Attachment A: Proposed benchmarking methodology for ESL pricing

This attachment provides additional information behind the ESL pricing methodology that staff propose to use. It is structured in the following manner:

- Explanation for why we are proposing to move forward with a benchmarking methodology rather than econometrics, cost modelling or an enterprise value modelling methodology.
- A step-by-step rundown of how the benchmarking approach could work.
  - Direct benchmarking, which we propose to be at the core of the approach, is outlined in substantial detail.
  - Adjusted benchmarking, which we propose to use as a supplement to direct benchmarking in certain cases, is briefly discussed thereafter.

This attachment also includes 3 appendixes. Appendix A has a detailed stylised example of how the direct benchmarking methodology could work; Appendix B outlines the tilted annuity approach for duration adjustments; and Appendix C reproduces a summary of the advantages and disadvantages of different valuation methodologies.

Choice of valuation methodology

The June 2023 Plum Consulting report titled 'International best practice in spectrum valuation methodologies' (the Plum 2023 report, which is **Attachment E** of this Spectrum Committee package) outlined 6 different types of spectrum valuation methodologies. These are: direct benchmarking; adjusted benchmarking; econometrics; avoided cost modelling; iterated cost modelling; and business modelling. The advantages and disadvantages of each methodology are summarised in Figure 9.1 of the Plum 2023 report, which is reproduced at Appendix C of this attachment.

The key issues to consider with these methodologies, particularly from the context of being a regulator, include the following:

- **Availability of data**
  - Reliable valuation estimates require access to sufficiently large, detailed and relevant datasets. For the modelling methodologies (avoided cost, iterative and business), this often involves commercially sensitive data and forecasts that we do not have visibility of as a regulator. For econometrics, it would be highly challenging to compile a large enough dataset to provide for robust results.
- **Relevance of data inputs and methodology outputs**
  - In the absence of available data, internal staff or external consultants would need to make assumptions that may be inconsistent or irrelevant for the valuations being estimated, eroding the reliability of any of the modelling valuation methodologies.
  - The outputs from modelling or econometrics may not be overly relevant to final ESL prices – i.e. avoided cost modelling often represents a valuation floor while business modelling often represents a valuation ceiling, but neither represent a market value.
- **Complexity, time and cost**

- Each of these methodologies are all relatively complex and time-consuming to complete and would likely require additional costly external support from expert consultants.
- There is a wide breadth of spectrum bands we are intending to generate valuation estimates for in this process. The modelling methodologies are unlikely to be appropriate as valuations for each band are likely to have interdependencies with one another and are unable to be assessed in isolation.

In addition to the staff analysis above and the summary of methodologies in the Plum 2023 report, some of these matters were canvassed in stakeholder submissions to our Stage 1 and Stage 2 public consultations. For example, Optus (with Analysys Mason) noted the potential lack of relevance of modelling data, as the data would be company-specific but ESL prices would likely be industry-wide.

Having assessed the relative advantages and disadvantages of each of the valuation methodologies based on the Plum 2023 report findings and stakeholder feedback, staff consider a benchmarking approach is appropriate, incorporating both direct benchmarking and adjusted benchmarking.

Staff identified complexities in the application of a benchmarking approach, which led to the procurement of 3 expert consultancy reports in 2024. The benchmarking approach described below reflects staff consolidated views, based on consideration of those reports.

Benchmarking introduction

The Plum 2023 report (page 15) provides a helpful overview of what benchmarking entails:

Benchmarking analysis is a common methodology used by regulators in spectrum valuation. It involves a comparison of actual prices from spectrum auctions or trades for a selection of data points. This is feasible in the case of bands used for cellular mobile services but not for bands used for other services (such as land mobile radio, microwave links, or satellite services).

The benefits of benchmarking include the following:

- When performed appropriately, benchmarking can determine a useful approximation of market value for each spectrum band, which aligns with our intent to apply opportunity cost pricing principles. This contrasts with modelling options that can reflect a valuation floor or valuation ceiling rather than the market value that falls within that range.
- It is relatively transparent and easy to understand, as each data point reflects the actual amount paid by operators for spectrum and is verifiable because it is based on publicly available data.
- It has the added benefit of being the simplest and least time-consuming of all the methodologies considered.

Benchmarking can be separated into direct benchmarking and adjusted benchmarking.

- Direct benchmarking uses prices paid for a particular spectrum band in other countries (as well as previous domestic prices) as a basis for valuation.
- Adjusted benchmarking uses the relative value of a particular spectrum band compared with one or multiple other spectrum bands in other countries as a basis for valuation.

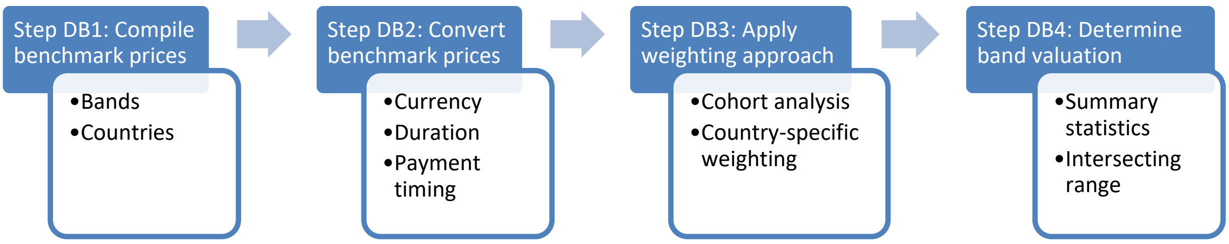
The broad approach staff propose for each particular spectrum band is to perform a direct benchmarking exercise, and to supplement this analysis with adjusted benchmarking in certain situations. These situations include where we do not have relevant domestic price benchmarks and the international benchmarks are from countries that have very different characteristics to Australia. In such cases, the value of a spectrum band in those countries may not be relevant but the difference in value between bands can be informative.

Direct benchmarking approach

Direct benchmarking involves determining a valuation for a particular spectrum band based on benchmark valuations for the same band (and potentially for directly substitutable bands, such as all sub-1 GHz IMT bands). The direct benchmarking approach to calculate a price for a particular spectrum band includes 4 broad steps, which are the following:

- **Step DB1:** Compile relevant benchmark prices for direct benchmarking purposes. These can be in groups of substitutable bands.
- **Step DB2:** Convert each benchmark price (in $/MHz/pop terms) to a consistent currency, duration and payment timing. This process involves using steps in our expert consultancy advice.
- **Step DB3:** Perform a weighting exercise (i.e. cohort analysis or applying country-specific weightings) on the available benchmark prices.[1]
- **Step DB4:** Determine the $/MHz/pop valuation (or range of valuations) from the standardised, weighted benchmark valuations.

Proposed ESL pricing approach – direct benchmarking



The method we propose to use for direct benchmarking is detailed below, and a hypothetical example for how it could work is stepped through in Appendix A.

Step DB1: Compiling benchmark prices

A benchmarking exercise requires a reasonable sample of domestic and international spectrum prices. Staff have been researching international auction results for many years with the main purpose of supporting our considerations for auction starting prices, so we already have a useful database with information sourced direct from international regulators' websites. Staff intend to broaden our database for this benchmarking exercise, and use market research services the ACMA subscribes to (such as Cullen International, and PolicyTracker) to extend our research.

The key steps in compiling benchmark prices are to select which benchmark prices to include as part of the analysis and which information is needed for each benchmark price.

[1] Further detail on cohort analysis and numeric weighting is provided in the specific section for Step DB3.

- When selecting benchmark prices, we will consider the similarity that a foreign country has to Australia, based on particular parameters, as well as whether the timing of the benchmark price remains relevant.
- When selecting the information we need for each benchmark price for a particular spectrum band, we need sufficient information to allow for conversions to a consistent currency, duration and timing, as well as data points for weighting. We would therefore want to collect the type of information included in the following table.

Table 1: Information required for benchmark prices

Item	Description
Price	Total price of allocation in local currency. Should include total of upfront fees and any ongoing fees (which can be discounted back to be added to the upfront fee amount).
Bandwidth (MHz)	The amount of spectrum available in the allocation (note: this may not be the same for the entire allocation).
Population	Population of the area available in the allocation. Would typically be an entire country but may be a subset of a country (e.g. our own 3.4/3.7 GHz bands allocation process did not include remote areas).
Price/MHz/pop	The price divided by the bandwidth divided by the population. This is the actual benchmark price to be used to inform our methodology. It may be a weighted average if bandwidth is not the same across the whole population being considered.
Licence dates / Duration	Start and end dates for the licence. The licence duration allows for duration adjustments and the start date allows valuations to be carried forward to a consistent date.
Exchange rate (spot and PPP)	The exchange rate for the local currency to the Australian dollar at the time of the allocation. The spot exchange rate is the traded value of currency, while the purchasing power parity (PPP) exchange rate reflects the relative prices for an equivalent basket of items.
Real GDP (or real GDP per capita)	Real GDP reflects the value of all goods and services produced in an economy. Real GDP per capita (which can be found by itself or by dividing real GDP by our population figures) correlates positively with 'per MHz per pop' spectrum prices.
Geographic area	The size of the geographic area for a spectrum allocation allows population density to be calculated. Population density correlates positively with 'per MHz per pop' spectrum prices as network deployment costs are reduced as density increases for a given population.
# of MNOs	The number of MNOs indicates the market concentration of national mobile markets. The number of MNOs correlates positively with 'per MHz per pop' spectrum prices, as it often means there is more competition in spectrum allocations.

Note: This list is not exhaustive with respect to parameters that could be used as weights – i.e. real GDP (or real GDP per capita), geographic area and # of MNOs items are examples of data that could be compiled to use as weights.

Step DB2: Converting benchmark prices

For benchmark valuations to be relevant in a direct benchmarking exercise, they each need to be converted to be consistent with the potential licence characteristics for the valuation we are seeking. The characteristics that will generally need to be converted include the currency (i.e. converting to Australian dollars), the licence duration (e.g. 20 years) and the payment date (e.g. the licence renewal date).

The steps to perform such conversions for benchmark valuations were provided in the expert consultancy reports. The steps we are proposing to use are outlined below, and primarily follow the steps from the report received from Ian Martin Advisory (the IMA report) in 2024 (note: the step numbers do not correspond to the step numbers in the IMA report).

Step DB2(1) – convert valuation to a single-year cashflow

Staff propose to use a tilted annuity approach (described in Appendix B) to convert benchmark prices for different licence durations, which in this step would be to a 1-year licence duration.[2]

The tilted annuity approach assumes that the value of an asset like a spectrum licence is based on the series of cashflows that it would generate for the licensee, and that licensees would pay up to the excess cashflows it could generate. The tilted annuity approach can help construct a series of cashflows based on the valuation and ascribe different valuations to different durations based on that cashflow series.

Important elements of the tilted annuity approach include the following:

- The 'tilt' in the tilted annuity refers to the expectation that nominal cashflows will grow from year to year.
- Each nominal cashflow can be discounted to present value using an appropriate discount rate, with staff considering the weighted average cost of capital (WACC) to be most appropriate.[3]
- A selection of cashflows in the series can approximate the equivalent value of a licence of a different duration (e.g. for a 15-year benchmark valuation, the sum of the present value of the first 5 annual cashflows would represent an equivalent 5-year licence valuation).

The tilted annuity formula typically starts with a single valuation for the entire licence duration, so for licences that involve upfront and ongoing (e.g. annual) fees, we should bring all payments back to present value using the WACC. This allows for a single valuation to be part of the tilted annuity approach and therefore converted for different durations.

While we discuss the concept of constructing a series of cashflows, staff note that there are relatively simple mathematical formulas that can be used for duration-adjustment calculations. Appendix B to this attachment details the mechanics of how the tilted annuity works, including how the series of cashflows is constructed and the formulas involved. It also

---

[2] The IMA report argues for the use of a flat annuity approach and criticises the tilted annuity approach. However, the issues identified with tilted annuity in the IMA report primarily concern carrying forward valuations in Steps 2 and 3 (equivalent to Steps DB2(3) and DB2(4) in this methodology). The IMA report (see p29–30) states that the issues "might have little impact on the public interest" for Steps 1 and 4 (equivalent to Steps DB2(1) and DB2(5) in this methodology), as it is simply adjusting for duration and not changing payment timing. We will therefore progress with the use of a tilted annuity approach for these steps.

[3] For detailed consideration on the appropriate specifications for use of the WACC, including the appropriate WACC rate to use, refer to chapter 4 of the IMA report or section 3.2 of the Frontier report (Attachment H of this Spectrum Committee package).

includes discussion of some further complications with the approach, such as which cashflow growth and WACC inputs to include.

The end result of this step is that we should have converted each benchmark price into its equivalent 1-year valuation, so all benchmarks are duration-consistent.

Step DB2(2) – convert to Australian dollars

The previous step converted all benchmark valuations to a common licence duration. This step continues the conversion process by converting to a common currency, which will be Australian dollars as ESL prices will ultimately be in Australian dollars.

The currency conversion process is based on point-in-time exchange rates – e.g. if we have a benchmark price from 2015, we would use 2015 exchange rates. Staff propose to conduct the analysis using both the 'spot' exchange rate and the purchasing power parity (PPP) exchange rate. Figure 5.2 in the Plum 2023 report outlines the reasoning for considering both types of exchange rate. The availability of PPP exchange rates is more limited (the World Bank has occasional annual data) than spot exchange rate data that is available daily. However, given PPP exchange rates are far less volatile, we intend to use PPP rates for the given year where available.

The end result of this step is that we should have converted each 1-year benchmark price into Australian dollars, with 2 values for each – one for the spot exchange rate and one for the PPP exchange rate.

Step DB2(3) – carry forward benchmark valuations to the present

The benchmark prices have already been converted to a common duration and currency, but the allocation/payment of spectrum will have occurred at different times. We therefore need to carry forward valuations to a common date based on historical data. Staff propose to carry forward values to a particular date close to the present day (e.g. 31 December 2024).

When carrying forward valuations, we want to assess how the value of spectrum has moved over time, rather than simply using the time value of money. While we could theoretically use a metric like the Consumer Price Index or the WACC to carry forward valuations, the IMA report outlines at Chart 3.3 (page 30) that the use of these metrics is not appropriate for carrying forward valuations as their growth rates are not representative of time trends for spectrum valuations. They would therefore lead to prices that are substantially higher than contemporary spectrum valuations.

There are several different ways that we could carry forward valuations, and different consultants advised different methods. There were consistent views regarding mobile profit as the best indicator of the cashflows being generated from spectrum, but profit data can be volatile and difficult to make a consistent series from. The use of mobile service revenue (MSR) may therefore end up being a more useful indicator.

As such, we consider Ian Martin Advisory's method (the MSR/MHz/pop index) in the IMA report is likely to be best suited for this purpose. The reasons for this include:

- MSR is more accessible than other potential data sources.
- MSR/MHz/pop accounts for the increasing supply of spectrum over time, which should theoretically lead to spectrum becoming less valuable on a 'per MHz' basis.
- MSR/MHz/pop ensures we are not double-counting population growth when carrying forward a $/MHz/pop value.

- The IMA report includes an attachment with historical growth in the MSR/MHz/pop index, which may require some refinement but is a highly useful starting point for this process.

The actual process for using the index is simple – you divide the benchmark price by the index value for its specific time period, then multiply the result by the index value for the time period to which it is being converted. For example, assume there is a benchmark price of $0.50/MHz/pop in 2015. If the index is at 80 in 2015 and 100 in 2024, and the price would be divided by 80 and multiplied by 100 to find a value of $0.625/MHz/pop for 2024.

Staff note that the Frontier Economics method for carrying forward valuations (as outlined in the Frontier report, which is **Attachment H** of this Spectrum Committee package) appears relatively sound as well, but average revenue per user (ARPU) data appears harder to compile, and ARPU is generally available for each MNO so would require weighting to find an industry-wide value.

The end result of this step is that we should have a 1-year licence valuation in a common currency (Australian dollars) and with a common date, with 2 values for each – one for the spot exchange rate and one for the PPP exchange rate.

Step DB2(4) – carry forward to payment date

The benchmark prices have now all been converted for duration, currency and time. The next step is to ensure the prices for each band are pushed forward to their potential payment date – e.g. if payment will be due on the licence expiry/renewal date, the price should reflect that specific payment timing.

While the previous step brought historical prices to the present, this step projects prices into the future. The key consideration in projecting prices, as outlined in greater detail in Plum Consulting's report for the ACMA provided in July 2024 (the Plum 2024 report, which is **Attachment F** of this Spectrum Committee package), is whether to use the current value of the spectrum or the expectations of the value of the spectrum in the future. For example, for the 850 MHz band ESLs, it may be a question of whether we project future prices based on how the spectrum is valued in 2025 (when we are intending to publish indicative prices) or how the spectrum is likely to be valued in 2028 (when the ESLs are due to expire).

The use of current values will still require forward projections based on the time value of money. Staff consider that MSR/MHz/pop forecasts should be used to push prices forward to future data. This recognises that ESL prices should involve payment based on expectations of value at the commencement of the new licence. It is also noted that use cases for ESL bands have been fairly stable over the long term, so we do not expect valuations for ESL bands to change substantially in the future based on changing expectations of use.

While using MSR/MHz/pop for Steps DB2(3) and DB2(4) may mean it would be more efficient to consolidate them into a single step, we note that having multiple steps is beneficial when considering groups of bands. For instance, 850 MHz expires in 2028 and 700 MHz expires in 2030, so they could have identical present-day prices but can be pushed forward into different values as they will likely be paid for at different times.

The end result of this step is we should now have a set of 1-year licence prices for a particular spectrum band at a proposed future date that reflects payment timing.

Step DB2(5) – convert to desired licence duration cashflows

The final step is to convert all of the 1-year valuations (with a common currency, duration and correct future timing) into desired licence durations.

We can use the same tilted annuity formula as in Step DB2(1) to expand 1-year valuations out to the desired duration (e.g. 20 years). See Appendix B to this attachment – specifically the section on converting valuations for longer licence durations – for further detail on how the formula would work for this step.

We note that the cashflow growth and WACC rates would not necessarily be the same as they were several years ago. However, we are intending to use stable long-term rates that mean there should not be a huge difference compared with using rates specific to each time period (this issue is noted in Appendix B).

The end result is that we will have a set of benchmark prices that are consistent for our desired licence duration, as well as currency (separate sets for spot and PPP exchange rates) and timing.

Step DB3: Weighting

Following the previous step, we have available a range of benchmark valuations that have consistent characteristics. However, these benchmark valuations are unlikely to all be equally relevant in the Australian context. For instance, domestic benchmarks are likely to be more relevant than international benchmarks. To adjust benchmarks for their relevancy, we can perform a weighting exercise. The Plum 2024 report provides substantial detail on how to undertake weighting.

The first step in weighting is determining the appropriate parameters to use as weights – common examples include real GDP or real GDP per capita, amount of bandwidth sold in an allocation, number of MNOs in that country's market, population density, etc. This data should have all been collected in Step DB1.

There are then 2 types of weighting exercises we can apply.

- **Cohort analysis**
  - Benchmark valuations are grouped into 'cohorts' for different parameters based off how similar they are to Australia in that parameter (e.g. the real GDP per capita cohort may include countries that are within 25% of Australia's real GDP per capita value).
  - We would need to do a sensitivity analysis by adjusting the weighting thresholds for each cohort (e.g. analyse the real GDP per capita cohort at 15% and 35%) to assess the reliability of our thresholds.
  - The same analysis is performed on the full sample of benchmark prices and on each individual cohort. For each of these analyses, we would find usable summary statistics (e.g. arithmetic mean, geometric mean, median, interquartile range, etc.). These statistics can help with Step DB4 in determining final prices.
- **Numeric weights**
  - For each parameter for each country, we calculate a weighting value based on its closeness to Australia's value (e.g. a real GDP per capita value that is 25% lower or higher than Australia's would have a weight of 0.75). There are several methods for calculating weights – refer to the Plum 2024 report for further detail.

- Where multiple weights are being used for a benchmark valuation, they can be combined using several different methods to create a single distinct weight. The methods include multiplying them together, taking the arithmetic mean or the geometric mean of the weights.[4]
- Based on the weighted values, we could then find whichever summary statistic (or range) is most relevant – e.g. the weighted mean or weighted median for a single value, or the weighted interquartile range for a range of values.

The end result of this step will be that weighted data – separate for the spot exchange rate and PPP exchange rate datasets – will be available from which to determine a final price for a given ESL band. It should be noted that staff have not yet determined the optimal approach for weighting – we expect both methods will have merit when the pricing analysis begins to take shape.

Step DB4: Determine band valuation

The method of determining the price of an ESL band will depend on the weighting method used in the previous step. For example, we could use the 'intersection range' of values that are common to each cohort if using a cohort analysis, while we could use a simple weighted average for the numeric weighting method. Staff have also not yet determined whether to use the spot exchange rate or PPP exchange rate datasets, or a combination of the results from the different datasets. See the explanation of this step in Appendix A for further detail on how these could work. We expect to be able to provide more detail on this step in a later Spectrum Committee paper where we propose preliminary views on pricing.

Adjusted benchmarking approach

We propose to include a supplementary adjusted benchmarking analysis where there is a lack of relevant domestic direct benchmarks for the spectrum band for which a valuation is being sought (the *target band*), but there are relevant domestic benchmarks available for one or multiple other spectrum bands (*comparator bands*).

Adjusted benchmarking works by finding the value relationship between the target band and the comparator band(s) in a variety of countries, then using that relationship to infer a target band value based on more relevant domestic valuations for the comparator band(s). Values can be inferred for the target band based on one comparator band (the *relative value method*) or multiple comparator bands (the *distance method*). The broad steps for each of these methods are largely the same, as outlined below.

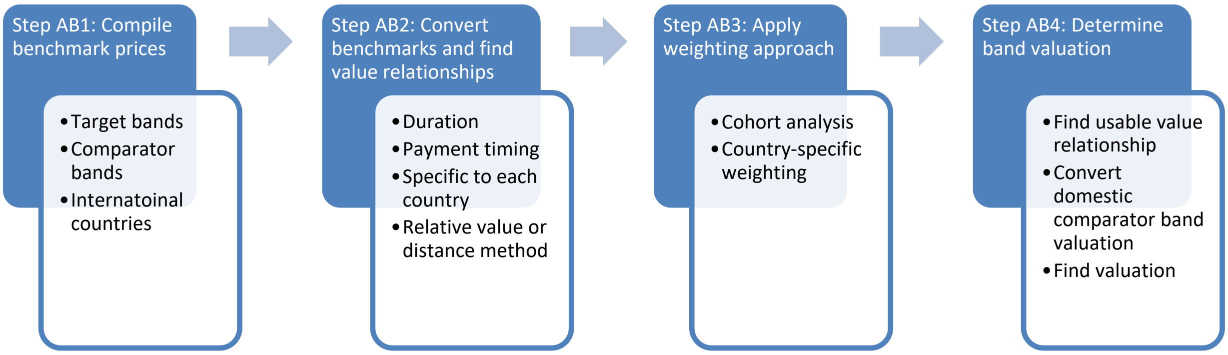
- **Step AB1:** Compile relevant benchmark prices – both for the target band and for any comparator bands.
- **Step AB2:** Convert each international benchmark price to a consistent duration and payment timing within each country. Determine the value relationship between the target band and the comparator band(s) in each country using the relative value method or the distance method.

---

[4] For example, assume a benchmark valuation has 3 weights: 0.8, 0.75 and 0.6. If we were to multiply them together, we would find $0.8 \times 0.75 \times 0.6 = 0.36$, which is a relatively low combined weight given each individual weight is much higher. If we were to take the arithmetic mean, we would find $(0.8 + 0.75 + 0.6) \div 3 = 0.72$. If we were to find the geometric mean, we would find $(0.8 \times 0.75 \times 0.6)^{\frac{1}{3}} = 0.71$. The arithmetic mean appears to be the best solution, particularly as a zero weight for any parameter would lead to a combined weight of zero using the multiplication or geometric mean approaches.

- **Step AB3:** Perform a weighting exercise (i.e. cohort analysis or applying country-specific weightings) on the available value relationships.
- **Step AB4:** Determine the value relationship (or range of relationships) from the standardised, weighted benchmark value relationships. Apply to the relevant domestic benchmark valuation(s) (converted to the equivalent licence duration and payment timing for the ESL target band) to determine the $/MHz/pop valuation (or range of valuations).

Figure 1: Proposed ESL pricing approach – adjusted benchmarking



As the steps for direct benchmarking and adjusted benchmarking are largely the same, the following discussion outlines how adjusted benchmarking is different.

Step AB1: Compile benchmark prices

There are multiple aspects to compiling benchmark prices for adjusted benchmarking:

- Determining the comparator bands for a particular target band. For example, we may have few relevant 2.3 GHz band benchmark prices, but we have more recent benchmark prices in 900 MHz and 3.4 GHz that could be used for adjusted benchmarking – we would need to compile those relevant 900 MHz and 3.4 GHz benchmarks.
- Finding relevant international benchmarks for the target band *and* the comparator band(s) – these benchmarks are only usable if there are both target and comparator band values for a given country.

Staff note that it is likely that this process will apply in reverse. In the course of research on international benchmarks, we may discover prices across different bands that would enable adjusted benchmarking – e.g. several countries with 2.3 GHz and 3.4 GHz benchmarks may enable adjusted benchmarking for 2.3 GHz using 3.4 GHz domestic benchmark prices.

We would want to find all the same information for each benchmark price (target and comparator bands included) as for direct benchmarking.

Step AB2: Convert benchmarks and find value relationships

Step AB2(1) – convert benchmarks

The processes involved in this sub-step depend on whether they apply to benchmarks for the domestic comparator band(s) or benchmarks for the international target and comparator band(s). The differences are the following:

- For benchmarks for the domestic comparator band(s), the same conversion process as for direct benchmarking will apply – i.e. with the correct licence duration and timing. We ultimately want to use a value relationship to convert it to a valuation for our target band, so we need the value relationship to be multiplied by comparator band(s) benchmarks with appropriate duration and timing characteristics.

- For benchmarks for international target and comparator bands, no currency conversions are required, but within a given country they need to be converted to the same licence duration and timing. For example, if a particular country has a target band benchmark that occurred in 2015 for a 15-year licence, and a comparator band benchmark that occurred in 2018 for a 12-year licence, we need to equalise the timing and duration characteristics of the benchmarks. Staff propose to convert comparator band benchmarks to be equivalent to the target band benchmark in each country.

Step AB2(2) – find value relationships

Following the previous sub-step, the benchmarks in each country will be converted to equal characteristics so that a true comparison of valuations can be determined. There are 2 potential methods to use for these comparisons.

- **Relative value method**
  - The relative value method can be used when there is a single comparator band.
  - It involves finding the ratio of the target band valuation to the comparator band valuation.
  - For example, if the target band valuation is $0.40/MHz/pop and the comparator band valuation in the same country is $0.80/MHz/pop, we would find that the relative value of the target band is 0.5.
- **Distance method**
  - The distance method can be used when there are multiple comparator bands.
  - It involves finding the distance from the value of one comparator band to the value of another comparator band.
  - For example, if the target band value is $0.40/MHz/pop and the comparator band values are $0.20/MHz/pop and $0.80/MHz/pop, the distance is calculated as 0.33, as the target band value is 0.33 of the way from $0.20 to $0.80. In formulaic terms, this is calculated as the following: $(0.40 - 0.20) \div (0.80 - 0.20) = 0.20 \div 0.60 = 0.33$.

For each method, we rely on the value relationships being the same direction for all instances. With the relative value method, this means the target band must be consistently higher or consistently lower in value than the comparator band. With the distance method, this means the 2 comparator bands must have a consistent value relationship (one is consistently higher than the other) and the target band must have a value in between.

Step AB3: Apply weighting approach

The weighting approaches (cohort analysis and numeric weighting) are exactly the same as for direct benchmarking, with the exception that the approaches are applied to the value relationships (value ratios or distances) rather than valuations themselves.

Step AB4: Determine band valuation

The approach to determining the band valuation is the same as for direct benchmarking, with the exception that the approaches are applied to the value relationships (e.g. a mean value or interquartile range for value relationships can be found). The value relationships that have been determined then need to be multiplied by the domestic comparator band benchmark(s).

For example, we may determine a relative value of 0.5 between the target band and the comparator band. If the comparator band benchmark valuation is $1.20/MHz/pop, we would then perform the adjustment process and find the target band valuation by multiplying that by 0.5 to reach $0.60/MHz/pop.

Appendix A: Methodology example – direct benchmarking

This section steps out a hypothetical example using the proposed direct benchmarking approach – the valuations are entirely made up and are for an unidentified spectrum band.

Step DB1 – Compile benchmark prices (example)

The first step is to compile benchmark prices in local currencies. We need to make sure we have appropriate surrounding information as well, such as year of allocation/payment, duration, population, etc. We ultimately want to find the price/MHz/pop in the local currency.

Table 2: Direct benchmarking example – compiled prices

Country	Year	Duration (Years)	Price (local)	Bandwidth (MHz)	Population	Price/MHz/pop (local)
USA	2021	15	80 billion	300	300 million	0.89
Canada	2021	20	8 billion	200	34 million	1.18
UK	2021	20	13.2 billion	250	66 million	0.80
Sweden	2013	25	14 billion	260	9 million	5.98
Germany	2019	20	27.5 billion	180	83 million	1.84
Norway	2021	20	15 billion	300	5 million	10.00
South Korea	2018	10	2.75 trillion	270	51 million	199.7
Spain	2018	20	4.8 billion	260	46 million	0.40
Australia	2017	11	6.5 billion	220	22 million	1.34
Belgium	2018	20	2 billion	200	11 million	0.91

We would also supplement this with data for country parameters at the point in time of the spectrum allocations – e.g. real GDP per capita, area (for population density), number of MNOs in the market, etc. The table could be like the following.

Table 3: Direct benchmarking example – compiled weighting data

Country	Year	Real GDP per capita (US$)	# of MNOs	Geographic area (million km^2)	Population density
USA	2021	70,000	4	9.834	30.5
Canada	2021	55,000	3	9.985	3.4
UK	2021	58,000	4	0.244	270.5
Sweden	2013	68,000	3	0.450	20.0
Germany	2019	63,000	3	0.358	231.8
Norway	2021	86,000	3	0.324	15.4
South Korea	2018	46,000	3	0.100	510.0
Spain	2018	43,000	3	0.506	90.9
Australia	2017	60,000	3	7.741	2.8
Belgium	2018	56,000	2	0.031	354.8

We would also compile exchange rate data. For this example, it displayed in Step DB2(2).

Step DB2 – Converting benchmark prices (example)

Step DB2(1) – convert valuation to a single-year cashflow (example)
We can convert the price/MHz/pop for each benchmark from its actual duration (in years) into a 1-year equivalent price using the following formula (which is outlined in much further detail in Appendix B):

$$PPV_n = FPV_L \times \left\{ \frac{1 - \left\{\frac{1+z}{1+r}\right\}^n}{1 - \left\{\frac{1+z}{1+r}\right\}^L} \right\}$$

In this instance, n is equal to one (for the 1-year valuation) and L is equal to the duration (in years) for the applicable benchmark price. We will use a WACC (r) of 8.4% and a cashflow growth rate (z) of 2.5% for this example.[5] We find the following 1-year valuations.

Table 4: Direct benchmarking example – 1-year valuations

Country	Duration (Years)	Price/MHz/pop (local)	1-year Price/MHz/pop (local)
USA	15	0.89	0.0852
Canada	20	1.18	0.0951
UK	20	0.80	0.0647
Sweden	25	0.60	0.4323
Germany	20	1.84	0.1488
Norway	20	1.00	0.8081
South Korea	10	199.7	25.3616
Spain	20	0.40	0.0324
Australia	11	1.34	0.1590
Belgium	20	0.91	0.0735

Step DB2(2) – convert to Australian dollars (example)
We can take the 1-year prices and use compiled spot and PPP exchange rates to convert to Australian dollars, as per the following table.

Table 5: Direct benchmarking example – currency conversions

Country	Local price	Exchange rate (spot)	A$ price (spot)	Exchange rate (PPP)	A$ price (PPP)
USA	0.0852	0.70	0.1217	0.75	0.1136
Canada	0.0951	0.95	0.1001	1.00	0.0951
UK	0.0647	0.55	0.1175	0.50	0.1293
Sweden	0.0432	6.75	0.0641	6.00	0.0721

[5] To make this process more practicable, we intend to use the same WACC and cashflow growth rate for each duration adjustment irrespective of country and time, as our expert consultant reports each noted that it is not realistic to be able to source useful data for each duration adjustment circumstance. Staff have not yet come to a landing on the exact WACC and cashflow growth rates to use (8.4% and 2.5% are just an example).

Country	Local price	Exchange rate (spot)	A$ price (spot)	Exchange rate (PPP)	A$ price (PPP)
Germany	0.1488	0.60	0.2479	0.60	0.2479
Norway	0.0808	7.00	0.1154	6.50	0.1243
South Korea	25.3616	900.00	0.0282	1000.00	0.0254
Spain	0.0324	0.62	0.0523	0.60	0.0541
Australia	0.1590	1.00	0.1590	1.00	0.1590
Belgium	0.0735	0.62	0.1185	0.60	0.1224

Step DB2(3) – carry forward benchmark valuations to the present (example)
We can now carry forward the A$ 1-year valuations to a common date, which we propose to be the end of 2024 at this stage. We can find the MSR/MHz/pop index values for the given year and 2024 to calculate the change.

Table 6: Direct benchmarking example – carry forward to present

Country	Year	Index value	A$ price (spot)	A$ price (PPP)	2024 A$ price (spot)	2024 A$ price (PPP)
USA	2021	97.05	0.1217	0.1136	0.1254	0.1170
Canada	2021	97.05	0.1001	0.0951	0.1031	0.0980
UK	2021	97.05	0.1175	0.1293	0.1211	0.1332
Sweden	2013	91.24	0.0641	0.0721	0.0702	0.0790
Germany	2019	95.57	0.2479	0.2479	0.2594	0.2594
Norway	2021	97.05	0.1154	0.1243	0.1190	0.1281
South Korea	2018	94.50	0.0282	0.0254	0.0298	0.0268
Spain	2018	94.50	0.0523	0.0541	0.0554	0.0572
Australia	2017	96.54	0.1590	0.1590	0.1647	0.1647
Belgium	2018	94.50	0.1185	0.1224	0.1254	0.1296

Note: The 'Index value' refers to the value of the MSR/MHz/pop index in the benchmark year. The converted 2024 prices assume a 2024 MSR/MHz/pop index value of 100.00.

Step DB2(4) – carry forward to payment date
For this unidentified spectrum band, we can assume the payment date will be 2028. We can push forward the valuations found in the previous step to 2028 using projections for the MSR/MHz/pop index.

Table 7: Direct benchmarking example – carry forward to 2028

Country	2024 A$ price (spot)	2024 A$ price (PPP)	2028 A$ price (spot)	2028 A$ price (PPP)
USA	0.1217	0.1136	0.1343	0.1253
Canada	0.1001	0.0951	0.1105	0.1049
UK	0.1175	0.1293	0.1298	0.1427
Sweden	0.0641	0.0721	0.0707	0.0795
Germany	0.2479	0.2479	0.2737	0.2737

Country	2024 A$ price (spot)	2024 A$ price (PPP)	2028 A$ price (spot)	2028 A$ price (PPP)
Norway	0.1154	0.1243	0.1274	0.1372
South Korea	0.0282	0.0254	0.0311	0.0280
Spain	0.0523	0.0541	0.0577	0.0597
Australia	0.1590	0.1590	0.1755	0.1755
Belgium	0.1185	0.1224	0.1308	0.1352

Note: The converted prices assume a 2024 MSR/MHz/pop index value of 100.00 and a 2028 MSR/MHz/pop index value of 110.38 (i.e. assuming 2.5% annual growth from 2024–2028). Given the constant difference between the 2 values (2028 value over 2024 value equals 1.1038), we can just multiply the 2024 values by this factor to find the 2028 projected values.

Step DB2(5) – convert to desired licence duration cashflows

We will use the tilted annuity formula to convert the 1-year cash flow into a licence value covering a duration of 20 years. We can use the same formula as was in Step DB2(1), but with inputs of $n = 20$ and $L = 1$.

Table 8: Direct benchmarking example – convert to 20-year valuations in 2028

Country	1-yr A$ price (spot)	1-yr A$ price (PPP)	20-yr A$ price (spot)	20-yr A$ price (PPP)
USA	0.1343	0.1253	1.6618	1.5510
Canada	0.1105	0.1049	1.3670	1.2986
UK	0.1298	0.1427	1.6055	1.7661
Sweden	0.0707	0.0795	0.8748	0.9842
Germany	0.2737	0.2737	3.3863	3.3863
Norway	0.1274	0.1372	1.5769	1.6982
South Korea	0.0311	0.0280	0.3849	0.3464
Spain	0.0577	0.0597	0.7145	0.7383
Australia	0.1755	0.1755	2.1718	2.1718
Belgium	0.1308	0.1352	1.6185	1.6724

We now have a set of valuations that have been converted for a consistent currency, duration and timing.

Step DB3 – Weighting (example)

The first aspect of weighting is to identify appropriate parameters that can be used to ascertain the relevance of benchmark prices. For this example, we can assume that real GDP per capita, the number of MNOs, and population density are 3 relevant parameters.

We can find the ratio of each country's data to Australia's data. To simplify this exercise, the 2017 data for Australia is taken to be constant, and simple value ratios have been found (e.g. there are no amendments to weights depending on closeness to Australia's values). The only complexity is that the value ratios are also 'mirrored' where other countries' values are larger than Australia's, which allows for equivalent percentage differences in either direction to have the same weight.[6] The value ratios are outlined in the table below.

Table 9: Direct benchmarking example – weighting ratios

Country	Year	Real GDP per capita (US$)	# of MNOs	Population density
USA	2021	0.86	0.75	0.09
Canada	2021	0.92	1.00	0.83
UK	2021	0.97	0.75	0.01
Sweden	2013	0.88	1.00	0.14
Germany	2019	0.95	1.00	0.01
Norway	2021	0.70	1.00	0.18
South Korea	2018	0.77	1.00	0.01
Spain	2018	0.72	1.00	0.03
Australia	2017	1.00	1.00	1.00
Belgium	2018	0.93	0.67	0.01

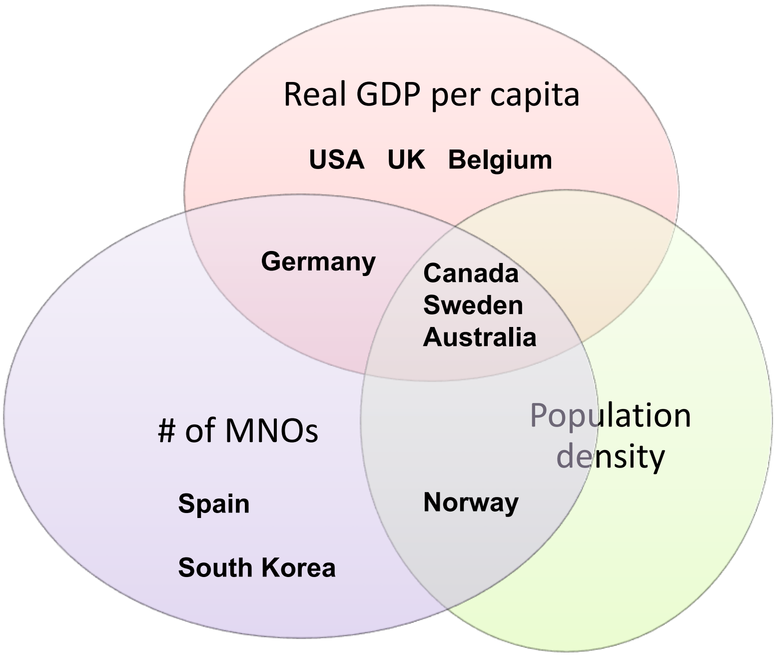
We can use these weights to support a cohort analysis or a numeric weighting exercise, as outlined in the separate examples below.

Step DB3 – Cohort analysis (example)

The key step in a cohort analysis is to determine thresholds at which we consider the parameter to be similar enough to Australia's to justify being in the same cohort. The threshold could be different depending on the parameter (e.g. it would not make sense to have a high threshold for population density, as the only country that could be considered similar is Canada). If we assume a threshold of 0.80 for real GDP per capita, 1.00 for number of MNOs and 0.10 for population density, we can group the countries into cohorts as per the Venn diagram below.

[6] For example, Australia has 3 MNOs. Weights should be smaller the further away the number of MNOs is from 3. Belgium has 2 MNOs, so we can calculate the weight as $2/3 = 0.67$. In contrast, the USA has 4 MNOs, but it is not appropriate to calculate the weight as $4/3 = 1.33$, as it should not be higher than one. As such, for countries with a number of MNOs larger than 3, we flip the equation, which means the USA would have a weight of $3/4 = 1/1.33 = 0.75$.

Figure 2: Cohort analysis – Venn diagram of cohorts



The next step is to effectively run the pricing analysis in Step DB4 on the entire sample and on each separate cohort.

Step DB3 – Numeric weighting (example)
If we were to use a numeric weighting approach, the key step is to determine a single weight for each country based on its similarity to Australia across multiple parameters. Staff propose to use the arithmetic mean or geometric mean, which would lead to the following outcomes.

Table 10: Direct benchmarking example – summary weights

Country	Year	Weight (arithmetic mean)	Weight (geometric mean)
USA	2021	0.567	0.391
Canada	2021	0.917	0.915
UK	2021	0.576	0.197
Sweden	2013	0.675	0.501
Germany	2019	0.655	0.227
Norway	2021	0.627	0.505
South Korea	2018	0.591	0.162
Spain	2018	0.583	0.282
Australia	2017	1.000	1.000
Belgium	2018	0.536	0.171

The weight for the geometric mean is more heavily influenced by outliers, in particular countries with much greater population density have their weights more heavily affected than if using the arithmetic mean (see UK, Germany, South Korea and Belgium). For this example, staff consider that the arithmetic mean is appropriate.

Step DB4 – Determining band valuation

The method for determining the final ESL price (or range of potential prices) depends on which weighting exercise was used.

Step DB4 – Determining price with cohort analysis (example)

If we use a cohort analysis, we want to find summary statistics for each specific cohort and for the sample as a whole (i.e. all benchmarks). The table below performs the analysis for values using spot exchange rates and PPP exchange rates. The analysis includes the sample size, the mean, then the values at each 0.25 percentile for each cohort (i.e. from minimum to maximum and including each quartile in between).

Table 11: Direct benchmarking example – cohort-specific summary statistics

	Cohort	Sample size	Mean	Min	1st quartile	Median	3rd quartile	Max
SPOT	Whole sample	10	1.536	0.385	0.998	1.591	1.651	3.386
	Real GDP per capita	7	1.812	0.875	1.486	1.618	1.917	3.386
	# of MNOs	7	1.497	0.385	0.795	1.367	1.874	3.386
	Pop density	4	1.498	0.875	1.244	1.472	1.726	2.172
PPP	Whole sample	10	1.561	0.346	1.063	1.612	1.749	3.386
	Real GDP per capita	7	1.833	0.984	1.425	1.672	1.969	3.386
	# of MNOs	7	1.518	0.346	0.861	1.299	1.935	3.386
	Pop density	4	1.538	0.984	1.220	1.498	1.817	2.172

The next step is to work out how to analyse these numbers appropriately. The Plum 2024 report suggests analysing either the full range or the intersection of ranges for each cohort. To make this example more manageable, the below diagram considers only the values using PPP exchange rates and demonstrates the concept of the ‘full range’ or the ‘intersection’ with respect to the interquartile ranges of each cohort (i.e. the range between the 1st quartile and the 3rd quartile). The full range falls between the red bounds – from the lowest 1st quartile value in any cohort to the highest 3rd quartile value in any cohort. The intersection falls between the green bounds and only includes the range of values that is included in every cohort – so it goes from the highest 1st quartile value for any cohort up to the lowest 3rd quartile value for any cohort.

Figure 3: Interquartile ranges for cohorts using PPP exchange rates

For this example, the intersection of the interquartile ranges appears appropriate – it includes a range of between $1.42/MHz/pop and $1.82/MHz/pop. The next step from here may depend on the band being analysed and the policy intent how we want to display the prices. For example, we could propose a range of prices or a single price on several different bases:

- a price range covering the whole intersection ($1.42–1.82)
- a narrower price range (e.g. $1.52–1.72)
- the midpoint in the range as a single price ($1.62)
- the lower bound of the range ($1.42), provided we intended to take a conservative approach to pricing.

We consequently multiply whichever price (or range of prices) by the bandwidth (in MHz) and population coverage of the relevant ESLs to determine the renewal prices (note: these prices would be determined with population projections made much closer to future payment dates).

Step DB4 – Determining price with numeric weights

The numeric weighting process is more involved when determining the weight for each country but the price-setting using the weights is simpler. For example, we can use the following information to determine a weighted-average price (i.e. with arithmetic mean weights and price inputs based on PPP exchange rates).

Table 12: Direct benchmarking example – weighted average information

Country	Year	2028 A$ price (PPP)	Weight	Weight percentage	Price x Weight
USA	2021	1.5510	0.567	8.43%	0.8791
Canada	2021	1.2986	0.917	13.64%	1.1909
UK	2021	1.7661	0.576	8.56%	1.0168
Sweden	2013	0.9842	0.675	10.03%	0.6642

Country	Year	2028 A$ price (PPP)	Weight	Weight percentage	Price x Weight
Germany	2019	3.3863	0.655	9.74%	2.2176
Norway	2021	1.6982	0.627	9.33%	1.0652
South Korea	2018	0.3464	0.591	8.78%	0.2046
Spain	2018	0.7383	0.583	8.66%	0.4302
Australia	2017	2.1718	1.000	14.87%	2.1718
Belgium	2018	1.6724	0.536	7.97%	0.8964
Total	**N/A**	**N/A**	**6.726**	**100.00%**	**10.7369**

The ‘Weight percentage’ column demonstrates the contribution that each benchmark price will make to the weighted-average price. Rather than each of the 10 benchmark prices being worth 10% each, they each vary, with more relevant benchmarks having higher weights.

To calculate the weighted average, you divide the sum of the ‘Price x Weight’ column by the sum of the ‘Weight (arithmetic mean)’ column to find 1.5963, which we could round to be $1.60/MHz/pop.

We consequently multiply the price (or range of prices) by the bandwidth (in MHz) and population coverage of the relevant ESLs to determine the renewal prices (note: these prices would be determined with population projections made much closer to future payment dates).

Appendix B: Tilted annuity approach

In Steps DB2(1) and DB2(5), staff propose to use a tilted annuity approach to convert valuations to different licence durations. This appendix provides additional detail on the approach.

The use of tilted annuity is formed on the basis that spectrum valuations reflect the value of a series of cashflows that would be generated from access to the spectrum. The Frontier report (page 5) provides a helpful explanation:

Licences provide spectrum users with the ability to earn a series of net cash flows. Prices paid for licences will therefore reflect values up to the present value of the net cash flows that can be earned. To compute the present value of the net cash flows, spectrum licence purchasers will take into account two key financial inputs: the discount rate, which reflects the value of future cash flows relative to current cash flows, and cash flow growth, which reflects changes in the earning potential of the licence over time.

Flat annuity vs tilted annuity

The series of net cashflows can be constructed using a 'flat' annuity or 'tilted' annuity calculation, with the difference being that a flat annuity has the same nominal cashflow for each period (i.e. zero growth rate) while a tilted annuity assumes a constant growth rate throughout the period (e.g. growing by 2.5% each year).

For the purposes of constructing a series of cashflows for a spectrum licence valuation to convert licence durations, staff consider a tilted annuity approach is more likely to reflect the expectations of companies that have invested in spectrum. We would typically expect cashflows to grow over time due to inflation, population growth increasing the user base of the spectrum, device proliferation resulting in more users with handsets that can use the spectrum, etc.

For both the flat annuity and tilted annuity approaches, future cashflows are discounted to present value using an appropriate discount rate, which is often the weighted average cost of capital (WACC). The WACC is the combined cost of debt and cost of equity to finance investment decisions. The ACMA has historically used the WACC as the discount rate and staff continue to consider it to be the most appropriate type of discount rate to compare investment decision-making at a point in time.

Tilted annuity – constructing a series of cashflows

We can construct a series of net cashflows that reflect a benchmark price using the tilted annuity approach. Section 3.1.1 of the Frontier report steps through the method for creating a series of cashflows from a tilted annuity formula. The method assumes cashflows are earned at the end of each year.

Table 1 from the Frontier report is reproduced below, using a discount rate of 8.4%, a cashflow growth rate of 2.5%, and a 15-year valuation of $0.23/MHz/pop. This example is intended to reflect the duration adjustment process used for the 1800 MHz band in the previous ESL process (see the Explanatory Statement at Federal Register of Legislation - Radiocommunications (Spectrum Access Charges - 1800 MHz Band) Determination 2012 (No. 2) as an example for further detail).

Table 13: Tilted annuity cashflows (from Table 1 of the Frontier report)

Year	Cash flows $/MHz/Pop	Discount factor $\frac{1}{(1+r)^t}$	Cash flows x discount factor	Present value factor $\frac{(1+z)^{t-1}}{(1+r)^t}$	Truncated licence value
1 (**A**)	0.0239	0.923	0.0220	0.923	0.0220
2	0.0245	0.851	0.0208	0.872	0.0429
3	0.0251	0.785	0.0197	0.825	0.0626
4	0.0257	0.724	0.0186	0.780	0.0812
5	0.0264	0.668	0.0176	0.737	0.0988
6	0.0270	0.616	0.0167	0.697	0.1155
7	0.0277	0.569	0.0158	0.659	0.1312
8	0.0284	0.525	0.0149	0.623	0.1461
9	0.0291	0.484	0.0141	0.590	0.1602
10	0.0298	0.446	0.0133	0.557	0.1735
11	0.0306	0.412	0.0126	0.527	0.1861
12	0.0313	0.380	0.0119	0.498	0.1980
13	0.0321	0.350	0.0113	0.471	0.2093
14	0.0329	0.323	0.0106	0.446	0.2199
15	0.0338	0.298	0.0101	0.421	0.2300
Sum			**0.23**		

Note: The 'Truncated licence value' column was not included in the Frontier report. It represents the sum of all present value cashflows up to and including the applicable year (e.g. the truncated licence value for year 10 is the sum of the values in the 'Cash flows x discount factor' column in years 1–10).

To create this table, you would start with the 15-year valuation of $0.23/MHz/pop, then calculate the first annual nominal cashflow (A) based on the following formula:

$$A = \frac{FPV}{\left(\frac{1}{r-z}\right) \times \left(1 - \left(\frac{1+z}{1+r}\right)^n\right)}$$

Where:
A = the first nominal cashflow (not discounted)
FPV = the total valuation of the licence term ($0.23/MHz/pop)
r = discount rate (WACC = 8.4%)
z = cashflow growth rate (2.5%)
n = number of periods (15 years)

When you insert those values into the formula, you find $A = 0.0239$.

The next step is to find the nominal cashflow for each year by starting with A and increasing it by the cashflow growth rate each year. This is outlined in the 'Cash flows' column.

Following that, you can discount each cashflow to present value using the WACC. The 'Discount factor' provides the values that you multiply the nominal cashflows with to find the present value (which is in the 'Cash flows x discount factor' column). The relationship of the present value of each cashflow to the initial nominal cashflow A is shown in the 'Present value factor' column (e.g. the present value of the year 5 cashflow can be calculated as $0.0239 \times 0.737 = 0.0176$).

The sum of the present value of all cashflows in the series will be equal to the original valuation – e.g. in the table above, the sum of the values in the 'Cash flows x discount factor' column equals $0.23/MHz/pop.

If you want to determine how much the value of a licence should be for different durations (assuming payment is made at the start of year 1), simply sum the present value cashflows for those years – these values are outlined in the 'Truncated licence value' column. For example, if a 15-year licence is $0.23/MHz/pop, an equivalent 10-year licence should be worth $0.1735/MHz/pop.

Tilted annuity – converting valuations for shorter licence durations
We can use formulas to determine the values calculated in the above table without needing to step through the constructed cashflows (although it is helpful to verify formulas by performing those steps). Plum Consulting took our previously used tilted annuity formula and described how to simplify it in the Plum 2024 report. The simplified version allows for more flexible conversions of any type of licence duration:

$$PPV_n = FPV_L \times \left\{ \frac{1 - \left\{\frac{1+z}{1+r}\right\}^n}{1 - \left\{\frac{1+z}{1+r}\right\}^L} \right\}$$

Where:
PPV_n = the present value of the licence duration for which a valuation is sought
FPV_L = the present value of the known licence duration
r = discount rate
z = cashflow growth rate
n = number of periods for the licence duration for which a valuation is sought
L = number of periods in the known licence duration

If you used the values from the example in the table from the Frontier report, you would have $FPV = 0.23$, $r = 8.4\%$, $z = 2.5\%$, and $L = 15$. The value of n could be any number of years, and PPV_n would be the truncated licence value for that duration.

For example, to convert the 15-year valuation to a 1-year valuation, the calculation would be:

$$PPV_1 = FPV_{15} \times \left\{ \frac{1 - \left\{\frac{1+z}{1+r}\right\}^1}{1 - \left\{\frac{1+z}{1+r}\right\}^{15}} \right\}$$

$$PPV_1 = 0.23 \times \left\{ \frac{1 - \left\{\frac{1+2.5\%}{1+8.4\%}\right\}^1}{1 - \left\{\frac{1+2.5\%}{1+8.4\%}\right\}^{15}} \right\}$$

$$PPV_1 = 0.23 \times \frac{0.0544}{0.5681}$$

$$PPV_1 = 0.0220$$

The value of 0.0220 is the truncated licence value for a 1-year duration (and is also the present value of the first annual cashflow).

Staff propose to use this formula in Step DB2(1) of the methodology to convert benchmark prices to a valuation for a 1-year duration.

Tilted annuity – converting valuations for longer licence durations
The same formula can be used to increase the duration of a licence – simply make L equal to the shorter licence duration being worked with and n equal to the duration of the licence for which a valuation is being sought. It is effectively reversing the parameters in the formula above – e.g. to convert a 1-year valuation of 0.0220 to a 15-year valuation of 0.23, you would do the following:

$$PPV_{15} = FPV_1 \times \left\{ \frac{1 - \left\{\frac{1+z}{1+r}\right\}^{15}}{1 - \left\{\frac{1+z}{1+r}\right\}^{1}} \right\}$$

$$PPV_{15} = 0.0220 \times \left\{ \frac{1 - \left\{\frac{1+2.5\%}{1+8.4\%}\right\}^{15}}{1 - \left\{\frac{1+2.5\%}{1+8.4\%}\right\}^{1}} \right\}$$

$$PPV_{15} = 0.0220 \times \frac{0.5681}{0.0544}$$

$$PPV_{15} = 0.23$$

The logic can extend to longer licences – e.g. to calculate a valuation for a 20-year licence duration, simply replace 15 with 20 in the example formula above. The result would be $PPV_{20} = 0.2727$. This effectively mimics extending the series of cashflows in Table 1 by another 5 years, then finding the value in the 'Truncated licence value' column at 20 years.

Staff propose to use this formula in Step DB2(5) of the methodology to convert benchmark prices to a valuation from a 1-year duration to a longer duration, such as 20 years.

Calculations for part-years
There are many benchmark prices that are for licence durations that include part-years – e.g. licences allocated in the ACMA's 3.6 GHz band auction commenced on 30 March 2020 and expire on 13 December 2030, which is an approximate duration of 10.7 years. The formula above assumes cashflows are earned at the end of each year, so including a 0.7-year period would not be consistent with how the rest of the cashflows are treated (as it is being discounted back by the WACC after 0.7 of a year rather than a whole year).

This issue can be fixed by going more granular in the tilted annuity formula. We can use number of days or months rather than number of years for the conversion. For the number of days to find a 1-year duration valuation, n would equal 365, L would equal the number of days from the start date to the expiry date of the licence, and r and z would be converted to daily compound rates (e.g. the daily WACC would be $r_{daily} = (1 + r_{annual})^{\frac{1}{365}} - 1$).

For example, if we want to find the 1-year licence valuation as per Table 1, we would input the following values (where 15 years is equal to 5,478 days):

$$PPV_{365} = FPV_{5478} \times \left\{ \frac{1 - \left\{\frac{1+z_{daily}}{1+r_{daily}}\right\}^{365}}{1 - \left\{\frac{1+z_{daily}}{1+r_{daily}}\right\}^{5478}} \right\}$$

$$PPV_{365} = FPV_{5478} \times \left\{ \frac{1 - \left\{\frac{1+0.0068\%}{1+0.0221\%}\right\}^{365}}{1 - \left\{\frac{1+0.0068\%}{1+0.0221\%}\right\}^{5478}} \right\}$$

$$PPV_{365} = 0.0220$$

This concept is important for Step DB2(1), where we propose to convert benchmark prices to equivalent 1-year valuations. Where possible, we will use known start and end dates to perform the duration adjustment with a daily approach.

WACC and cashflow growth considerations

A key complication with the tilted annuity approach is which cashflow growth and WACC inputs to include, as expectations for each rate can vary depending on the country and time being considered.

The expert consultants' reports indicated that specific country- and time-based rates are preferable, as we should be making comparisons based on investment expectations that are context-dependent. However, it was noted that these inputs are highly unlikely to be accessible, particularly for other countries. In addition, given the long duration of spectrum licences, the consultants' advice was to consider a long-term WACC that is less subject to short-term fluctuations.

To make this process more practicable, we intend to use the same WACC and cashflow growth rate for each duration adjustment irrespective of country and time. Staff have not yet come to a landing on the exact WACC and cashflow growth rates to use but will consider the advice we have received and determine these in the leadup to providing preliminary views on pricing.

Appendix C: Summary of valuation methodologies

Figure **Error! No text of specified style in document.**.1: Advantages and disadvantages of various valuation methodologies

Valuation methodology	Advantages	Disadvantages
Direct benchmarking	• Reflects actual prices paid by operators for similar spectrum bands • Transparent as it is based on published auction results and not assumptions and detailed modelling	• Large dataset needed • There may be a lack of data points for certain bands • May be difficult to make 'like for like' comparisons as international benchmarks may reflect specific circumstances
Adjusted benchmarking	• Transparent as it is based on published auction results • Can be used when have relatively few data points	• Ratios for other countries may reflect auction- or business-specific factors which may not appropriate comparators • There may be a lack of data points for certain bands
Econometrics	• Robust statistical method if suitable data exists • Relies on actual prices paid	• Large dataset needed • Quantitative information on certain drivers of value may not be available and thus cannot be captured in the analysis • Regression models may not provide stable forecast of spectrum value, especially where sample size is limited
Avoided cost modelling	• Country-specific contexts can be directly captured in the model • Provides outputs on infrastructure requirements (such as base stations) which is not possible with benchmarking methods	• Complex modelling • Requires access to information which may not be available to the regulator – this results in uncertainty in results • Results may be highly sensitive to input and network assumptions
Iterated cost model	• Less data required – in particular traffic forecasts not required • Endogenous approach – takes account of consumers' willingness to pay for data and network costs to derive a mobile traffic forecast rather than using a mobile data traffic forecast	• Complex modelling • Requires access to information which may not be available to the regulator – this results in uncertainty in results • Assumptions needed over price elasticity of demand and cost-volume relationships
Full enterprise value or Business modelling (DCF)	• Theoretically this provides an upper bound on spectrum value to an operator as it estimates profits from running a mobile network; this gives an indication of an upper limit on what regulators and governments can charge for spectrum	• Likely to overestimate spectrum value • Complex modelling requiring accurate forecasts of future costs and revenues which may not be available • Considerable uncertainty in results given information asymmetry between regulator and operators, and substantial differences in business cases among operators and potential new entrants