, so corporate income tax is based on a firm's return to equity.

Different methodological approaches have been used to estimate the WACC in the Australian telecommunication sector:

- NBN Co's 2023 Special Access Undertaking, recently accepted by the ACCC, provides a framework to determine future nominal cashflows using a nominal post-tax vanilla WACC specific to NBN, and separately calculates corporate income tax expenses.[37]
- NBN Co's 2013 Special Access Undertaking, accepted by the ACCC, accepts a WACC equal to the risk-free rate plus 350 basis points,[38] which is further explained by Officer and Bishop to be an approximation of a nominal post-tax vanilla WACC.[39] This was used to determine future nominal cashflows, with tax costs calculated separately.
- The ACCC's 2015 Access Determination in relation to Telstra's Fixed Line Services used a real post-tax vanilla WACC specific to Telstra to determine real future cashflows and real prices for regulated service prices. The real prices were then indexed by inflation to determine nominal prices.[40]
- The ACCC's 2020 Access Determination in relation to Mobile Terminating Access Services, set prices based on international benchmarks adjusted for differences in WACC's between countries. The ACCC used a benchmark nominal and real pre-tax WACC to align with the cost of capital for a hypothetical Australian mobile network operator.[41]
- The ACCC's 2009 Pricing Principles in relation to Mobile Terminating Access Services was supported by a cost model that estimated the nominal costs of building and operating a network and applied a nominal pre-tax WACC to determine future nominal cashflows.[42]

Notably, the ACCC has used a post-tax WACC in circumstances where the WACC is applied to the cashflows of an individual company, whose tax liabilities can be separately modelled. The ACCC has used a pre-tax WACC when its decision is applied to multiple companies in the mobile sector with different tax structures and liabilities.

These earlier decisions have resulted in quite different values for the WACC being applied by the ACCC over time (see Table 4.1 and Attachment B). Most of the variance is due to the risk-free rate and debt premium changing over time and different approaches being applied for the equity beta.

Variability in the risk-free rate and debt risk premium over time is driven by changes in the 10-year government bond rate and corporate bond rate, respectively. This variance reflects changes in monetary policy and how private markets price corporate debt.

Variability in the beta across the decisions in Table 4.1 is due to differences in the risk profiles of mobile and fixed businesses – the equity beta applying to fixed networks is lower at 0.7 while it has been 1.3 and 0.8 when applied to mobile networks. The difference in equity betas applied to mobile networks is likely to be due to differences in measurement

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37 The ACCC accepted the SAU in ACCC, *Proposed Variation to the NBN Co Special Access undertaking: Final Decision*, October 2023; however, the approach to WACC is summarised in ACCC, *Variation to the NBN Co Special Access Undertaking: Draft Decision*, April 2023, at s. 4.10.

38 ACCC, *NBN Co Special Access undertaking: Final Decision*, 13 December 2013, at s.8.3.2.

39 Officer, Bob and Bishop, Steven, *Report on WACC component of NBN Co's Special Access Undertaking*, September 2012, p. 21.

40 ACCC, Public Inquiry into Final Access Determination for Fixed line Services: Final Decision, October 2015, s.6.

41 ACCC, *Public Inquiry on the Access Determination for the Domestic Mobile Terminating Access Service: Final Report*, October 2020, s.4.11.

42 ACCC, *MTAS Pricing Principles Determination*, November 2007; however, most of the ACCC's discussion on an appropriate WACC is in ACCC, *Draft MTAS Pricing Principles Determination*, June 2007, s.A.2.2.

approaches. While the most recent equity beta used by the ACCC in relation to mobile networks was 0.8, we believe this probably undervalues the risk faced by mobile network businesses in Australia.

Table 4.1: WACC values used in ACCC telecommunications-sector determinations

Date	2009	2013	2015	2020	2023*
Decision	ACCC MTAS Pricing Principles	ACCC NBN SAU	ACCC Fixed Services Access Determination	ACCC MTAS Access Determination	ACCC NBN SAU
Cost base	Mobile network	NBN	Telstra fixed network	Mobile network	NBN
WACC type	Nominal pre-tax	Nominal post-tax	Real post-tax	Nominal and real pre-tax	Nominal post-tax
Gearing	40%	40%	40%	37%	37%
Risk-free rate	5.70%	3%	2.76%	0.90%	4.20%
Market risk premium	6%	7%	6%	6.10%	7.10%
Equity beta	1.3	0.7	0.7	0.8	0.66
Debt premium	1.02%	3.10%	1.74%	1.28%	0.80%
Debt issuance costs	0.083%		0.07%	0.07%	0.13%
Expected inflation			2.50%	2.42%	3.10%
Tax rate	20%			30%	30%
Gamma	0%		0.45	0.585	0.585
Cost of equity	13.5%	7.9%	7.0%	5.8%	8.9%
Cost of debt	6.8%	6.1%	4.6%	2.3%	5.1%
Nominal vanilla WACC	10.82%	7.2%	6.0%	4.5%	7.5%
Nominal pre-tax WACC	12.85%			4.99%	8.29%
Real vanilla WACC			3.42%	2.01%	4.26%
Real pre-tax WACC				2.51%	5.03%

*Notes: * These parameters were proposed by NBN Co. The ACCC did not need to make a decision on these parameters and noted some issues them. We have included them for comparative purposes only.*

Source: Flat Rock Consulting

The most recent decision the ACCC has made on WACC was in 2020 and applied to mobile network operators. We can apply the methodology adopted in that ACCC decision, updated with contemporary information from a recent AER decision to arrive at a contemporary WACC value. We also provide a scenario with a higher equity beta of 1. The 2024 nominal pre-tax WACC in these scenarios would be 8.9% to 9.8%, assuming an equity beta of 0.8 and 1.0, respectively. The 2010 values would be 10.4% and 11.3%, respectively. These values could be used by the ACMA to consider ESL renewal proposals. Table 4.2 sets out the methodological approach adopted by the ACCC and updated WACC parameters. Attachment B provides more detail underlying Table 4.2.

Table 4.2: Proposed WACC estimates using ACCC methodologies

Date	2010	2024	2010	2024	Latest ACCC methodology (2020)
Scenario	Low Equity Beta		High Equity Beta		
Cost base	Mobile network		Mobile network		
Gearing	37%	37%	37%	37%	Arithmetic average of 25 OECD benchmark mobile companies' 5-year average gearing levels.
Risk-free rate	5.59%	4.36%	5.59%	4.36%	Average yield on 10-year Commonwealth Government Securities (CGSs) over a twenty trading day period close to the date of this decision
Market risk premium	6.20%	6.20%	6.20%	6.20%	AER Precedent
Equity beta	0.8	0.8	1	1	Asset beta derived from arithmetic average of 25 OECD benchmark mobile companies, then delevered using Brealey-Myers formula.
Debt premium	1.93%	1.46%	1.93%	1.46%	Benchmark credit rating of A- and a term of ten years, calucated using a weighted average to Bloomberg's BVAL 10-year Australian corporate bond yield curves for broad-A and broad-BBB.
Debt issuance costs	0.086%	0.086%	0.086%	0.086%	ACCC precedent
Expected inflation	2.32%	2.92%	2.32%	2.92%	Annualised ten year geometric average of the RBA's headline forecasts for the first two years, and the midpoint of the RBA's target band for years 3–10
Tax rate	30%	30%	30%	30%	Statutory company tax rate
Gamma	0.57	0.57	0.57	0.57	AER Precedent
Cost of equity	10.5%	9.3%	11.8%	10.6%	
Cost of debt	7.6%	5.9%	7.6%	5.9%	
Nominal vanilla WACC	9.5%	8.1%	10.2%	8.8%	
Nominal pre-tax WACC	10.4%	8.9%	11.3%	9.8%	
Real vanilla WACC	6.97%	5.00%	7.73%	5.75%	
Real pre-tax WACC	7.93%	5.84%	8.81%	6.71%	

Source: Flat Rock Consulting

5 Mobile service revenue and MSR/MHz/pop as an indicator of spectrum value

As discussed above MSR can be used an indicator of spectrum value either directly or after adjusting by the amount of spectrum or the investment in spectrum held by MNOs.

The worth of such an index is in how well it might guide possible changes in spectrum value if a similar considered transaction (such as an auction) occurred at a different time such as when licences may be renewed. We consider the key driver of such consideration by MNOs is MSR, with changes in MSR leading to changes in expectations of future cashflow. A better guide is MSR per MHz per pop held by MNOs which provides an indication of how much spectrum is required to generate expected MSR and expected future cashflow.

We prefer a nominal index, as MSR is reported in nominal terms, and the benchmarking exercise is likely to record nominal spectrum licence prices. Reported MSR is also in part driven by population growth through subscriber and network effects. Our proposed index includes a separate population component. The index will consequently be applied to a $/MHz/pop price, and that price would ultimately be multiplied by a contemporary estimate of population to arrive at a licence fee.

To create an index, we divide MSR by aggregate spectrum held and by population and can set a base of 100 in any year. The index would work by applying the relative index value to previous prices in the year in which the benchmark transaction occurred (or resetting that year to base 100) and applying the index value of the year of ESL renewal to the relevant price.

Thus, for example, an 800MHz price of $1.35 per MHz/pop in 2013 (set as a base year of 100) might index at 1.22 in 2028, indicating a 2028 value of $1.647 per MHz pop. Or it might index at 0.64 in 2028, indicating a value of $0.864 per MHz pop. (The different indexing may reflect whether a single index is used for all spectrum, or different indexes apply to different broad ranges.)

The implication of this indexing approach is that a block of 700MHz spectrum in 2028 might be expected to generate 22% more MSR, or 36% less MSR, than was expected in 2013. While we know retrospectively the extent to which 2013 expectations were met or not, we don’t know (and can’t know) whether 2028 expectations would be met. What we do know is the measure of MSR (and recent trends in and drivers of MSR) in both periods and the population and volume of spectrum held to generate MSR as key inputs to relative expectations.

If this MSR/MHz/pop index approach is to be considered by the ACMA for ESL pricing, a key issue worth further consideration is whether indices might be different for different broad spectrum band ranges including low band, lower mid-band and upper mid-band given the potential for dissimilar changes in pricing and value creation across each broad spectrum band range over time.

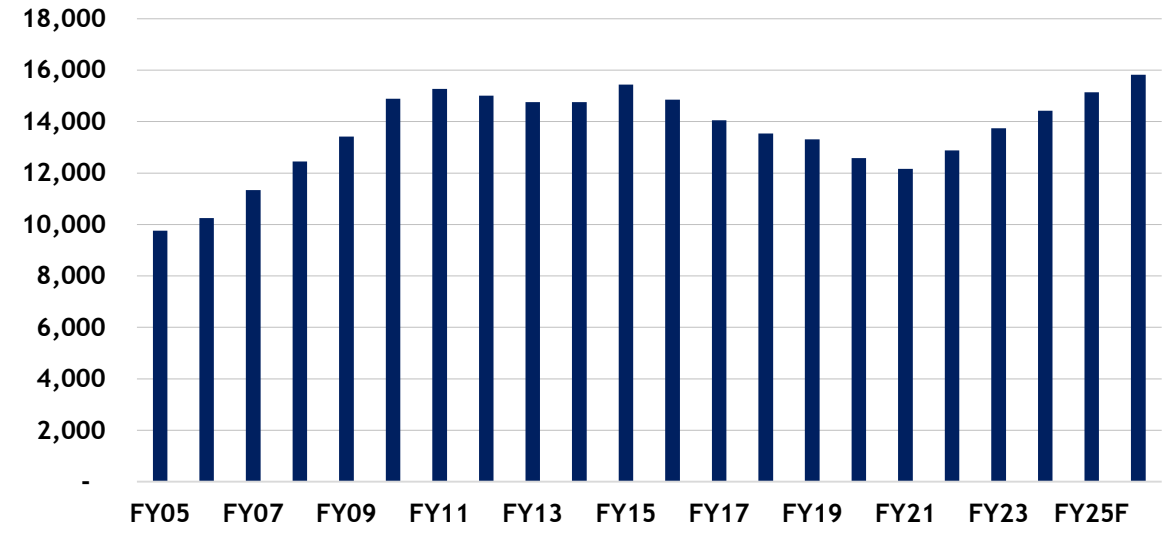
5.1 Mobile service revenue

We estimate mobile service revenue (MSR) for the three MNOs has increased from c$9.8bn in FY05 to $13.7bn in FY23, and a forecast of $15.8bn in FY26F. This represents nominal growth of 2.3% pa over 21 years, about the same rate as inflation over the period. (Note the qualifications to this MSR data in chart 5.1.)

In aggregate, the picture represents four distinct periods of growth:

- A period of strong growth from 2005 to 2011 (7.8% pa, with several years above 10%) as 3G services matured, mobile data usage consolidated and with the introduction of smartphones and data usage across the wider retail market. Telstra benefited from this growth more substantially than Optus and TPG on the back of its NextG investment and consolidation or rural and regional networks into expanded GSM coverage (following the closure of its CDMA network).
- A period of MSR consolidation from 2011 to 2015 (0.3% pa) in the initial years of 4G through which Telstra notably maintained good growth (6.4% pa) while Optus plateaued (-1.1%pa) and VHA MSR declined (-8.8% pa) as it lost market share following network service issues.
- A period of decline from 2015 to 2021 (-3.9% pa) as many mobile services switched to OTT and the MNO market was more contested by a recovering VHA, Optus's decision to expand network further into regional markets and TPG's proposed strategy to contest the mobile market as a network operator (i.e., pre-merger with Vodafone). The negative MSR trend was compounded in FY20 and FY21 by the impact of COVID lock down and border closures on inbound and outbound roaming revenue and some short term consumer support issues, in part offset by greater mobile data usage.
- A period of recovery from 2022 (5.8% pa to 2024, and perhaps tapering below 5% pa by 2026). That growth driven by a return of good subscriber growth following the reopening of borders, recovery of mobile roaming revenue and a recovery in price power across the three MNOs.

Chart 5.1: Indicative aggregate MNO Mobile Service Revenue (A$m)



Note: Not adjusted for different year end for each of the three MNOs. Includes MNO wholesale revenue but not the retail mark-up of MVNOs. NSR/IMA has made some minor adjustments to some historic MSR items to reflect changes in revenue reporting over time. Mobile interconnection has been excluded as a discrete MSR item to avoid double counting across MNOs. The last three years FY24 to FY26 are IMA forecasts.

Source: MNO financial reports and NSR/IMA estimates

It is also notable that MTAS rates reduced significantly over the period. Voice termination drove significant incoming call MSR in the first decade indexed with initial rate reductions

partly offset by call volume increases. The voice termination rate reduced from 21c per minute in 1H05 to 3.6c per minute in 2015, before a further 53% reduction in 2016 SMS termination which had a significant one-off effect on reported MSR in FY16 and FY17.

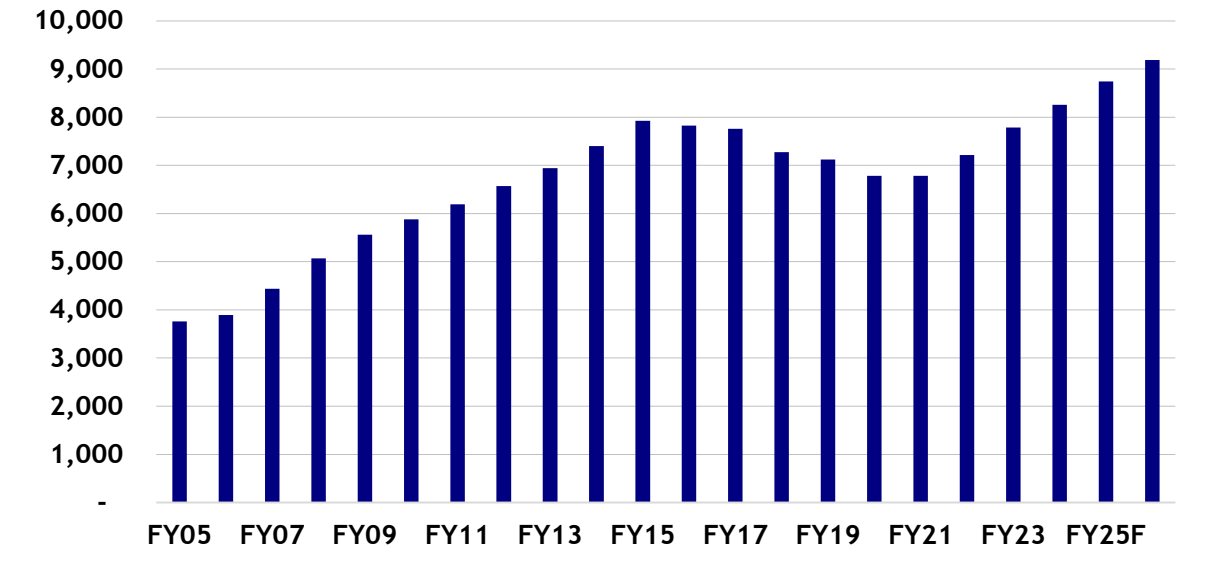
As well, the LT MSR pattern is markedly different across the three MNOs with Telstra most successful and most consistent in maintaining MSR growth across the period. Notably, it attracted subscribers and premium (ie higher ARPU) revenue at the expense of the other two MNOs following what we consider to be strategic and/or operational errors. (We discuss these further in the following three sections.)

5.1.1 Telstra's Mobile Service Revenue

Telstra's MSR increased strongly between 2005 and 2015 from $3.76bn to a then peak of $7.93bn in 2015. These were strong years for smart phone usage and data growth on maturing 3G networks. From FY07 Telstra's annual MSR growth was consistently above 5% pa and averaged 7.7% over the decade to FY15. As well as 3G-related subscriber take-up and data usage growth, Telstra MSR growth benefitted through the latter years of this period as it picked up subscribers from Vodafone which suffered from ongoing network quality issues.

Its MSR plateaued at c$7.8bn in FY16 and FY17 in part due to the impact of the significant reduction in the regulated MTAS rate in January 2016. The MTAS reduction effects were spread over two years, 2H16 and 1H17. That change was followed by MSR falling to a low of $6.78bn in FY20 and FY21. These years were typified by rising displacement of some voice and data traffic to OTT service providers in a maturing 4G market setting, a rise in network competition and rivalry for subscribers from Optus and the threat of a fourth MNO entrant in TPG (pre-merger with Vodafone).

Chart 5.2: Telstra's Mobile Service Revenue (A$m)



Note: June year end. NSR/IMA has made some minor adjustments to some historic MSR items to reflect changes in revenue reporting over time. Notably mobile interconnection has been excluded as a discrete MSR item to avoid double counting across MNOs. The last three years FY24 to FY26 are IMA forecasts.
Source: Telstra financial reports and NSR/IMA estimates

The negative MSR effects after FY15 were compounded in FY20 and FY21 by the impact of COVID lock down and border closures on roaming revenue and some short term consumer support issues, in part offset by greater mobile data usage.

Telstra MSR picked up strongly in FY22 at 6.4%, continued to grow strongly in FY23 at 7.9% and is on track for c8.0% in FY24. Its MSR recovery would be closer to 5% pa in this period but for the effects of network outage and cyber security issues on subscriber growth and average revenue.

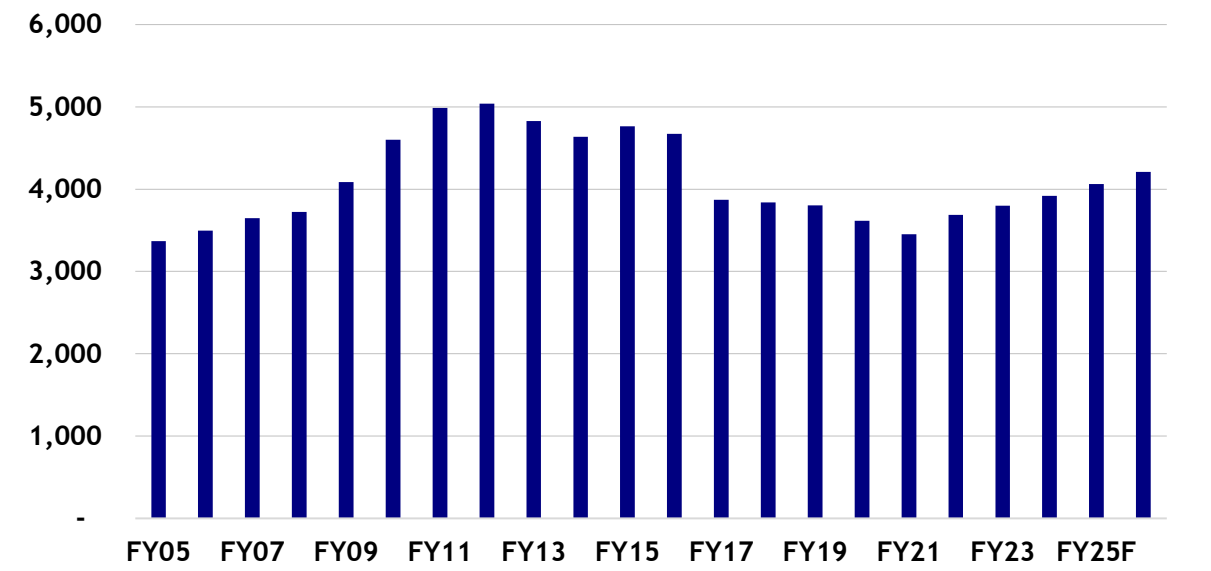
We forecast Telstra MSR growth to average 5.7% pa over three years to A$9.2bn. If so, this would represent a CAGR of 4.3% over 21 years from $3.76bn in FY05. We note there are growing doubts among investors about Telstra's ability to maintain good growth in its mobile services revenue given market changes including MNO and other SP competition.

5.1.2 Optus Mobile Service Revenue

As with Telstra, Optus's MSR increased rapidly in the initial smartphone era from $3.4bn in 2005 to a peak of $5.0bn in 2012, an average rate of 6.0% pa over seven years. However, where Telstra continued to expand MSR for a further three years to 2015, Optus MSR plateaued for several years at c$4.6-4.7bn pa.

In the peak growth period Optus's MSR growth averaged c10% pa for three years to FY11. However, for the following decade MSR growth declined by an average of 3.5% pa including two years of low single digit growth.

Chart 5.3: Optus's Mobile Service Revenue (A$m)



Note: Singtel and Optus have a 31 March financial year end. NSR has made some minor adjustments to some historic MSR items to reflect changes in revenue reporting over time. Optus reported a 75% drop in incoming call and SMS revenue in FY17 following the ACCC decision to drop the regulated MTAS rate in January 2016. The last three years FY24 to FY26 are IMA forecasts.

Source: Optus financial statements, Singtel MD&A and NSR/IMA estimates.

The change in regulated MTAS rates had a significant effect on Optus's MSR in FY17, with Optus reporting a 75% drop in incoming call revenue from $774m to $194m. (Singtel's March year-end 2017 financial report included 9 months of lower MTAS rates than in FY16.) It advised "operating revenue declines were driven by the Australian Competition and Consumer Commission's regulated reduction of industry mobile termination rates from 1

January 2016…".[43] However, the EBITDA impact was minor suggesting the bulk of this MSR effect was due to payments between MNOs with a largely offsetting cost reduction.

As with Telstra the period after FY16 was typified by rising displacement of some voice traffic to OTT Service providers in a maturing 4G market setting, a rise in network competition and rivalry for subscribers across the three MNOs and the threat of a fourth MNO entrant in TPG (pre-merger with Vodafone).

The compounding effects of Covid impacts on declining MSR noted in the case of Telstra, were greater for Optus given its greater reliance on roaming revenue, migration and international visitors.

From a low of $3.45bn in FY21 (ie, its lowest MSR since $3.47bn in FY05) Optus MSR recovered by 6.9% in FY22 and a further 3.0% in FY23 and a similar rate is indicated for FY24. Its MSR recovery would be closer to 5% pa in this period but for the effects of network outage and cyber security issues on subscriber growth and average revenue.

We forecast Optus MSR growth to average 3.5% pa over three years to A$4.2bn. If so, this would represent a CAGR of 1.1% over 21 years from $3.37bn in FY05.

Optus's low long term MSR growth stands in marked contrast to Telstra at 4.3% pa over the same twenty-one-year period. Indeed, the two MNOs reported similar MSR in FY05 at A$3.37bn and A$3.76bn respectively but have followed widely diverging growth paths over two decades since. This reflects, we consider, Telstra's greater focus on network coverage and capacity following its Nextgen 3G and 4G network strategy initiated in 2005.

5.1.3 TPG's (Vodafone) Mobile Service Revenue

TPG has changed ownership and reporting arrangements significantly over the period we review, with the initial 3rd MNO licensee Vodafone merging with the 4th licensed MNO Hutchison in mid-2010 to form VHA. Subsequently VHA merged with TPG in June 2020.

The latter merger had limited impact on reporting of MSR and we have a reliable record of reported revenue from 2010 (including 2009 pro-forma MSR). We have estimated like-for-like MSR for 2005 to 2008 for a pro-forma VHA 3rd MNO based on HTA and Vodafone financial reports (refer note to chart 5.4).

We estimate VHA (proforma) MSR at $2.64bn in FY05 and strong growth to $4.4bn in 2010, an average rate of 10.9% pa over five years. However, unlike Telstra and Optus, VHA was unable to sustain MSR growth after 2010 despite an emerging and maturing 4G network growth period.

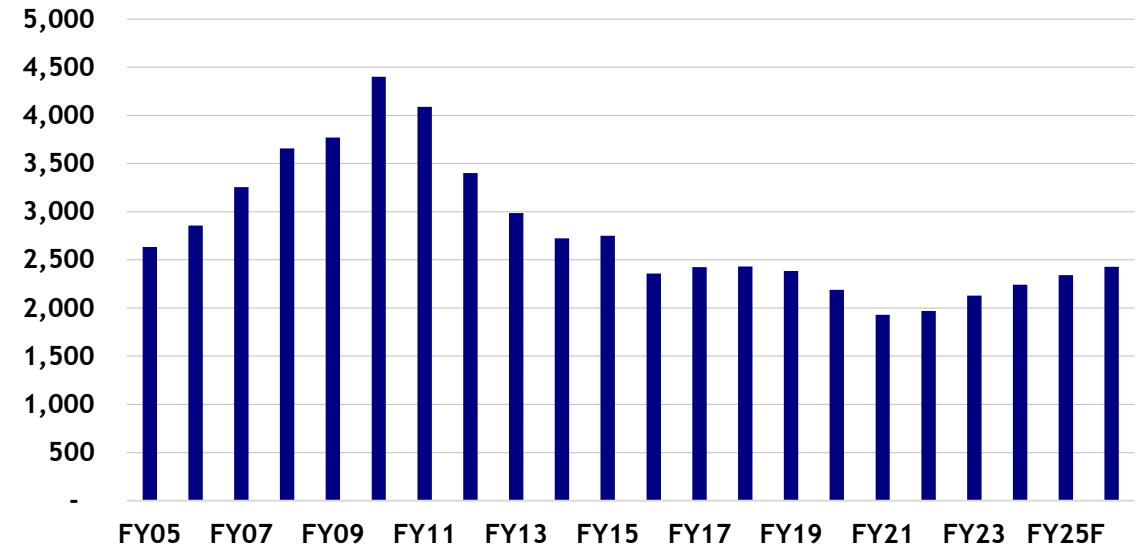
Network quality issues led to a decline in subscribers and price power and a rapid decline in MSR. VHA's MSR declined by 38% over four years to 2.7bn in FY14, before stabilising at that level in FY15. A further 14.3% drop in FY16 was mainly due to the change in regulated MTAS rates (which had a full year effect on VHA given its December year-end).

However, eventual hard-won recovery in network service quality was offset by a relative decline in network coverage leading to a slower recovery in MSR in FY17 and FY18 at 1.6% pa. The recovery, as such, coincided with industry-wide displacement of some voice traffic to OTT Service providers in a maturing 4G market setting, a rise in network competition and rivalry for subscribers across the three MNOs and the threat of a fourth MNO entrant in TPG (pre-merger with VHA).

[43] Singtel Management Discussion and Analysis May 2017.

As with Optus, the compounding effects of Covid impacts on declining MSR were significant for TPG in FY20 and FY21 (post-merger) given it also relied relatively more on roaming revenue, and subscriber growth driven by migration and international visitors.

Chart 5.4: TPG's (Vodafone Australia/VHA/HTA) Mobile Service Revenue (A$m)



Note: TPG has a 31 Dec year end. Vodafone Australia merged with HTA in 2010 to form VHA, which merged with TPG in June 2020. VHA reported revenue on a Dec YE from 2009 (pro-forma), and we have estimated pro-forma revenue for prior years based on HTA and Vodafone results adjusted to Dec year end. NSR has made some minor adjustments to some historic MSR items to reflect changes in revenue reporting over time. The last three years FY24 to FY26 are IMA forecasts.

Source: TPG, VHA, Vodafone Australia and HTA financial reports and NSR/IMA estimates.

From a low of $1.93bn in FY21 (ie, less than half of the 2010 VHA highpoint) TPG MSR recovered by 2.1% in FY22 and 9.3% in FY23 to A$2.16bn.

We forecast TPG MSR growth to average 4.1% pa over three years to A$2.43bn. If so, this would represent a CAGR of -0.4% over 21 years from our pro-forma estimate of $2.64bn in FY05.

TPG's lack of long term MSR growth stands in marked contrast to Telstra at 4.3% pa over the same twenty-one-year period and, indeed, even Optus at 1.1% pa. Pro-forma VHA's 2005 MSR was about 78% of that reported by Optus in the same year (unadjusted for year end); by 2023 this ratio had dropped to 57%. As with our view on Optus's MSR growth, we consider the widely diverging growth paths over two decades primarily reflects differences in network quality and coverage over the period.

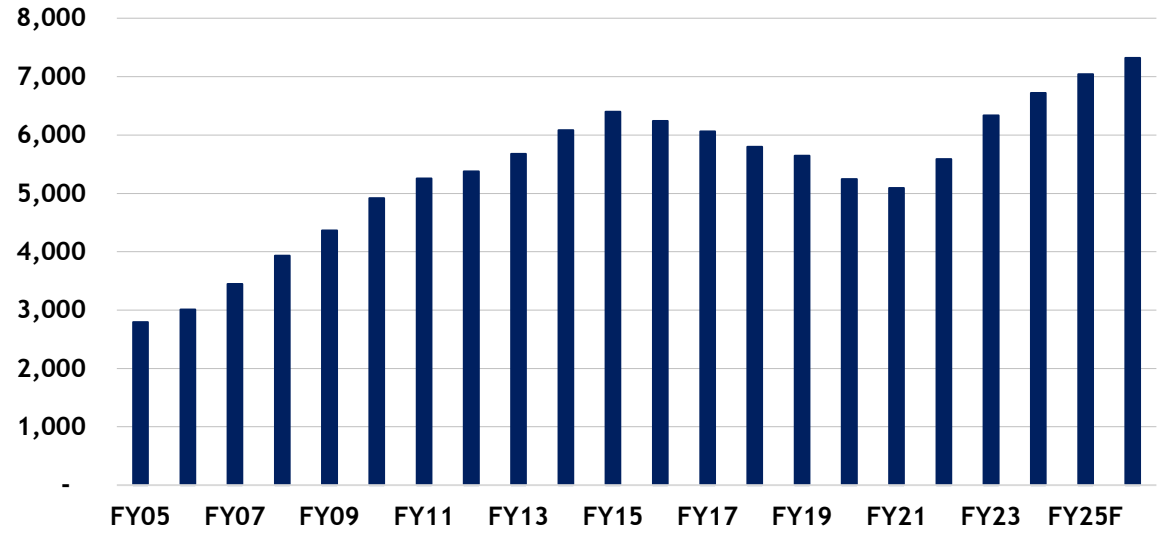
5.1.4 Notes on Mobile EBITDA across three MNOs

While MSR is sufficiently well defined to clearly indicate patterns of value in use over twenty years, there is less clarity with mobile EBITDA over such a long period. As with MSR, a twenty-year time series for mobile EBITDA is influenced by changes in ownership at TPG and VHA, different reporting arrangements across the MNO, changes in accounting principles and reporting adjustments over time.

Telstra has reported mobile EBITDA since about 2015 but may have changed joint cost allocations as its fixed network reduced in revenue and earnings contribution since then. We have estimated trend EBITDA for prior years. Its reported EBITDA measure includes

handset margins rather than purely margin on MSR although we note handset margins are very small and hardly affect overall mobile EBITDA.

Chart 5.5: Indicative aggregate MNO mobile EBITDA (A$m)



Note: Not adjusted for different year ends. NSR has estimated mobile EBITDA made some adjustments to some historic MSR items to reflect changes in revenue reporting over time.

Source: TPG, VHA, Vodafone and HTA financial reports and NSR/IMA estimates.

Optus doesn't report mobile EBITDA however we have estimated it on a consistent basis over twenty years. Our estimate may not well reflect changes in joint cost allocation as the business mix has adjusted increasingly from fixed to mobile service.

While TPG doesn't report mobile EBITDA, for most of the twenty-year period under consideration VHA operated as a standalone mobile business prior to its merger with TPG, and reported EBITDA reflected mobile only operations. We have estimated trend EBITDA on a pro-forma basis back to 2005 (ie for the period prior to the merger of Vodafone Australia and Hutchison Australia).

Despite these qualifications we provide this estimate of mobile EBITDA over 20 years in aggregate for the three MNOs as an indicator of change in the operating cashflow generated from mobile services.

It is also worth noting that Telstra has a larger share of mobile EBITDA than it has of MSR, at close to 60%. So, the pattern of strong growth in mobile EBITDA from 2005 to 2015 largely reflects MSR gains and increasing scale at Telstra, particularly as its NextG investment was realised. The pattern tends to mask the poorer EBITDA performance of Optus and VHA, particularly with VHA during its period of network quality issues. It also masks to some extent the greater EBITDA decline at Optus and VHA/TPG in the period of mobile market decline after 2016 and during the two years impacted by Covid-19 responses.

To the extent these differential cash earnings patterns across the three MNOs reflect the normal impacts of competition, quality of strategic decisions and operational performance they might still be considered as a reasonable indication of actual market driven cash returns from mobile operations. However, they might also reveal some underlying structural pattern in a three player market with significant economies of scale.

If the ACMA wanted to consider mobile EBITDA as a measure of value-in-use beyond the broad aggregate indication, the measures would require more analysis to ensure they are

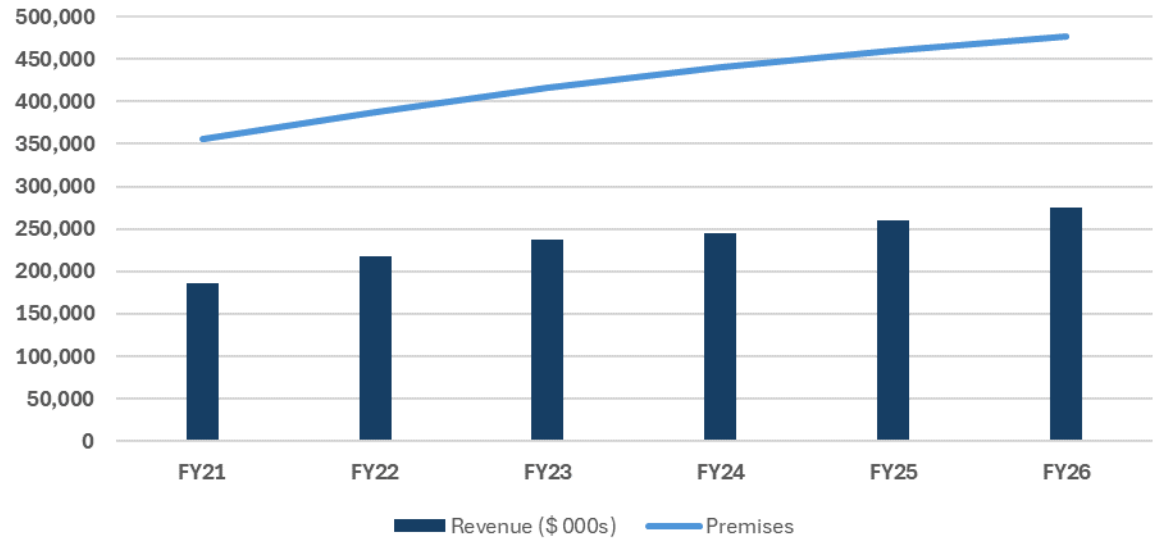
sufficiently robust in reflecting mobile operations cash earnings and are sufficiently comparable across the twenty-year period.

5.1.5 NBN and other licensee valuation indicators

We don't have similar time series indicators of value-in-use for NBN Co and the other spectrum licensees but make the following observations.

NBN's use of spectrum is predominantly to support its fixed wireless broadband service, and it has a strong recent interest in expanding both coverage and capacity. This has the effect of both expanding its Fixed Wireless Access (FWA) user base as well as service offerings, both lifting its FWA revenue (chart 5.6).

Chart 5.6: Indicative NBN Co Fixed Wireless revenue and premises



Notes: *NBN Co revenue estimates exclude payments from the Regional Broadband Scheme compensating NBN Co for historical and forward looking losses in the supply of Fixed Wireless and Satellite services.*

Source: *Flat Rock Consulting estimates; NBN forecasts in support of nbn's Amended SAU Variation; ACCC NBN Wholesale Market Indicators Report.*

However, there is not a comparably clear pattern of value in use to drawing a reliable index: the duration of available data is only a few years, or a small fraction of the spectrum licence period; and NBN Co's FWA revenue is only a small fraction of its total revenue. As well, while NBN is notionally a commercial enterprise it has yet to make a profit and indeed it still operates on negative cashflow. That is to say that its FWA operations don't contribute materially to earnings, and these remain negative in any case.

Moreover, NBN has wider obligations than achieving a commercial return, including national coverage and the related cross-subsidy, and FWA is a key competent of meeting coverage obligations in high cost areas.

While we don't see merit in a standalone index for NBN FWA, we note that the three MNOs also use some of their spectrum for FWA broadband services, to some extent competing with NBN. (We haven't included MNO FWA revenue in the MSR indicators on materiality grounds.)

Given that NBN competes with the MNOs for broadband services and for spectrum, we suggest the same index should apply to renewal of spectrum it may have interest in.

For the rail authorities and media companies the value-in-use of spectrum relates to operational cost savings from use of spectrum to support operational communications and outside broadcast or news gathering respectively. It may be possible to benchmark this operational use to respective reported operating costs but the spectrum component is likely to reflect only a minor share of such cost, and this may vary considerably from year to year.

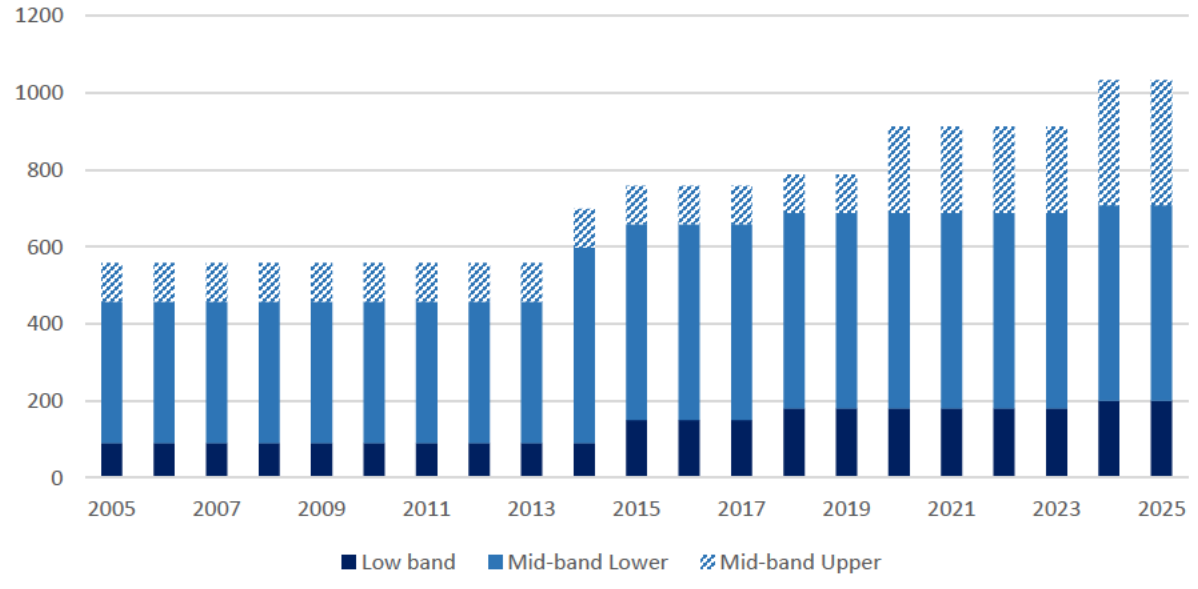
To the extent the relevant spectrum is priced on public interest grounds we consider there is merit in a consistent price signal intertemporally and with regard to alternative users and uses of the spectrum. That might mean an index could be consistent with aggregate market, for instance as a constant factor to a wider spectrum market index.

5.2 Aggregate spectrum held by MNOs

MNOs generate MSR from a combination of network investment and spectrum, and other operational resources. Network investment has increased steadily on an annual basis over twenty years, at least in nominal terms, with related capital expenditure benchmarked to related service revenue.[44]

Spectrum investment is 'lumpy' and not so readily related to annual MSR. Aggregate MNO mobile spectrum holdings were relatively unchanged over nearly ten years from 2005 to 2014, and then increased in a series of steps from a total of 558MHz to 1033 MHz, an 85% increase overall.

Chart 5.7: MNO aggregate spectrum holdings 2005 to 2025 (MHz held on 30 June/1 July)



Note: *Low band is up to 1GHz. Mid band spectrum has been split between lower mid band (1.8GHz, 2.0GHz and 2.3GHz) and upper mid band (3.4 to 3.8GHz). We have not included mmWave holdings at this time. Where there is a difference in spectrum holdings between metro and rural areas, the chart shows metro holdings. We include spectrum contracted for expected use even where a licence has not yet commenced.*

Source: *IMA/ACMA estimates.*

[44] Typically, an MNO might target network capex of say 14% of MSR, plus or minus 2%.

We have broken down the aggregate holding across the MNOs into three broad valuation categories reflecting major price differentials realised across the three categories:

- Low band holdings remained unchanged until 2014, and have since increased by 122%, from 80MHz to 200MHz following the digital dividend and residual spectrum auctions and, more recently, the 850 MHz expansion band (which have been allocated but yet to commence).
- Aggregate lower mid band spectrum holdings also remained unchanged until the 2014 2.5GHz auction,[45] which increased the aggregate holdings in band range from 368MHz (in metro areas) to a total of 508 MHz (ie by 38%). However, initially lower holdings of 40MHz of 1800MHz spectrum in rural and regional areas expanded to 150MHz in 2017, equivalent to metro holdings. We note 2.3GHz holdings were not initially used for mobile broadband service, and for some regional areas wasn't available until 2011.
- The main quantitative and, possibly, qualitative development in aggregate spectrum holdings was in the upper mid band. Spectrum in the 3.4-3.8GHz range wasn't considered of value in the initial part of the twenty year period with value emerging in the years after Optus's acquisition of Vivid Wireless in 2012 and becoming material by 2020. For completeness, we have included the 100MHz of 3.4GHz held by Vivid Wireless in 2005 and acquired by Optus in 2012.[46] It had little value in supporting mobile services until about 2020, however, the impact of that is better captured in a relative value weighting.
- We haven't included mmWave spectrum in this aggregation given its value is yet to be demonstrated and the volumes (in MHz terms) are an order of magnitude greater than spectrum with demonstrated value. In terms of value per MHz it has limited use currently in a spectrum value index.

5.3 Population

The Australian Bureau of Statistics (**ABS**) publishes population data based on adjusted Census counts and updated with quarterly estimates of births, deaths, overseas and interstate migration. These population data differ slightly from the ACMA population data used in the Hierarchical Cell Identification Scheme (HCIS) and the determination of spectrum licence taxes. For example, the ACMA uses a total Australian population of 23,347,848 in 2016 and 25,362,351 in 2021.[47] The ABS population estimates are 24,385,100 and 25,771,400 at the end of 2016 and 2021, respectively.[48]

45 Nationally ex Perth until 2016.

46 Allocated by auction in 2000 and used initially for fixed wireless service.

47 ACMA, *Updating Tax Determinations With New Census Population Data: Consultation Paper*, August 2022, p.1. Some reasons for the discrepancy include the ACMA uses population as measured on Census night (second Tuesday of August) rather than end of year, and does not take into account the ABS' re-estimation of population after the initial data is published to account for Census overcount and undercount.

48 ABS, *3101.0 National, State and Territory Population*, Table 1, December 2023.

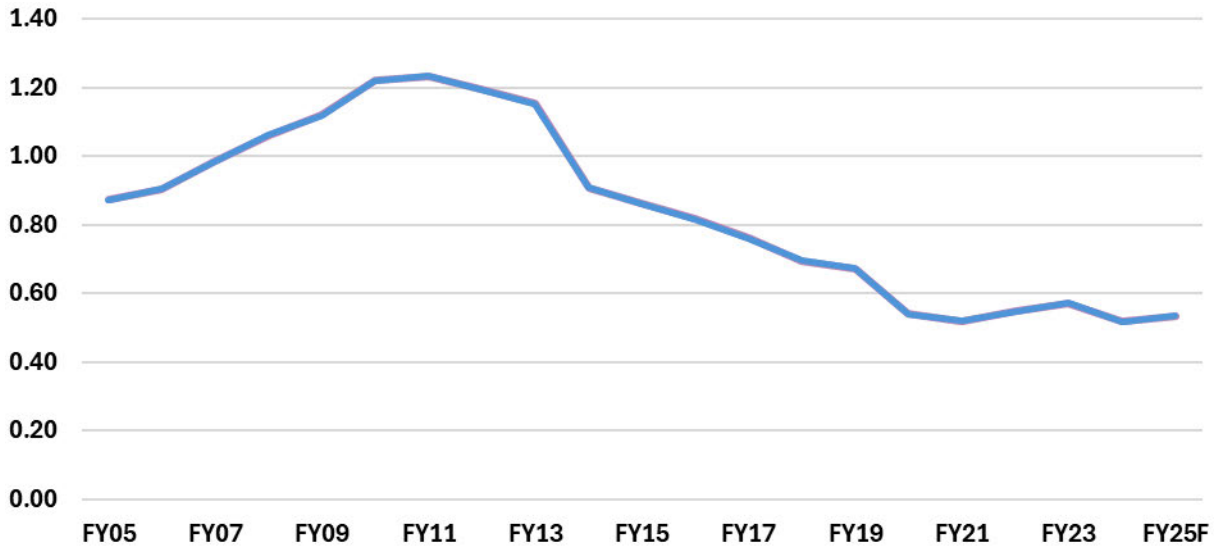
We use the ABS population statistics for the index, as it is provided on a quarterly basis over the period of the index. We also use an ABS population forecast to project the index to 2025.[49]

5.4 Towards an MSR per MHz per pop index

Weighting MSR by spectrum held reflects that, over the long term, MNOs require more spectrum to provide sufficient network capacity to meet the changing needs of the mobile and wireless services market and generate MSR. That requirement continued despite a period of decline in MSR and a less certain outlook ahead.

MSR/MHz/pop held by MNOs increased from about $0.87 in 2005 to a peak of about $1.23 in 2011, and was $0.86 in 2015, the peak year of MSR coinciding with an additional holding of 60MHz of digital dividend low band spectrum.

Chart 5.8: Aggregate MSR per MHz held by MNOs ($m per MHz)



Note: *Includes 100MHz of 3.4GHz from 2005.*
Source: *IMA estimates*

The period of decline in MSR after 2015 coincided with an increase in spectrum held by MNOs, exacerbating the rate of decline in MSR on a per MHz per pop basis. While market MSR dropped by 18.5% over the five years to 2020, MSR per MHz per pop dropped by 37.3% over the same period.

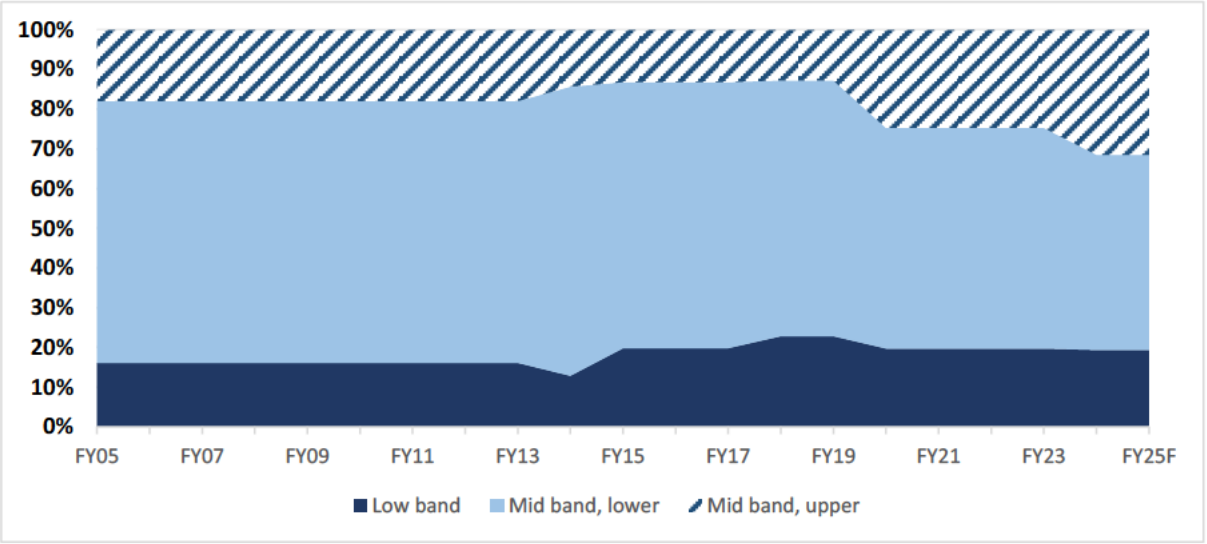
The value of spectrum is partly dependent on its scarcity. As more spectrum is made available and it becomes less scarce, all other things help constant, its value can be expected to decline.

The change in spectrum mix from 2015 commenced with an increase in low band holdings following the digital dividend and residual spectrum auctions. The effect of this was to increase the relative holding of (more valuable) low band spectrum from 16% of total in the

[49] ABS, *Population Projections, Australia*, 23 November 2023. We use the medium growth projection for 2025.

ten years to 2015 to 23% by 2018, before falling to 20% with the recent 3.4-3.8GHz auctions.

Chart 5.9: Aggregate MNO mobile spectrum by broad bandwidth range (% of total)



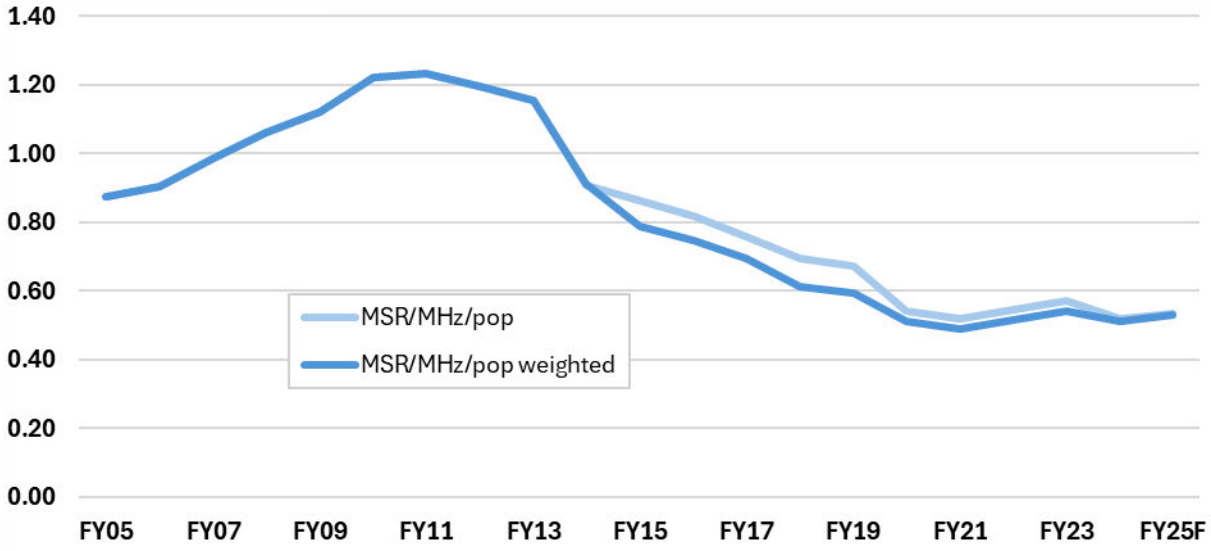
Note: *Low band is up to 1GHz. Mid band spectrum has been split between lower mid band (1.8GHz, 2.0GHz and 2.3GHz) and upper mid band (3.4 to 3.8GHz). We have not included mmWave holdings at this time. Where there is a difference in spectrum holdings between metro and rural areas, the chart shows metro holdings.*

Source: *IMA estimates*

However, over a long period of time the relative merits of different bandwidth ranges change as technology and services evolve. Notably mid band spectrum has become of increasing relative use and the 3.4-3.8GHz range of mid band spectrum has become increasingly valuable given its relatively high data transmission rates.

As an illustration of the possible allowance for different band width holdings we have weighted the three band width ranges by indicative nominal price paid at recent auctions: low band at 1.35; mid band lower at 0.6 and mid band upper at 0.0 until 2020 and then 0.2. The level of weightings therefore broadly reflects future expectations at the time of each auction. The effect of even such an approximate value weighting illustrates that the impact of the MSR downturn after 2015 and downturn in MSR per MHz is somewhat greater if the index takes some account of the higher valuations of low band spectrum relative to mid band spectrum and incremental low band holdings in the years after 2015.

Chart 5.10: Aggregate MSR per MHz per pop held ($m per MHz per pop)



Note: *Low band weighted at 1.35, mid-band lower at 0.6 and mid-band upper at 0.0 until 2020 and then 0.2*
Source: *IMA estimates*

5.3.1 Some issues worth considering in an MSR/MHz/pop index

Mobile Service Revenue is consistently reported in aggregate by the three MNOs although there are differences in some of the sub-categories of revenue reported including mobile broadband and wholesale. Since we are taking an aggregate measure, such reporting differences won't affect the quality of the index. They may matter if there is a need for different indexes for low band v mid-band and higher levels of spectrum.

We also note minor changes in revenue reporting over time and that we have included MSR as reported by the MNOs without adjusting for different reporting periods. We think these are not material to the value of the generated.

The three MNOs use some of their mobile spectrum for wireless broadband services, the revenue for which is reported as fixed service revenue and not included in our outlined index. Proper matching of revenue generated (and therefore the extent to which cashflow expectations are net) requires that fixed wireless revenue be included. However, it's a minor amount relative to mobile revenue and not likely to greatly affect the index.

Similarly, we have included some upper mid-band spectrum held by NBN Co in some areas (but not necessarily nationally) but not included any related NBN FWA revenue. Again, the amounts are relatively small and unlikely to affect the index. In any case, it should be possible to allow for all NBN FWA spectrum and revenue if this MSR/MHz/pop index is to be pursued.

Spectrum held by MNOs has varied materially between metro and regional areas for some bands. However, spectrum holdings are relatively consistent across the six major metro markets (with some minor exceptions) where the bulk of related revenue is generated. Adjusting for regional variations in spectrum held is likely to be complex without adding much further insight to an MSR/MHz/pop index given the small marginal impact. In effect we

assume all spectrum is held by MNOs as a national licence matching the geographic area in which MSR is earned.

A key issue is to what extent different bandwidth holdings have contributed to MSR, or to expectations of MSR and cashflow at the time of previous pricing. Twenty years ago, low band spectrum was considered significantly more valuable than mid-band spectrum for mobile service, with its relative value possibly peaking ten years ago as MSR reached its then peak. Since then, valuations of mid band spectrum have risen sharply although still well below that of low band spectrum. The different rates of change in relative value, and the extent to which each is important to expected cashflow, may require variations in the index applied to each broad spectrum range. Notably, we haven't included mmWave spectrum in this outlined index given its value is yet to be well-demonstrated while the spectrum amounts are huge in terms of MHz.

6 ITU spectrum valuation methodologies

The ITU has provided advice on valuation of spectrum as a 'scarce resource' for reserve pricing purposes, noting the economic characteristics of spectrum including that its value is derived from end use. "The demand for spectrum is a derived demand. Valuation of spectrum is determined to a large extent by its demand which, in turn, depends on the willingness and ability to pay of … Telecom Service Providers (TSPs) who use it as an input in the production of telecom services. Thus, valuation represents: what price would the market eventually be willing to pay for spectrum?" [50]

The ITU considers two broad approaches to spectrum valuation, indexing from previous auctions, or estimating value in use. It says of there are merits and drawbacks with each approach. "Prudence says better to draw on several models to arrive at a reasonable valuation and then base a reserve price on such a valuation".[51]

It proposes indexing from previous auction using one of three approaches:

- The Base Rate being the government long term bond rate.
- The Weighted Average Cost of Capital (WACC) being the rate of return that an entity needs to earn to recompense its investors.
- The Cost Inflation Index (CII) as a measure of inflation when computing long-term capital gains on assets. The CII can also be used to compute the indexed present value of assets purchased in the past.

The ITU also proposes three fundamental valuation approaches which draw on revenue and cost measures of TSP. In each case its consideration applies to an incremental allocation of spectrum in an already established business model.

- Producer surplus.
- Production function
- Surplus revenue approach.

[50] ITU, *Methodologies for valuation of Spectrum, ITU-T Technical Report*, approved at the ITU-T Study Group 3 meeting held in Geneva, 5-13 April 2017, p.3.

[51] Ibid, p. 4.

6.1 Producer surplus approach

The 'Producer Surplus' that arises when additional spectrum is allocated to an existing TSP is based on the inverse relationship between the quantum of spectrum allocated and the expenditure on the radio access network (RAN) required for serving a particular level of demand. The allocation of additional spectrum to an existing TSP will create an incremental producer surplus.

"Let us consider a TSP offering GSM service having 'x' MHz of spectrum. The TSP has drawn its long term demand model and thereby it has made projections of (i) geographical coverage requirements and (ii) network capacity requirements in each year with 'x' MHz of spectrum available to it. In order to fulfil its requirements of coverage and capacity, the TSP has to make capital expenditure on the network apart from incurring operating expenditure to run the network every year. Accordingly, the TSP has estimated the total expenditure on the network to be incurred in each year during the next 'y' years, which shall be required to fulfil its projected demand.

If the TSP obtains an additional spectrum of 'a' MHz today, the capital expenditure on the network and operating expenditure to run the network in each year, required to fulfil the same demand, will be lower owing to the inverse relationship between the spectrum available and the expenditure on the network. A working hypothesis could be that the value that the TSP places on the additional spectrum is approximately equal to the cost savings upon its acquisition.

It would be necessary to estimate the expenditures to be incurred during the next 'y' years for the two cases described above i.e. one with the available spectrum of 'x' MHz and the other with spectrum of 'x+a' MHz on the basis of demand and network expenditures and compute the present value (PV) of the estimated expenditures.

6.2 Production function approach

The ITU also considers valuation of spectrum using a production function approach based on the Cobb-Douglas function.to estimate the relationship between inputs and output.

$X = Ay^{\alpha}z^{\beta}$

In the above equation, the dependent variable (X) is the minutes of usage. The independent or explanatory variables are: (i) Allocated amount of spectrum (y) and (ii) No. of Base Transceiver Stations (BTSs) deployed by a service provider (z). The parameters α and β reflect the percentage change in minutes of usage for a percentage change in spectrum and BTS respectively.

The above specification is based on the assumption that the two inputs spectrum and BTS can be substituted for each other over a given range of output. An optimal mix of both will be used by service providers to produce the required traffic and that optimal mix is determined by input prices. A higher charge for spectrum will induce service providers to substitute the less expensive BTS for spectrum over the relevant range to get the same minutes and vice versa.[52]

[52] Ibid, p. 5-7.

6.3 Revenue surplus approach

An alternative approach to assess the value of spectrum could be from the perspective of a TSPs willingness to invest in spectrum to realize the net revenue potential or revenue surplus from the wireless market over the licence period.

The approach is based on the concept of net present value (NPV) and draws on industry data such as the number of subscribers, revenue, ARPU as well as respective growth rates of subscribers and ARPU, EBITDA and projected capex. Rates of depreciation, return on capital investment, and discount rates need to be adjusted on country to country basis.

The NPV of projected revenue surplus per MHz of spectrum over the license period (net of all expenses/costs) would potentially represent the maximum amount which a buyer would be willing to pay for acquiring the one MHz of spectrum.

Attachment A: Spreadsheet model for benchmark adjustments

Attachment B: WACC benchmarking

Attachment C: MSR index calculation