NERA
ECONOMIC CONSULTING

Deriving ALFs from Lump-Sum Valuations – A Response to Ofcom's 2018 Consultation

A NERA Economic Consulting report prepared on behalf of Telefónica UK

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Project Team

Tomas Haug
Dominik Huebler
Adjmal Sirak
Robin Mamrak

NERA Economic Consulting
Marble Arch House
66 Seymour Street
London W1H 5BT, UK
Tel: +44 20 7659 8500 Fax: +44 20 7659 8501

Unter den Linden 14
10117 Berlin, Germany
Tel: +49 30 700 150 601
www.nera.com

Contents

1. Introduction

Telefónica UK has asked NERA to review Ofcom's Consultation on Annual Licence Fees (ALFs) for 900 MHz and 1800 MHz, published 8 June 2018 (henceforth "2018 Consultation")[1]. This report reviews Ofcom's approach and calculations with respect to determining a discount rate to use when converting lump-sum payments into annuities (i.e. ALFs). It does not address the separate question as to whether Ofcom's lump-sum values correctly reflect the market value of licences for 900 MHz and 1800 MHz spectrum. This report is written for Telefónica UK to be included in its response to the 2018 Consultation.

Ofcom follows the same general approach to estimating the discount rate that it introduced in the previous consultation phase from 2013 to 2015. It uses a cost of debt estimate derived from operators' observed debt yields and adjusts this for a risk-sharing premium. In that phase, Ofcom made significant revisions to its methodology for deriving the discount rate which corrected several shortcomings in its initial approach. Nevertheless, we have identified a number of concerns regarding Ofcom's approach to estimating the discount rate in the 2018 Consultation, in many cases elaborating on similar arguments that we already advanced in 2015 and Ofcom's responses to them. These can broadly be grouped into two areas:

1. **Mistakes in calculating key elements of the discount rate.** We identify a number of elements in Ofcom's technical determination of an appropriate discount rate that lack a sound theoretical basis. For instance, Ofcom's approach fails to account for the "one-off" nature of the ALF transaction when determining the weighted average cost of capital (WACC), which leads to an overestimation of the WACC by 0.5 to 1.5 percentage points. Ofcom also fails to remove the liquidity premium from the cost of debt (0.3 to 0.4 percentage points) and fails to adjust the cost of debt for securitisation (0.1 percentage points). These adjustments alone imply that Ofcom has overestimated the discount rate by 0.4 to 0.7 percentage points.
2. **The risk-sharing adjustment is too high.** Ofcom's justification for choosing an adjustment factor of 25% is flawed and entails a certain degree of arbitrariness. Building on our previous submissions, we evaluate the degree of risk sharing using real options. Even when employing a range of discount rate enhancing assumptions in our simulation analysis, we find a maximum plausible discount rate of $r = 1.26\%$ instead of Ofcom's consultation value of 1.5%. Using Ofcom's other consulted figures for the real post-tax CoD of 0.2% and the WACC of 5.5%, we find that the appropriate risk sharing adjustment is 20%, not 25%

When taken in combination, these adjustments mean that Ofcom should be applying a discount rate of between 0.52% to 0.84% (real, post-tax) to derive ALFs. A discount rate at the lower end of this range would be consistent with Ofcom's stated intention of taking a "conservative approach", i.e. one that leads to lower ALFs.

The remainder of the report is set out in four parts and an appendix:

- Section 2 describes Ofcom's approach to determining the discount rate;
- Section 3 identifies a series of mistakes in Ofcom's calculation of key elements underpinning its discount rate; we present new evidence and correct these errors;
- Section 4 shows that the risk premium resulting from Ofcom's approach is implausibly large; and

[1] Ofcom (8 June 2018): Annual Licence Fees for 900 MHz and 1800 MHz frequency bands, Consultation; henceforth „2018 Consultation".

- Section 5 identifies problems with Ofcom's risk-sharing framework and proposes a new option-pricing framework approach that provides a more accurate assessment.

2. Ofcom's estimate of the discount rate

Ofcom follows the same general approach to estimating the discount rate that it employed in its 2015 "Final Statement" on setting ALFs.[2] It uses a cost of debt estimate derived from operators' observed debt yields, adjusted for a risk sharing premium. In this section, we briefly outline Ofcom's approach to determining the discount rate, which is ultimately used to convert the lump-sum value of the spectrum into ALFs.

Table 2.1 presents the main parameters from the 2018 Consultation and compares them to the 2015 Final Statement.

Table 2.1
Comparison of Ofcom's parameters 2015 vs. 2018

	2018	2015
Tax Rate	17.1%	20.0%
CPI Inflation	2.0%	2.0%
Cost of Debt (CoD)		
CoD (nominal, pre-tax)	2.7%	3.3%
Correction to CoD for Inflation Risk Premium	0.1%	0.1%
CoD (nominal, post-tax)	2.2%	2.6%
CoD (real, post-tax)	0.2%	0.6%
Weighted Average Cost of Capital (WACC)		
WACC (nominal, pre-tax)	9.1%	9.1%
WACC (nominal, post-tax)	7.5%	7.3%
WACC (real, post-tax)	5.5%	5.2%
Discount Rate		
Risk-Sharing Percentage Uplift	25.0%	25.0%
Risk-Sharing Premium	1.3%	1.2%
Discount Rate (real, post-tax)	1.5%	1.7%

Source: NERA analysis based on Ofcom's 2015 Final Statement and 2018 Consultation.

Ofcom continues to derive the discount rate based on two polar cases for the allocation of risks that it developed in the previous consultation phase:

1. **Lower polar case**: If the licensee alone bears the consequences of a decrease in economic value of the spectrum licence (i.e. ALFs remain fixed over the 20-year period independent of changes in the value of spectrum), the ALF – from the government's point of view – most closely resembles a 20-year fixed coupon debt instrument. Hence, the cost of debt would be the appropriate discount rate.
2. **Upper polar case**: If changes in the economic value of spectrum translate directly into changes of the ALF payments such that the government bears all the risks associated with changes in the value of the licence, Ofcom considers that the appropriate discount rate is the WACC, which through the asset beta takes account of the return variability.

[2] Ofcom (24 September 2015): Annual licence fees for 900 MHz and 1800 MHz spectrum, Statement.

Based on these hypothetical polar cases, Ofcom continues to use a risk-sharing framework to account for the perceived balance of risk-sharing between the government and the MNO. This takes into consideration the options for Ofcom and the MNOs to review the level of the ALFs in case of "material misalignment". An MNO may relinquish spectrum or ask for a revision of the ALFs in adverse market conditions, and Ofcom can adjust the ALFs if spectrum increases in value.

Ofcom adds a risk-sharing premium to the cost of debt to compensate for the risk of future reviews. The final discount rate is calculated as:

$$(1)\ ALF\ Discount\ Rate = Debt\ Rate + Risk\text{-}Sharing\ Percentage \times (WACC - Debt\ Rate),$$

where the second term represents the risk-sharing adjustment. Put differently, the discount rate is a weighted average of the cost of debt and the WACC (i.e. Ofcom's polar cases).

In the 2018 Consultation, Ofcom derives the values of the two polar cases as follows:

- **Cost of debt:** As shown in Table 4.4 of the 2018 Consultation, Ofcom determines the cost of debt based on current bond yields with times to maturity of about 10 years for a sample of British mobile network operators' (MNO) parent companies as well as an index of BBB-rated bonds. Ofcom proposes a cost of debt of 2.7% (nominal, pre-tax), which is then corrected for any inflation risk premium and converted to a real post-tax cost of debt of 0.2%. This value serves as the lower polar case in Ofcom's approach to determining the discount rate.
- **WACC:** Ofcom's WACC estimate of 9.1% (nominal, pre-tax) is taken from Ofcom's 2018 Mobile Call Termination (MCT) Market Review.[3] The corresponding real post-tax WACC is 5.5%, which Ofcom considers the upper polar case for the discount rate.

As in 2015, Ofcom uses a risk-sharing percentage of 25% in the 2018 Consultation, based on a number of simplified scenarios simulating the government's share of economic risks in case of a tariff adjustment during the 20-year licence period.[4]

Based on this parameter and the above equation, Ofcom determines a **final discount rate of 1.5%** (real, post-tax).

[3] Ofcom (28 March 2018): Mobile Call Termination Market Review 2018-2021, Final Statement.

[4] Ofcom 2015 Final Statement, para 6.93 to 6.117.

3. NERA comments on Ofcom's cost of debt and WACC

In principle, ALFs are fixed payments and thus akin to debt. Ofcom accepted this finding in 2014.[5] The introduction of the risk-sharing premium reflects the fact that – akin to lower quality debt – the fixed repayment schedule is associated with a degree of uncertainty because the MNO (the "borrower") has the option to request an adjustment to the payment terms. Ofcom therefore bases its discount rate on an estimate of the cost of debt, which is adjusted for additional risk sharing.[6]

Building on comments we already made in 2015, we identify a number of elements in Ofcom's determination of the cost of debt and the WACC that lack a sound theoretical basis. In this section, we address these points and Ofcom's responses to them in the 2015 Final Statement, namely:

- the discount rate in the upper polar case is overestimated (Section 3.1);
- the use of British Telecom as a benchmark for the cost of debt overstates the credit risk faced by MNOs (Section 3.2); and
- Ofcom does not account for liquidity risk (Section 3.3) and securitisation (section 3.4) in its estimation of the appropriate cost of debt.

Below, we address Ofcom's comments on these issues and present new evidence on the appropriate magnitudes to consider.

3.1. Ofcom overestimates the discount rate in the upper polar case

In the previous consultation phase, Ofcom made various changes to its approach. For instance, since its provisional decision in the third consultation phase in 2015 (henceforth "2015 Provisional Decision")[7], Ofcom has been using *current* estimates of the *cost of debt*.

This approach is consistent with the fundamental difference between:

- the situation faced by the government in the case at hand where the government essentially provides one-off "financing" to the MNOs; and
- the case of regulated MNOs who are put in a position where they may be required to attract new funds at any point during the multi-year regulatory period.

Ofcom recognises this point in its 2015 Provisional Decision:

> *"the ALF annualisation exercise starts from a notional one-off transaction, Communications Providers (CPs) need to finance regular on-going capex programmes (which the WACC within a charge control has to support). (…) The costs of financing in the long run are*

[5] Ofcom (1 August 2014): Annual licence fees for 900 MHz and 1800 MHz spectrum, Further consultation.

[6] We comment on the risk-sharing framework in Section 5, where we provide a full assessment of the technical determination of the discount rate estimate.

[7] Ofcom (19 February 2015): Annual licence fees for 900 MHz and 1800 MHz spectrum, Provisional decision and further consultation.

> *therefore relevant in ensuring appropriate investment signals are sent through the charge control."*[8, 9]

While we agree with this approach, it is inconsistent for Ofcom to recognise the "one-off nature" of the ALF transaction while continuing to use a long-run WACC.

In its 2015 Final Statement, Ofcom defended its decision to use a long-run WACC as follows:

> *"it is appropriate to combine the current cost of debt with the longer-run WACC, because in the upper polar case spectrum is similar to other assets used in the provision of mobile services. In that polar case, payments for spectrum are not fixed, so cannot be "bought out" at today's prevailing cost of debt."*[10]

We agree that under the upper polar case payments for spectrum are volatile and therefore cannot be bought out at the *cost of debt*. However, "buying" spectrum is still a one-off transaction that does not require continuous re-investment even if the return on financing that investment is volatile. There are also no on-going capex programmes. Hence, the relevant financing cost is the *current* cost of capital (i.e. a short-term WACC) and not a long-run estimate such as the MCT WACC.

As the framework used in 2015 and re-employed in the 2018 Consultation uses a long-run estimate, it incorrectly estimates the upper polar case and results in an inappropriate risk-sharing premium. Further, the combination of a *current* cost of debt measure in the lower polar case with a *long-run estimate* in the upper polar case is inconsistent and leads to an upward biased discount rate in the current market environment.

This finding is independent of Ofcom's argument about the comparability of the risk of spectrum and MNOs as a whole.[11] Below we illustrate the impact of using a short-term WACC for an MNO instead of the (long-term) MCT WACC. We draw on two polar cases for illustrating what a short-term WACC for an MNO might look like assuming either:

a) constant total market returns (TMR) such that any change in the risk-free rate is being offset directly by an inverse change in the equity risk premium (ERP); or

b) a constant ERP in line with historical levels independent of current low real risk-free rates.[12]

As shown in Table 3.1, the short-term WACC that Ofcom should have used in this case is around 0.5 to 1.5 percentage points lower than the long-run WACC that Ofcom uses in its MCT decision.[13] The correct use of a short-term WACC reduces the risk-sharing premium between 10 and 40 basis points such that the risk uplift would have been in the order of 0.9 to 1.2 percentage points instead of 1.3 percentage points.

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8 Ofcom 2015 Provisional Decision, Annex 10, para A10.11.

9 In doing so, Ofcom has followed one of the main points we raised in 2014 in our response to Ofcom's second consultation. See NERA (17 September 2014): Deriving ALFs from Lump-Sum Valuations – A Response to Ofcom's Second Consultation, A Report for Telefónica UK (henceforth "NERA 2014").

10 Ofcom 2015 Final Statement, para 6.43.

11 Ofcom 2015 Provisional Decision, para 4.27 to 4.29.

12 We use -1.6% as the real-risk free rate based on real government liability curve data from the Bank of England.

13 These estimates of the short-term WACC should be seen as illustrative of the potential relative effect of moving to a short-run number. We have not independently assessed Ofcom's estimates of other parameters including beta and total market returns and our use of them should not be considered an active endorsement of their accuracy.

Table 3.1
Comparison of MCT WACC and short-term WACC

	MCT WACC	Short-Term WACC (constant TMR)	Short-Term WACC (constant ERP)
RPI Inflation	3.3%	3.3%	3.3%
Risk-Free Rate (real, RPI deflated)	0.0%	-1.6%	-1.6%
Risk-Free Rate (nominal)	3.3%	1.6%	1.6%
Equity Risk Premium	6.3%	7.9%	6.3%
Implied Real Total Market Return	6.3%	6.3%	4.7%
Debt Beta	0.10	0.10	0.10
Asset Beta	0.69	0.69	0.69
Gearing	30.0%	30.0%	30.0%
Equity Beta	0.94	0.94	0.94
Cost of Equity (nominal, post-tax)	9.2%	9.1%	7.6%
Debt Premium	1.1%	1.1%	1.1%
Tax Rate	17.1%	17.1%	17.1%
Cost of Debt (nominal, pre-tax)	4.4%	2.7%	2.7%
CPI Inflation	2.0%	2.0%	2.0%
WACC (nominal, pre-tax)	9.1%	8.5%	7.2%
WACC (nominal, post-tax)	**7.6%**	**7.1%**	**6.0%**
WACC (real, CPI deflated, post-tax)	**5.5%**	**5.0%**	**3.9%**
Ofcom Overestimation of Short-Term WACC		0.5pp	1.5pp

Source: NERA calculation based on Ofcom (28 March 2018) Mobile Call Termination (MCT) Market Review 2018-21, Final Statement.
Notes: Ofcom's 2018 MCT Market Review only indicates parameter ranges for the derivation of the WACC. Therefore, we relied on values from Ofcom's 2018 Wholesale Local Access (WLA) Market Review (e.g., debt premium, gearing) and back-solved from Ofcom's final WACC estimate of 7.0% (real, pre-tax) to derive the remaining parameter values above (e.g., asset beta). The implied real total market return (TMR) in the "constant TMR" case is calculated as the sum of the MCT equity risk premium (ERP) and risk-free rate while in the "constant ERP" case it is calculated as the sum of the MCT ERP and the current risk-free rate, which we assume to be -1.6% based on real government liability curve data from the Bank of England with 10 years to maturity over a one-month horizon as of 17 May 2018.

3.2. The use of BT's debt as a benchmark

In the 2018 Consultation, Ofcom determines the cost of debt based on bond yields for a sample of three comparators: Vodafone, Telefónica, and British Telecom (BT). In 2015, Ofcom used Orange and Deutsche Telekom (but not BT) in addition to Vodafone and Telefónica. This change in the comparator sample was caused by BT's acquisition of EE, the largest British MNO, which was formerly owned jointly by Orange and Deutsche Telekom.

Table 3.2 shows the bond yields used by Ofcom in its 2018 Consultation to estimate the cost of debt. Among these yields, Ofcom places the highest weight on the index of 10-year BBB-rated bonds and determines a range for the cost of debt of 2.5% to 3.0%. Ofcom argues that the appropriate cost of

debt would likely be below 2.8% to reflect the British MNOs' average bond yields. Based on this assessment, Ofcom determines its best estimate for the cost of debt to be 2.7%.[14]

Table 3.2
Ofcom's approach to estimating the cost of debt

	Credit Rating	Debt Maturity	Years to Maturity	12M Average Yield	12M Min. Yield	12M Max. Yield	Average May 2018
Vodafone	BBB+	2025	7	2.3%	2.0%	2.7%	2.5%
		2032	15	3.3%	3.1%	3.5%	3.3%
Telefónica	BBB-	2026	8	2.6%	2.2%	2.9%	2.7%
		2029	11	2.9%	2.5%	3.2%	3.0%
BT	BBB	2028	11	2.7%	2.2%	3.2%	3.0%
		2031	14	3.1%	2.9%	3.5%	3.3%
10Y BBB-rated Bonds		2018	10	2.6%	2.3%	2.9%	2.7%

Source: Ofcom 2018 Consultation, Table 4.4.

We note that the May average yield is primarily driven up by one long-dated Vodafone bond and the inclusion of BT in the sample. Including BT in the sample to determine the cost of debt may overstate risk, because BT Group faces higher risk than MNOs owing to its pension deficit and unregulated activities. In other documents, Ofcom goes to great lengths pointing out this difference and disaggregating the risk of BT Group.[15] However, it does not address this issue in the current ALF consultation.

In the 2018 Wholesale Local Access (WLA) Market Review, Ofcom disaggregates BT Group's asset beta into three parts: Openreach Copper Access, Other UK Telecoms, and Rest of BT. Within this framework, BT's activities as an MNO (i.e. BT's subsidiary EE) fall into the category Other UK Telecoms. This category faces lower risk than BT Group as a whole, with a difference in the asset beta of 0.05. The resulting WACC (nominal, pre-tax) is 8.9% for Other UK Telecoms as opposed to 9.3% for BT Group.[16]

Inevitably the impact of BT Group's high risk unregulated activities and pension deficit will be felt by both equity and debt holders. Hence, BT Group's observed cost of debt overstates the credit risk faced by MNOs. By not applying any such disaggregation here, Ofcom overstates the true credit risk to be included in the ALF.[17]

3.3. Liquidity risk

In NERA 2014, we calculated a liquidity risk adjustment of 32 to 45 basis points based on a debt premium of 120 basis points. The range for the liquidity premium of 27.0% to 37.3% of the total debt premium was determined by reviewing recent academic literature and referring to regulatory

[14] Ofcom 2015 Final Statement, para 4.76 to 4.78.

[15] See, e.g., Ofcom (28 March 2018): Wholesale Local Access Market Review, Statement, Annex 20.

[16] In the 2018 MCT Market Review, Ofcom also refers to the WACC for Other UK Telecoms from the WLA Market Review. Although the MCT WACC is not taken from the WLA Market Review, Ofcom argues that both estimates are "very close".
See Ofcom (28 March 2018): Mobile Call Termination Market Review 2018-2021, Final Statement, para 5.40.

[17] While Ofcom's findings suggest that a risk adjustment is warranted, we note that Ofcom does not apply any such adjustment when determining the MCT cost of debt.

precedent in the UK. Subtracting the liquidity risk from the spread of corporate bond yields over the risk-free rate is necessary for determining the appropriate discount rate, because illiquidity is not a relevant risk for the UK government when setting ALFs.

Updating this calculation using Ofcom's latest numbers and the implied debt premium of 110 basis points (see Table 3.1), we calculate a slightly lower up-to-date liquidity risk adjustment of 30 to 41 basis points.

According to Ofcom's 2015 Provisional Decision, the government bears full liquidity risk because it cannot re-sell the ALF contract to a third party and, if anything, the illiquidity of the ALF contract would justify a higher premium over the cost of debt.[18] Ofcom therefore rejected our claim for further reductions of the discount rate to remove any liquidity premium from the cost of debt. It repeated that rejection in its 2015 Final Statement arguing that the lack of ability to re-sell is not just a risk but a certainty.[19] However, Ofcom's inclusion of the liquidity premium in the discount rate directly contradicts its own statements in other places of the consultation process.

In the second consultation, Ofcom argues that:

> *"the Government should be indifferent between payment for the spectrum in the form of a lump-sum payment or ALF. This means that* ***the discount rate used to annualise the lump-sum value should reflect the risk of the cash flows coming from MNOs to the Government*** *through the ALF"*[20] *(Emphasis added)*

The risk of the cash flows coming from MNOs to the Government is driven by the "default risk" associated with the payments.[21] Liquidity risk is not associated with the cash flows coming from MNOs (but rather Ofcom's hypothetical ability to trade the right to these payments) and hence, by Ofcom's own standard, should not be included in the discount rate.

Given that there is no realistic prospect of the government transferring oversight of the use of spectrum to a third party even under a lump sum payment scheme, liquidity risk exposure is the same under both cases that Ofcom is purportedly considering. Hence, it does not affect Ofcom's (or the government's) indifference between the two cases and should be disregarded. Ofcom's approach implicitly assumes that it needs to behave like a bank lending money to the MNOs (as one of a range of options of potential borrowers) rather than comparing the cash flow risks between only two options, neither of which offers a realistic prospect of "re-selling" the rights and obligations from overseeing spectrum use.

In conclusion, Ofcom's approach to liquidity risk appears internally inconsistent with the standards it has itself set out in the past. By corollary, the government should only be compensated for the MNOs' idiosyncratic default risk and not for any liquidity risk. Accordingly, Ofcom should introduce a downward-adjustment to the cost of debt (nominal, pre-tax) of 30 to 41 basis points.

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18 Ofcom 2015 Provisional Decision, Annex 10, para A10.50.

19 Ofcom 2015 Final Statement, Annex 10, para A10.53.

20 Ofcom (1 August 2014): Annual licence fees for 900 MHz and 1800 MHz spectrum, Further consultation, para 4.12.

21 In this context default can be thought of as the MNO either returning the spectrum (full default) or successfully asking for a review (partial default). In both cases the Government will lose part of the expected revenue such that both events can be considered cash flow risk events. Similarly, conventional bonds are considered in default also when coupon payments are delayed or partially made.

3.4. Securitisation

In NERA 2014, we calculated a securitisation adjustment of 10 to 12 basis points.[22] This adjustment accounts for the fact that Ofcom's estimate of the cost of debt is based on unsecured corporate debt, whereas the ALF can be viewed as a debt obligation secured against the value of the spectrum licence. As we showed in NERA 2014, such an adjustment is in line with rating agency practice in the regulated sector.[23]

In the 2018 Consultation, as in the previous phase, Ofcom does not adjust the cost of debt for greater security of the ALF contract compared to unsecured corporate debt. In its 2015 Final Statement, Ofcom says that securitisation may only be one out of many factors, where the others are not relevant to ALF.

According to Ofcom:

> *"it is not clear that securing ALF against the spectrum asset would be considered comprehensive and effective as a form of enhancement."*[24]

This assessment followed from a more nuanced assessment in the 2015 Provisional Decision, where Ofcom acknowledged that structural enhancements, such as securitisation would likely merit some uplift according to Moody's rating methodology for regulated electric and gas networks:

> *"While securitisation is not specifically mentioned (in Moody's Rating Methodology for Regulated Electric and Gas Networks), it is likely that this would be considered such an enhancement."*[25]

Ofcom then concluded that the evidence submitted did not warrant a full notch uplift:

> *"it is not clear what uplift (if any) would be afforded for security against a specific asset in isolation (although it seems likely to be less than the full notch suggested by NERA); and as Telefónica acknowledged, the value of any security is likely to be weaker due to correlation between default and spectrum value."*[26]

In NERA 2014, we approximated the underlying one-notch rating uplift by taking one third of the yield spread between A- and BBB-rated bond indices (i.e. a difference of three notches of credit quality) as our proposed adjustment to the cost of debt. However, as set out in more detail in Section 4, Ofcom's risk-sharing framework implicitly assigns a BB+ rating to the credit risk associated with the ALF payments. The spread between BBB and BB rated bonds therefore forms the starting point for calculating the securitisation adjustment. Table 4.1 shows that this spread is around 170 basis points. This implies that a one-notch rating uplift would be equivalent to an adjustment of roughly 50 to 60 basis points (i.e. one third of the full grade uplift). Thus, our proposed securitisation adjustment of 10 to 12 basis points reflects only a small fraction of a one rating notch uplift.

We also note that NERA 2014 already accounted for Ofcom's second argument, namely the negative correlation between the value of the spectrum licences used for securitisation and the probability of the MNO defaulting on its ALF payments. Even if we accept Ofcom's argument that factors other than securitisation contribute to structural enhancements according to Moody's methodology, it is

[22] NERA 2014, Section 4.2.

[23] See, e.g., Moody's (2014): Rating Methodology, Regulated Electric and Gas Networks.

[24] Ofcom 2015 Final Statement, Annex 10, para A10.38.

[25] Ofcom 2015 Provisional Decision, Annex 10, para A10.35.

[26] Ibid., Annex 10, para A10.37b and c.

apparent that Ofcom implicitly includes a degree of "headroom" in its estimates. This overstates the likely discount rate by not allowing for *any* uplift for securitisation despite Ofcom acknowledging that the ALF structure would likely bring some benefits.

3.5. Interim conclusion (before considering risk sharing)

For the reasons set out above, Ofcom's 2018 discount rate of 1.5% is an overestimate. Table 3.3 shows the adjustments to Ofcom's calculation of the discount rate based on our observations in Sections 3.1 through 3.4, and compares them to the original parameters. Applying a short-term WACC, removing the liquidity premium from the cost of debt, and adjusting the latter for securitisation leads to a discount rate (real, post-tax) of between 0.8 and 1.1%.

Table 3.3
NERA vs. Ofcom estimates of the discount rate (before considering risk sharing)

	Ofcom 2018	NERA (lower bound)	NERA (upper bound)
Cost of Debt (CoD)			
CoD (nominal, pre-tax)	2.7%	2.7%	2.7%
Correction to CoD for Inflation Risk Premium	0.1%	0.1%	0.1%
Correction to CoD for Liquidity Risk Premium	n/a	0.4%	0.3%
Correction to CoD for Securitisation	n/a	0.1%	0.1%
CoD (nominal, post-tax)	2.2%	1.7%	1.8%
CoD (real, post-tax)	0.2%	-0.3%	-0.2%
Weighted Average Cost of Capital (WACC)			
WACC (nominal, pre-tax)	9.1%	7.2%	8.5%
WACC (nominal, post-tax)	7.5%	6.0%	7.1%
WACC (real, post-tax)	5.5%	3.9%	5.0%
Discount Rate			
Risk-Sharing Premium	1.3%	1.0%	1.3%
Discount Rate (real, post-tax)	1.5%	0.8%	1.1%

Source: NERA analysis.

4. Ofcom's approach generates an implausibly large risk premium

In this section, we compare Ofcom's proposed discount rate to market evidence on debt rates for traded bonds to determine the implied rating and probability of default. This approach is in line with our 2015 submission to Ofcom's third consultation (henceforth "NERA 2015")[27] where we compared Ofcom's proposed discount rate to bond spreads with a comparable spread, recognising that the ALF setting with its possibility of adjustment is akin to lower quality debt. In that paper, we concluded that Ofcom's approach generated an implausibly large risk-sharing premium.[28] Ofcom did not comment on this in its 2015 Final Statement.

In its 2018 Consultation, Ofcom calculates a premium of 1.3% (real, post-tax) based on the risk-sharing equation shown in Section 2. This premium adds an uplift of more than 600% to the rate before risk sharing of 0.2% (i.e. the cost of debt).

In Table 4.1, we compare the premium that Ofcom uses to the actual observed differences between corporate bond yields with different credit ratings. We show yields on a BBB and BB/B bond index and calculate the implied yield for a BB-rated index, assuming a linear relationship. We contrast these numbers with Ofcom's proposed discount rate, converted to a nominal, pre-tax basis.

Table 4.1
Sub-investment grade corporate bond yields and difference to BBB spreads (nominal, pre-tax, in %)

Time Horizon	BBB	BB/B	Implied BB	Ofcom ALF	NERA (interim range)
1 Month	3.17	5.85	4.96	4.23	3.36-3.78
1 Year	2.94	5.43	4.60		
Difference to BBB Spreads (in bps)					
1 Month	n/a	268	179	106	19-61
1 Year	n/a	250	167	129	42-84

Source: NERA analysis based on data from iBoxx (iBoxx Sterling Non-Financials BBB 10-15Y) and Bank of America Merrill Lynch (ICE BofAML Sterling High Yield BB-B). Cut-off date: 17 May 2018.
Note: Yields in the column "Implied BB" were calculated by taking two thirds of the spread between BBB and BB/B yields. That is, we assume the yields of the BB/B index to represent the average of both ratings and that yields increase linearly from BBB to B. The value in the column "Ofcom ALF" represents the discount rate (real, post-tax) determined by Ofcom (i.e., 1.5%) converted to a pre-tax nominal basis.

Table 4.1 shows that Ofcom's ALF discount rate is broadly in line with a BB+ rating (i.e., two out of three notches down from BBB to BB). That is, the discount rate is placing the implied "credit risk" that the UK government supposedly allocates to the ALF into sub-investment grade (or "junk") territory, which contains speculative investments only. Our range derived in Section 3.5 is more akin to a BBB- rating, i.e., one notch below the rating of the parent companies.

Table 4.2 shows historic average cumulative default rates for corporate bonds with different ratings over a 10- to 20-year horizon.

[27] NERA (15 April 2015): Deriving ALFs from Lump-Sum Valuations – A Response to Ofcom's Third Consultation, A Report for Telefónica UK; henceforth „NERA 2015".

[28] NERA 2015, Section 3.1.

Table 4.2
Corporate average cumulative default rates by rating

Rating	10Y	15Y	20Y
		Standard & Poor's	
BBB	3.9	5.7	n/a
BB	13.5	16.4	n/a
		Moody's	
Baa	4.89	8.24	10.91
Ba	19.86	28.29	33.97

Source: Standard & Poor's (2016): 2015 Annual Global Corporate Default Study and Rating Transitions, p. 59, Table 24; Moody's (2006): Measuring Corporate Default Rates, p. 14, Table A1 (withdrawal-adjusted).
Note: Moody's Baa and Ba ratings are the equivalent of BBB and BB ratings, respectively, for Standard & Poor's.

The BB+ rating implicit in Ofcom's discount rate comes with a high expectation of default. It effectively implies that Ofcom allocates a probability of more than 20% to a default event over the next 20 years. It further implies a very low recovery rate. BB-rated bonds have a recovery rate of only 40.8% (i.e., a loss of 59.2%) over a five-year period.[29] This is far from realistic as the most likely "default event" in the context of ALF would be a renegotiation of ALF payments, which would involve a more limited loss of value to government in percentage terms (e.g. a 10% reduction of the licence fee at review would be equivalent to a 90% recovery rate). A full default in the sense of the MNO returning spectrum to the Government rather than re-selling it to another user is essentially unprecedented in the industrialised world.

A more detailed review of the 25% risk-sharing assumption is therefore indispensable which we will turn to in Section 5.

[29] Moody's (28 February 2011): Corporate Default and Recovery Rates 1920-2010, p. 21.

5. NERA analysis of the risk sharing adjustment

Our findings above highlight the need for further analysis of the risk-sharing assumption including its foundations and implications. In this section, we first review Ofcom's current approach to estimating the risk-sharing adjustment. We then develop and populate a real options model as a cross check and extension of Ofcom's approach. The remainder of this section is structured as follows:

- Section 5.1 summarises Ofcom's approach to determine the risk sharing adjustment.
- Section 5.2 introduces real options as an analytical framework consistent with Ofcom's approach.
- Section 5.3 quantifies the option value included in the license agreement.
- Section 5.4 converts the option value into a discount rate.
- Section 5.5 shows that our modelling assumptions are cautious in the sense that they are discount rate enhancing.
- Section 5.6 investigates the sensitivity of our findings towards the volatility of the underlying and the trigger threshold.
- Section 5.7 summarises our findings.

5.1. Ofcom's approach to risk sharing

Starting with the 2015 Provisional Decision, Ofcom has calculated the ALF discount rate by applying a risk-sharing adjustment to the cost of debt that adds 25% of the difference between the WACC and the cost of debt. Ofcom argues that neither polar case should be used as a discount rate and that instead a weighted average of the two should be used to account for risk sharing between the government and MNOs. It then attempts to assess the degree of both the MNOs' and the government's exposure to changes in the market value of spectrum over time.

Ofcom estimates the 25% risk sharing adjustment based on simplified scenarios simulating the potential fallout for the government in case of a tariff adjustment halfway through the 20-year licence period to illustrate the government's share of economic risks. Acknowledging substantial difficulties in estimating the true allocation of economic risks, Ofcom notes that:

> *"there is no clear way of quantifying the effect of the possibility of review taking place on the Government's share of risk and the consequent effect on an appropriate discount rate. Therefore, while we consider that the illustrative examples discussed in Annex 10 provide a point of reference which could suggest that the Government may bear a significant share of the risk, the assessment of the share of risk that should be incorporated in the discount rate is inevitably a matter of judgement rather than of fact."*[30]

Based on this regulatory judgement, Ofcom applies a value for the government share of operating risk of 25% (i.e., the risk-sharing adjustment), stating:

[30] Ofcom 2015 Provisional Decision, para 4.59.

> *"we have not identified clear reasons to prefer any particular figure within this narrower range of 0% to 50%, given the complexity and uncertainty relevant to the analysis. The mid-point within this narrower range is 25%."*[31]

In its 2015 Final Statement, Ofcom defends the choice of a 25% adjustment by repeating its arguments from the 2015 Provisional Decision and addressing stakeholder comments.[32] In the 2018 Consultation, Ofcom does not provide any new justification for the risk-sharing percentage and simply refers to its 2015 Statement instead.[33]

5.2. Valuing risk sharing using real options

In NERA 2015, we proposed to use established option pricing theory to determine the appropriate risk sharing adjustment in the ALF setting and presented a stylised model of how this might be accomplished.[34]

In its 2015 Final Statement, Ofcom concluded that

> *"option pricing is therefore not dissimilar to how we set up the issue: how we best estimate the discount rate commensurate with the risk sharing conferred by the possibility of future review. We consider that option theory is consistent with our conceptual approach."*[35]

As Ofcom maintains the same conceptual approach in the 2018 Consultation as in its 2015 Final Statement, it follows that option pricing theory remains applicable. Nevertheless, Ofcom concludes in its 2015 Statement that option pricing does not provide better guidance in estimating an appropriate risk sharing adjustment.[36]

This conclusion rests on three criticisms of the stylised option model that we presented in NERA 2015:

> *"NERA adopted a number of simplifications: a) it used a stylised example rather than an actual estimate of the option values, b) it used a 3-period model rather than a 20-year model and c) on this basis, NERA calculated only the put option value and not the call option value. However, if we were to use option pricing, we would need to calculate the value of both the put option and the call option for a 20-year period. This would require us to adopt a complex model and the results would be dependent on and sensitive to several key assumptions, such as the volatility of the value of the underlying asset (i.e. spectrum) and defining the values of spectrum which would trigger a review. An option pricing approach may also obscure the critical assumptions on which the discount rate is dependent."*[37]

Undeniably, option pricing theory provides a consistent way to estimate an appropriate risk-sharing adjustment if Ofcom's concerns above can be addressed. In the remainder of this section we expand the stylised model presented in NERA 2015 to address Ofcom's concerns and validate the risk sharing adjustment. We make the following adjustments relative to our 2015 model:

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31 Ibid., para 4.62.

32 Ofcom 2015 Final Statement, para 6.93 to 6.117.

33 Ofcom 2018 Consultation, para 4.83.

34 NERA 2015, Section 3.3 and Appendix A.

35 Ofcom 2015 Final Statement, para 6.113.

36 Ibid., para 6.116

37 Ibid., para 6.115.

1. We calibrate our option pricing model to actual figures where available.
2. We consider a 20-period model rather than a 3-period model.
3. We continue to abstract from the possibility of adjusting the ALFs upwards (the call option) and focus on the put option instead. In doing so we focus on the Government's downside risk, i.e. we adopt a cautious approach that will provide an upper bound on the option value to the MNO and thus the ALF.[38]
4. We run robustness checks to capture the sensitivity of the model to the underlying assumptions. We check the sensitivity of our results with regards to the volatility of the underlying asset (i.e. spectrum) and the value of spectrum that would trigger a review. Our sensitivity analysis provides clarity of the main factors driving our results.

In the following subsection, we provide a detailed overview of the rationale underlying the use of an options-based model of ALFs as well as a description of our model implementation and further modelling assumptions.

5.3. Quantification of option value

5.3.1. Underlying theory

In the 2018 Consultation, Ofcom repeats its argument from the 2015 Final Statement that the appropriate discount rate is given by the cost of debt only in the case where the licensee bears the risk associated with the variation in the market value of the spectrum.[39] Ofcom further argues that in fact, the licensee does not bear this risk in full, as it may hand back the spectrum and thereby discontinue ALF payments.

In its 2015 Final Statement, Ofcom notes that

> *"Hand back would be most likely to occur when the licensee is unable to trade the spectrum rights under the licence with the current level of ALF liabilities, i.e. the ALF is higher than the value of the licence to the marginal excluded user. The potential for the licensee to hand back the licence could provide a 'hard stop' on the licensee's exposure to the risk of ALF not being changed in the face of large falls in market value (in that the licensees can always decide to hand spectrum back and so are not dependent on our discretion as to whether or not to open a review of ALF in these circumstances)."*[40]

In NERA 2015, we argue that this "hard stop on the licensee's exposure to the risk of ALF not being changed in the face of large falls in market value" is akin to the government granting a real option to the MNO to hand back the licence.[41] The value of this real option can be determined by modelling the real option as a put option on the spectrum.[42] Ofcom considers this reasoning consistent with its own

[38] We recognise that this approach means Ofcom will need to adjust the value we present below but using a highly conservative approach as an upper bound on the ALF can still be insightful in assessing the reasonableness of the risk sharing adjustment if even a conservative approach results in a discount rate below Ofcom's estimate.

[39] Ofcom 2018 Consultation, para 4.69

[40] Ofcom 2015 Final Statement, para 6.87

[41] In practice, the ability to ask for an ALF review is equivalent to handing back the license if the ALF is re-set to a level where the re-set ALF abstracts the full (remaining) economic value of the spectrum. This approach to re-setting ALFs in the case of a review is consistent with Ofcom's duty to price the licence at its full market value.

[42] NERA 2015, p. 11

approach, as set out above. Below, we expand our option pricing model presented in NERA 2015 to value the real option involved in ALF setting using a binomial tree.[43]

This involves the following steps:

1. Selection of the input parameters describing the key elements of the contract (set out in Section 5.3.2);
2. Construction of a "binomial tree" to model the possible outcomes of the "underlying", i.e. the value of spectrum over time (set out in Section 5.3.3);
3. Valuation of the put option using "backward induction" for each individual state of the world (set out in Section 5.3.4); and
4. Conversion of the option value into a discount rate premium (set out in Section 5.4).

5.3.2. Key model parameters & model assumptions

To make the analogy between the ALF setting and the real option fully transparent, we begin by setting out the key parameters for pricing the option and their respective interpretation in the ALF setting.

A put option constitutes the right, but not the obligation of the option buyer to sell an asset ("the underlying") at a prespecified price ("the strike price"). In the ALF setting, the MNO is the option buyer and the Government is the option seller. The act of stopping ALF payments and returning the licence can be thought of as the right of the MNO to "sell" the future rights to the profits from the spectrum (the underlying) for the "price" (strike price) of the future flows of ALF payments (which the government will now not receive).

The present value of a put option depends on the following five inputs.

1. Time to maturity

We use a 20-year model to address one of the criticisms Ofcom had with regard to our 2015 model. In particular, Ofcom noted

"it used a 3-period model rather than a 20-year model (…) if we were to use option pricing, we would need to calculate the value of both the put option and the call option for a 20-year period."[44]

We address this point by extending our model to cover the full 20-year period for the put option. The fact that we do not include any offsetting value from the call option increases the discount rate. We discuss the implications of this choice for the present value of spectrum below.

2. Present value of the underlying

The present value of the underlying is given by the present value of the spectrum, i.e. the lump sum value (LSV) in this case. In ALF setting, the lump sum value (LSV) is spread over a period of 20 years. Ofcom explicitly highlights the equivalence principle between LSV and ALF:

"[…], we are seeking to spread the lump-sum value over a notional 20-year period to calculate a constant real annual payment from the licensees to the Government. In principle, an average

[43] Our model is a discrete time version of the Black and Scholes model (1973). See e.g. Cox et al (1979). A discrete time model is better suited to the situation at hand as the ALF is paid annually and not time continuously.

[44] Ofcom 2015 Final Statement, para. 6.115

efficient MNO […] and the Government should be indifferent between payment for the spectrum in the form of a lump-sum payment or ALF."[45]

Hence, the LSV represents the value of the right to use spectrum during a 20-year period. To convert this value into a constant real annual payment, the underlying should be modelled as the value of the right to use the spectrum *for the remainder* of the 20-year period. We emphasize the distinction between the value of spectrum per se and the value of the underlying, i.e. the value of the right to use spectrum for that part of the 20-year period which have not yet been covered by ALF payments.

At the beginning of period 1, the underlying has a value equal to the LSV, as the full 20 years still lie ahead and no ALF instalment has been paid yet. As time passes and the MNO pays ALFs to the Government, the value of the underlying declines because the remaining life of the initial usage period decreases.[46] Given that Ofcom will be resetting ALFs periodically to capture the market value of the spectrum, the expectation of the licence continuing beyond year 20 has zero present value as the expectation is that the ALF will be set equal to the market value of the spectrum. Hence focussing on the initial 20-year period is consistent with how Ofcom determines the LSV. As pointed out above, this does not imply that the value of spectrum per se is zero after 20 years, only that the expectation of excess profits after year 20 can reasonably be set to zero.

In the binomial option pricing model, the value of the underlying follows a so-called binomial stochastic process. This process is discrete in time, with the number of periods corresponding to the length of the reference period (i.e. 20 years). The model assumes that in each period, the value of spectrum and hence the value of the underlying as well can either go up or down. The probability of either an up or down movement depends on the volatility of the underlying (see below). The "branches" of the binomial tree over the 20-year licence period span all possible developments from 20 consecutive "up" movements to 20 consecutive "down" movements and all combinations in between (see Figure 5.1 for a simplified illustration covering the first 3 periods). We implement the convergence of the underlying value to zero through applying a linear discount factor on top of the binomial tree. This is consistent with Ofcom's goal of achieving a constant real annual payment. Further detail is provided in Section 5.3.3 and Appendix A.3.

3. Volatility of the underlying

The volatility of the underlying is a key value driver in the option pricing model. It governs by how much the value of spectrum may change from one year to the next. The simple intuition is that the value of the "insurance" provided by the option to hand back spectrum and discontinue ALF payments is higher the more volatile the value of spectrum and thus the more likely a material misalignment is.

In the case of a traded security, historical volatility can provide guidance on the underlying's volatility. A common method used to remedy the lack of volatility data on an untraded underlying (like the value of spectrum) is the use of traded comparators. For example, Brealey and Myers (2000) state:

> *"When we value a real option by the risk-neutral method, we are calculating the option's value if it could be traded. This exactly parallels standard capital budgeting."*[47]

[45] Ibid., para. 6.38

[46] If the value of spectrum evolves as expected during the first 10 years, the MNO and the Government should be indifferent between payment of 50% of LSV and ALF for the remaining 10 years. Hence, the expected value of the underlying after 10 periods must be 50% of LSV.

[47] See also Trigeorgis (1998): "*The 'correctness' of using NPV (value maximization) rests, of course, on the assumption of market completeness*".

We consider the volatility of the share prices of the three listed parent companies of MNOs, i.e. Vodafone, Telefónica, and BT. This approach is in line with Ofcom's assumption that the risk of the licence is comparable to the risk of the MNO parent companies.[48] In a second step, we adjust the volatility of MNOs' share prices to calculate *asset* volatilities as a proxy for the volatility of the underlying by correcting for the impact of leverage. We employ the following straightforward and widely used approach:

Equation 1: $$\sigma_A = \frac{E}{A}\sigma_E$$

where σ_A is the asset volatility, σ_E the equity volatility, E the firm's equity (which we empirically measure as the firm's market capitalisation) and A the firm's total assets (which we empirically measure as the sum of market capitalisation and the book value of debt). As set out in more detail in the appendix, we estimate the underlying volatility of 11% per annum as the average asset volatility of the three listed MNO parent companies.

We understand that Ofcom is particularly concerned about the sensitivity of the option value towards the volatility of the underlying.[49] Therefore, we investigate this sensitivity in Section 5.4.

4. Discount rate

Another parameter influencing the option price is the discount rate, which is equal to the risk-free rate in a risk neutral setting of real option pricing. As in NERA 2015 we consider a CPI-real risk-free rate of 0% as broadly consistent with evidence on longer-term maturity bonds and inflation expectations. We further discuss the assumption of a zero risk-free rate in Appendix A.1.

5. Strike price

The strike price is the "payment" the MNO receives from the Government when the option is exercised. In the ALF setting, exercising the option grants the MNO the right to discontinue ALF payments. Hence, the strike price at the beginning of each period must equal the present value (at the time) of the remaining ALF payments until the end of the 20-year reference period. At the beginning of period 1, the strike price equals the full LSV, which by definition is equal to the NPV of future ALF payments. With every annual payment, the value of the future stream of ALF payments falls, thus implicitly re-setting the strike price after each payment. In technical terms, we value the put option "at the money."

Conceptually, this is a very cautious approach because Ofcom has previously stated that it will only allow for a renegotiation in the case of "material misalignment" and there will be significant transaction costs associated with returning the licence (see Section 5.5).

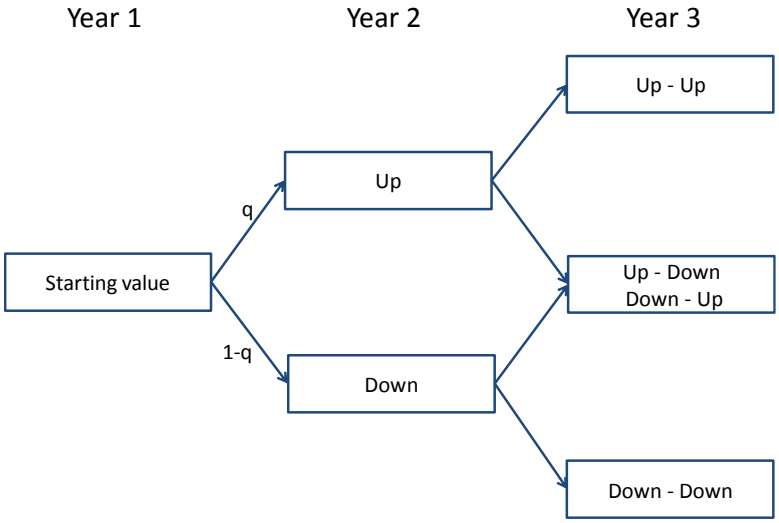
5.3.3. Constructing the binomial tree

Amongst these five inputs, the option value depends first and foremost on the volatility of the underlying. As set out above, we use a discrete time model for valuing the real option. In discrete time, the volatility determines the size of the up- and down-movement of the binomial tree (or "lattice") which models the evolution of the underlying. We illustrate the lattice of possible states of the world in Figure 5.1. For ease of illustration we show a lattice covering 3 periods, whereas our quantitative analysis is based on a lattice covering the full 20 periods.

[48] Ofcom 2015 Final Statement, para. 6.35

[49] Ibid., para. 6.115

Figure 5.1
Stylised visualisation of the evolution of value along the binomial tree



Source: NERA illustration.

Real option valuation is generally undertaken using so-called "risk-neutral probabilities." It allows us to price options correctly in the real world where investors are risk averse. John Hull writes in his seminal book:

> *"[We] can make the assumption that investors are risk-neutral. […] The world we live in is, of course, not a risk-neutral world. The higher the risks investors take, the higher the expected returns they require. However, it turns out that assuming a risk-neutral world gives us the right option price for the world we live in, as well as for a risk-neutral world. Almost miraculously, it finesses the problem that we know hardly anything about the risk aversion of the buyers and sellers of options."*[50]

We apply the concept of risk neutrality to value the real option associated with the MNOs' ability to adjust their ALF liabilities by asking Ofcom to review the ALF levels and / or handing back the license as a last resort.

The volatility of the underlying determines the up- and down movements of the market value of spectrum. We provide more detail on the underlying calculations in the appendix. On this basis, we calculate the key model parameters summarised in Table 5.1 as being consistent with a volatility estimate of 11% per annum.

Notable, we find the risk-neutral probability for the up-movement to be 47%, and the risk-neutral probability for the down-movement to be 53%. The fact that the probability of the downward-movement is higher than 50% is a consequence of our estimates for the underlying volatility and the risk-free rate. As we explain in Section 5.6.1 and Appendix A.1 these are cautious estimates that are likely to overestimate the true discount rate.

[50] Hull, John, "Options, Futures and Other Derivatives", 8th Edition, p. 257.

Table 5.1
Summary of key model parameters

Model Parameter	Figure
Number of periods	20
Notional LSV	1,000
Volatility of underlying	11%
Risk-free rate	0%
Value multiple in case of up-movement	$e^{11\%} = 1.12$
Value multiple in case of down-movement	$e^{-11\%} = 0.90$
(Risk-neutral) probability of up-movement	$\frac{1 + 0\% - 0.90}{1.12 - 0.90} = 47\%$
(Risk-neutral) probability of down-movement	$100\% - 47\% = 53\%$

Source: NERA Analysis

As the reference period over which the LSV is spread consists of 20 periods, the value of the underlying declines by $1/20 = 5\%$ of LSV per year (as one further instalment of the ALF has already been paid in the previous period). Hence, for a notional LSV of 1,000, the value of the underlying at the beginning of period 1 is 1,000, the *expected* value of the underlying at the beginning of period 2 is 950, the expected value at the beginning of period 3 is 900 and so on. The expected value of the underlying at the beginning of period 20 is 50. As explained above, we value the option "at the money", i.e. set the strike price (i.e. the payment from the Government to the MNO) equal to the *expected* value of the underlying. Hence the strike price at the beginning of period 1 is 1,000, at the beginning of period 2 it is 950, and so on. At the beginning of period 20 the strike price is 50. We illustrate how to combine the linear depreciation towards zero with the binomial lattice in the appendix.

Note that we used a standardised value of spectrum here to illustrate the declining value of the option over time in simpler numerical terms. We would get the exact same result in percentage terms (which is what drives the discount rate adjustment in Section 5.4) if we used (for example) Telefónica's actual spectrum holdings and associated LSV and ALFs. The choice of numeraire for the value of the spectrum / LSV is essentially irrelevant for the results.

5.3.4. Valuation of the real option – backward induction

In order to value the real option, the MNO will consider its expected profits from future use of the spectrum (including the option to return spectrum at a later date) against returning the licence and not having to pay ALF anymore. Hence, the MNO will consider the expected value of the option in future years before considering whether to exercise the option "today". The value of the put option is given by:

Equation 2: Value Put = Max [Payoff today; probability weighted value in the future]

From a technical point of view, this amounts to determining the value of the put option at each node of the tree taking account of the stochastic process of the underlying. The payoff today is given by the difference between the strike price and the market price of the underlying. The expected future value of the option depends on the future strike price (i.e. the known future ALF payments) and the expected future market price of the underlying (i.e. the risky future value of spectrum and the profits associated with using it). We employ a process referred to as "backward induction" – that is, a process of reasoning backwards in time to determine a sequence of optimal actions (exercising / not exercising the option) at each point in time. We provide further detail on this approach in the appendix.

Putting these elements together, we derive the option value associated with the licensee's right to hand back the spectrum and discontinue ALF payments for the remainder of the contract's lifetime. For a notional LSV of 1,000 we find an option value of 102.45, i.e. the existence of the option increases the value of the LSV by around 10%. This 10% uplift is an upper bound on the net value (to the MNO) of the put and call options that the government and MNO are respectively extending to one another (see Section 5.5).

5.4. Converting the option value into discount rate adjustments

In the next step, we need to include the option value that we have determined using backward induction and risk-neutral pricing in the calculation of the ALF. This can either be done by adjusting the LSV or by adjusting the discount rate using a "risk-sharing" adjustment. As the latter closely mirrors Ofcom's conceptual approach we focus on the discount rate.

First, consider the lower polar case were the MNO does not have the right to hand back the spectrum and there is no prospect of adjusting the ALFs irrespective of the market value of spectrum. As Ofcom points out, the appropriate discount rate in that case is the Cost of Debt.[51] Using Ofcom's consulted figure of 0.2% for the real post-tax CoD, the corresponding ALF is 50.95 for a standardised LSV of 1,000.[52] Hence, the MNO is indifferent between paying 1,000 upfront or paying 50.95 at the beginning of each year for the lifetime of the contract when there is no prospect for ALF review.

Next, consider the case where the ALF setting includes a put option as described above. We have found that for a notional spectrum value of 1,000, the value of the put option is P = 102.45. Hence, the combined value of spectrum and the put option is 1,000 + 102.45 = 1,102.45. The adjusted ALF is the fixed annuity that spreads the present value of spectrum in addition to the value of the put option over the reference period of 20 years when discounted at the CoD:

Equation 3 $$LSV + P = \sum_{t=1}^{20} \left(\left[\frac{1}{1+CoD} \right]^{t-1} ALF \right)$$

Given the notional spectrum value LSV = 1,000, the corresponding price of the put P = 102.45, and Ofcom's consulted CoD = 0.2%, we find the annuity of ALF = 56.17. Hence, the MNO is indifferent between paying for the spectrum and the put option upfront or paying 56.17 at the beginning of each year without the prospect of review.

As we have set out earlier, the MNO's right to hand back the spectrum and discontinue ALF payments is akin to holding the spectrum and the put option. Therefore, the appropriate discount rate to spread the LSV excluding the option value is the one that spreads the notional spectrum value of 1,000 over 20 years, and results in an annuity of 56.17, i.e. the annuity equivalent to the one that we derived when explicitly considering the option value:

Equation 4 $$LSV = \sum_{t=1}^{20} \left(\left[\frac{1}{1+r} \right]^{t-1} ALF \right)$$

We find a discount rate of $r = 1.26\%$ instead of Ofcom's consulted 1.5%. Using Ofcom's other consulted figures for the real post-tax CoD of 0.2% and the WACC of 5.5%, we find that the appropriate risk sharing adjustment is 20%, not 25%:

[51] Ofcom 2015 Final Statement, para. 6.59

[52] As we set out in Section 5.3.3, using a standardised LSV has no implications for any of the implied discount rates.

Equation 5 $$\frac{r-CoD}{WACC-CoD} = \frac{1.26\%-0.2\%}{5.5\%-0.2\%} = 20\%$$

5.5. Cautious choice of modelling assumptions provides an upper bound

In Section 5.3, we set out a high-level overview of our modelling assumptions (further detail is provided in the appendix). Here, we explain how we have continually chosen assumptions that will lead to an upper bound estimate of the (net) option value enjoyed by the MNOs and thus an upper bound on the risk-sharing adjustment that is applicable to ALFs. We refer to such assumptions as "cautious."

Exclusive focus on the Government's downside risk

Our analysis has so far focussed on the MNOs' ability to hand back the licence / ask for review of the ALF payments. As set out in NERA 2015, the Government also has the option to review and increase ALF payments in case there is a material and unexpected increase in spectrum value. The right to review and increase ALFs is akin to a real option that could be modelled as a call option on spectrum the MNO sells to the Government.[53] In fact, Ofcom – on behalf of the Government – has exercised this option in the 2018 Consultation. It has identified new factors leading it to increase the LSV for 1800 MHz spectrum and increasing (real) ALF in response.

In our current approach, we focus exclusively on the put option, i.e. on the Government's downward risk and thereby ignore the Government's upward potential. If the call option were included in our analysis, the appropriate discount rate and hence the risk sharing adjustment would be lower than under the approach described here. To make this point transparent, recall that our approach is only considering the value of the spectrum (the LSV) and the value of the put option (P). The government's call option has *negative* value to the MNO that offsets part of the value of the put option when compared to a situation where no option exists either way, as long as the call option is not completely without value.

In technical terms:

Equation 6 $$LSV + P - C < LSV + P \text{ for any } C>0$$

Therefore, restricting the analysis to the put option alone contributes to overestimating the appropriate discount rate. By entirely discarding the call option (i.e. assuming it has zero value), we are explicitly not making the assumption that its value offsets the value of the put option (which seems to have been Ofcom's misunderstanding of our reasoning in NERA 2015[54]) but instead we determine an *upper bound* on the net option value available to the MNO.

Valuing the Put Option "At the Money"

Setting the strike price "at the money" is a cautious assumption, because it implies that the option can be exercised by the MNO as soon as the value of spectrum falls below its expected value, i.e. the MNO will be able to hand back spectrum and / or renegotiate the ALF as soon as there is a minor (negative) mismatch between the value of spectrum and future ALF payments. [55]

[53] NERA 2015, Appendix A.6

[54] Ofcom 2015 Final Statement, para. 6.111

[55] Note that in practice the option will not necessarily be exercised as soon as the payoff turns positive. Instead the MNO will only exercise the option if its payoff in the current period is higher than the expected value next period.

There are several reasons why such an approach overstates the flexibility (and thus the option value) the ALF framework affords to the MNO:

- Ofcom has already indicated that it will apply a significant materiality threshold before allowing any adjustment;[56]
- Ofcom has already indicated that it will not undertake any adjustment in the first five years unless there are exceptional circumstances;[57] and
- There may be financial and reputational costs to handing back spectrum or asking for an ALF review.

These factors mean that a MNO is unlikely to hand back spectrum if there has only been a moderate decrease in spectrum value. Consequently, pricing the option "out of the money", i.e. assuming a strike price below the expected value of spectrum represents a more adequate base case representation of reality.

The exercise of the option is more likely when the option is priced "at the money" than in the case where it is priced "out of the money", i.e. with a strike price below the expected value of the underlying. As the probability of execution increases, the option becomes more valuable and hence the implied discount rate and the resulting risk sharing adjustment decrease.

For these reasons, our approach of setting the strike price at the expected price of the underlying is likely to overestimate the value of the option and therefore leads to inflated estimates of the discount rate and the associated risk sharing adjustment. This further contributes to our approach being cautious.

Cost of Debt and WACC

When converting the option value into the appropriate discount rate, we have assumed Ofcom's consulted (real, post-tax) cost of debt of 0.2%. When calculating the associated risk sharing adjustment we also consider Ofcom's consulted figure for the WACC. As we argue in Section 3.5, Ofcom's estimates of the cost of debt and WACC are likely overstating the relevant parameters. As an alternative, we consider our upper case estimates for the cost of debt and WACC after adjustments (see Table 3.3) of -0.2% and 5.0%, respectively. When we apply these figures in our conversion of the option value to the appropriate discount rate and the risk sharing adjustment, we find estimates of 0.84% instead of 1.5% for the discount rate and 20% instead of 25% for the risk sharing adjustment. Hence, using Ofcom's consulted figures contributes to our approach being cautious.

5.6. Further robustness analysis

In its 2015 Final Statement, Ofcom voiced the following concerns with regard to the sensitivity of the option value to certain assumptions.

> *the results would be dependent on and sensitive to several key assumptions, such as the volatility of the value of the underlying asset (i.e. spectrum) and defining the values of spectrum which would trigger a review. An option pricing approach may also obscure the critical assumptions on which the discount rate is dependent."*[58]

We discuss these assumptions in turn below.

[56] Ofcom 2018 Consultation, para. 6.13

[57] Ofcom 2015 Final Statement, para. 6.84

[58] Ibid., para 6.115.

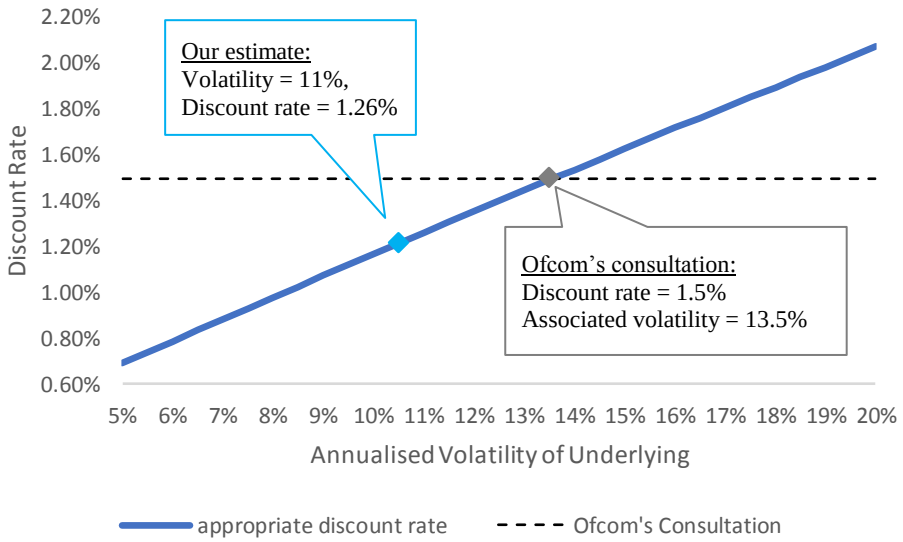
5.6.1. Volatility of the underlying asset

We estimate the volatility of the underlying based on equity volatilities of the listed parent companies for three MNOs, namely Vodafone, Telefónica, and BT Group, and adjust for leverage. Our baseline estimate for the volatility of the underlying is 11% and the associated baseline estimate for the discount rate is 1.26% (see Section 5.4 and the appendix).

We understand Ofcom is concerned about the sensitivity of the discount rate towards the volatility of the underlying. We address this concern by running a sensitivity check. We compute the appropriate discount rate for a range of potential volatility figures spanning the range [5.0%, 5.5%, …, 20.0%]. The associated discount rates are plotted in Figure 5.2. For an underlying volatility of 5.0% the associated discount rate is 0.69%. If the volatility is 20.0%, the discount rate is 2.07%. This sensitivity analysis shows that volatility is a key driver of the discount rate.

We can use this to find the volatility level that is consistent with Ofcom's discount rate of 1.5%. This is 13.5%.

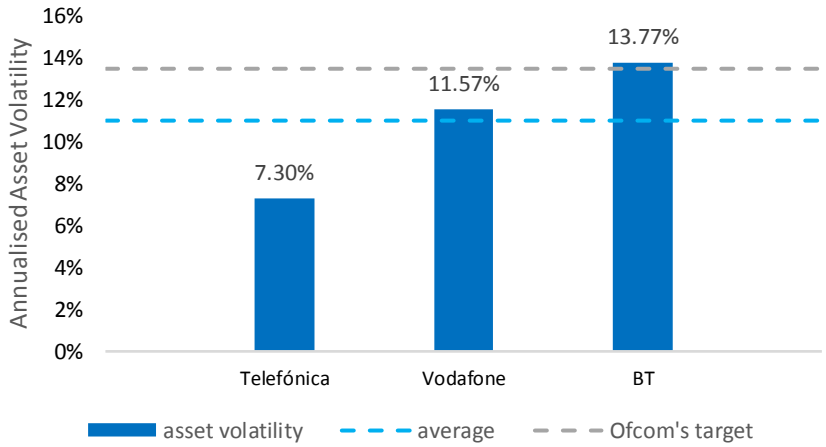
Figure 5.2
Sensitivity of the discount rate towards the underlying volatility



Source: NERA Analysis

Next, we consider whether an asset volatility of 13.5% is plausible in the context of spectrum value. We first consider the individual volatility estimates for the MNO parent companies, as illustrated in Figure 5.3.

Figure 5.3
Annualised asset volatilities of the three listed MNOs



Source: NERA Analysis

Vodafone exhibits an asset volatility of 11.6% while Telefónica exhibits a volatility of 7.3%, i.e. almost half of the figure implied by Ofcom's consulted discount rate. BT Group is the only one of the three listed MNO parent companies with an asset volatility close to 13.5%. However, as Ofcom has repeatedly pointed out in the past, BT Group is not an unbiased comparator for the risk / volatility of a UK MNO. As set out in Section 3.2 Ofcom has previously ruled that EE faces lower risk (which is generally associated with lower systematic and overall volatility) than BT Group as a whole.

In Table 5.2, we calculate the appropriate discount rates and risk-sharing adjustments for the volatilities of each of the three listed MNO parent companies. The figures Ofcom use in its consultation (1.5% discount rate and 25% risk-sharing adjustment) closely resemble those of BT Group, a comparator that Ofcom has previously discarded as unsuitable (see Section 3.2). Using the asset volatility of Telefónica or Vodafone instead would lead to much lower estimates.

Table 5.2
Appropriate discount rate and risk sharing adjustment for each MNO

Firm	Asset Volatility	Appropriate Discount Rate	Associated Risk Sharing Adjustment
Telefónica	7.3%	0.91%	13%
Vodafone	11.6%	1.32%	21%
BT Group	13.8%	1.52%	25%

Source: NERA Analysis

5.6.2. Trigger threshold for ALF revision

Ofcom explains that

> "*a future review is likely to be conducted only if there is evidence that a material misalignment between ALF and the market value of spectrum has developed.*"[59]

[59] Ofcom 2015 Final Statement, para. 6.95

Incorporating this feature of ALF in the option model would require estimating a threshold value for the underlying at which a review is triggered and setting the strike price equal to this threshold. Ofcom rightly notes that the lower the threshold the lower the Government's share of the risk.[60] We do not attempt to estimate a figure for this threshold, but instead pursue the most cautious approach possible in setting the threshold to the expected value of the underlying. Thereby, our model captures the theoretical maximum flexibility that the Government could grant to the MNO, which is increasing the discount rate compared to a more realistic approach that includes a higher materiality threshold.

As per the quote above, our assumption does not reflect the actual nature of ALF, but is likely to overestimate the appropriate discount rate. Hence, any sensitivity around our assumption could only reduce the risk borne by the Government. This would further reduce the appropriate discount rate as well as the risk sharing adjustment below our baseline figures of 1.26% and 20%, respectively. In conclusion, there cannot be any sensitivity around our approach to value the real option "at the money" that justifies Ofcom's consulted figures of 1.5% and 25%.

5.7. Summary

In this section, we have developed a real option model of the ALF framework to provide a cross-check on Ofcom's risk-sharing adjustment. In doing so we have addressed Ofcom's comments on our stylised model developed in NERA 2015.

We model the volatility of the underlying price of spectrum over a 20-year reference period using observed asset volatilities for the three listed MNO parent companies, namely Vodafone, Telefónica and BT Group. Using the standard technique of "backward induction", we value the option the Government provides to MNOs by allowing them to return spectrum and / or to ask for a re-determination of the ALFs. When including the value of the option in the adjusted discount rate we find a discount rate of $r = 1.26\%$, instead of Ofcom's consultation value of 1.5%. Using Ofcom's other consulted figures for the real post-tax CoD of 0.2% and the WACC of 5.5%, we find that the appropriate risk sharing adjustment is 20%, not 25%.

The above estimate for the discount rate of 1.26% is based on a range of cautious assumptions, namely:

- not considering the off-setting value of the Government's option to increase charges (which has negative value to the MNO);
- valuing the option "at the money" rather than incorporating Ofcom's statement that it will only review ALFs when there is a material misalignment (thus overstating the flexibility and thus the value the option affords the MNOs); and
- using Ofcom's estimates of the cost of debt and WACC despite the concerns with their estimation set out in Section 3.5.

Consequently, 1.26% is the absolute upper bound on the appropriate discount rate. Furthermore, when incorporating the adjustments discussed in Section 3 into the real options analysis, we find an upper-case estimate for the appropriate discount rate of 0.84%.

We also undertake a range of robustness tests, specifically assessing the extent to which sensitivities around the assumed underlying asset volatility and threshold value for ALF revisions can explain a discount rate and risk-sharing adjustment in line with Ofcom's values. We find that to do so, the underlying asset volatility for spectrum would have to be nearly twice the observed asset volatility for

[60] Ofcom 2015 Final Statement, para. 6.100

Telefónica and in line with the asset volatility for BT Group, an unsuitable comparator for the risk/ volatility of UK MNOs.

6. Impact on ALFs

Our analysis shows that Ofcom has overestimated the cost of debt, the WACC applicable for ALF setting and the risk adjustment factor. In turn, this has led to overstated discount rates and ALFs. Section 3.5 showed several issues with Ofcom's calculation of the cost of debt and the WACC. We have calculated an upper bound for the risk sharing adjustment of 20% (rather than 25%) derived from real options analysis using very cautious (meaning adjustment-enhancing) assumptions. Combining these adjustments, we determine **a range for the discount rate of 0.52% to 0.84%** (real, post-tax) to derive the ALFs for the 900 MHz and 1800 MHz bands.

This estimate is based on a number of cautious (i.e. ALF-enhancing) assumptions. In particular, our calculations do not consider the value of the Government's option to increase ALFs when spectrum value increases (something that Ofcom has already shown it will do as part of the 2018 consultation) and do not account for the fact that Ofcom will only re-set the value if there is a material misalignment.

Therefore, taking into account Ofcom's stated commitment to adopting a conservative (i.e. discount rate reducing) approach when calculating ALFs, suggests Ofcom **should adopt the lower bound of our estimate of 0.52%** rather than its current estimate of 1.5% (real, post-tax) which is neither conservative nor based on plausible assumptions as we have demonstrated here.

Appendix A. Details on real options valuation

A.1. Risk-free rate

We have assumed a real risk-free rate of 0%. Given the contract's initial lifetime of 20 years, a positive real risk-free rate could be considered adequate as well. In that case, the option value would be smaller, because future payoffs would be associated with higher discount rates. Consequently, the appropriate discount rate and risk sharing adjustment would be smaller, too. Hence, assuming a risk-free rate of 0% contributes to our approach of being conservative.

A.2. Volatility estimate

As set out in the main text, we use Equation 1 to estimate asset volatilities from share price volatilities. While more complex approaches such as Merton's boundary condition[61] exist and potentially provide more precise estimates under certain criteria regarding the firm's debt, they tend to produce results of a roughly similar order of magnitude.[62]

We estimate the volatility of equity returns for the three listed MNO parents Vodafone, Telefónica, and BT Group during the 12-month period from 21 June 2017 through 20 June 2018. We determine the average leverage ratio E/A during the same period, where we measure equity E as market capitalisation and assets A as the sum of market capitalisation and the book value of debt. We summarise our findings in Table A.1.

Table A.1
Average asset volatility of the three MNOs

Figure	Telefónica	Vodafone	BT Group
Annualised share price volatility	17.69%	18.66%	21.67%
Average leverage ratio	41%	62%	64%
Asset volatility	7.3%	11.6%	13.8%
Average		**10.8%**	

Source: NERA Analysis

Our estimates for the asset volatility for Telefónica, Vodafone, and BT Group are 7.3%, 11.6% and 13.8%, respectively. We consider the simple average of c.11% as a reasonable estimate for the volatility of the underlying and use it as our baseline figure. Section 5.6.1 contains a detailed sensitivity analysis relating to the impact of different volatility assumptions.

A.3. Binomial tree

In the main text, we set out our use of a binomial tree to model the evolution of spectrum value during the 20-year period. At the beginning of period 1, we assume a notional value of 1,000 for the

[61] More complex approaches exist, notably Merton's boundary condition (Merton 1974), of which Equation 1 is a simplified version. Merton follows an option pricing approach to relate equity and debt volatility, showing that:

(2) $$\sigma_A = \sigma_E \frac{E}{A\,N(d1)}$$

Where N(d1) derives from the option-theoretic approach as in the classic Black-Scholes-formula.

[62] See Nikolova (2003), who provides empirical asset volatility estimates under different approaches including Equation 1 as well as Merton's boundary condition (Merton 1974) and shows that these methods lead to similar asset volatility estimates.

spectrum. Each period the value may increase or decrease by a multiple that is determined by the volatility of the underlying.

Cox et al (1979) show that the following relationship between the volatility and the size of the up- and down-movement holds:[63]

Equation 7 $$up = e^{\sigma\sqrt{t/n}} \text{ and } down = 1/up,$$

where σ is the volatility of the security return and e is the base of the natural logarithm (2.71828…), t is the time period and n is the number of price changes within one period.[64] In our baseline calibration we assume an asset volatility of 11%. Hence, the up-movement multiple is $e^{0.11} = 1.12$ and the downward-movement multiple is $e^{-0.11} = 0.9$.

The risk neutral probabilities are given by:

Equation 8 $$q = \frac{Risk\ free\ rate - down}{up - down},$$

where q is the risk neutral probability of the up-state and (1-q) is the probability of the down-state. Given our estimates of 11% for the volatility and 0% for the real risk-free rate, we find $q = 47\%$ and hence $1 - q = 53\%$.

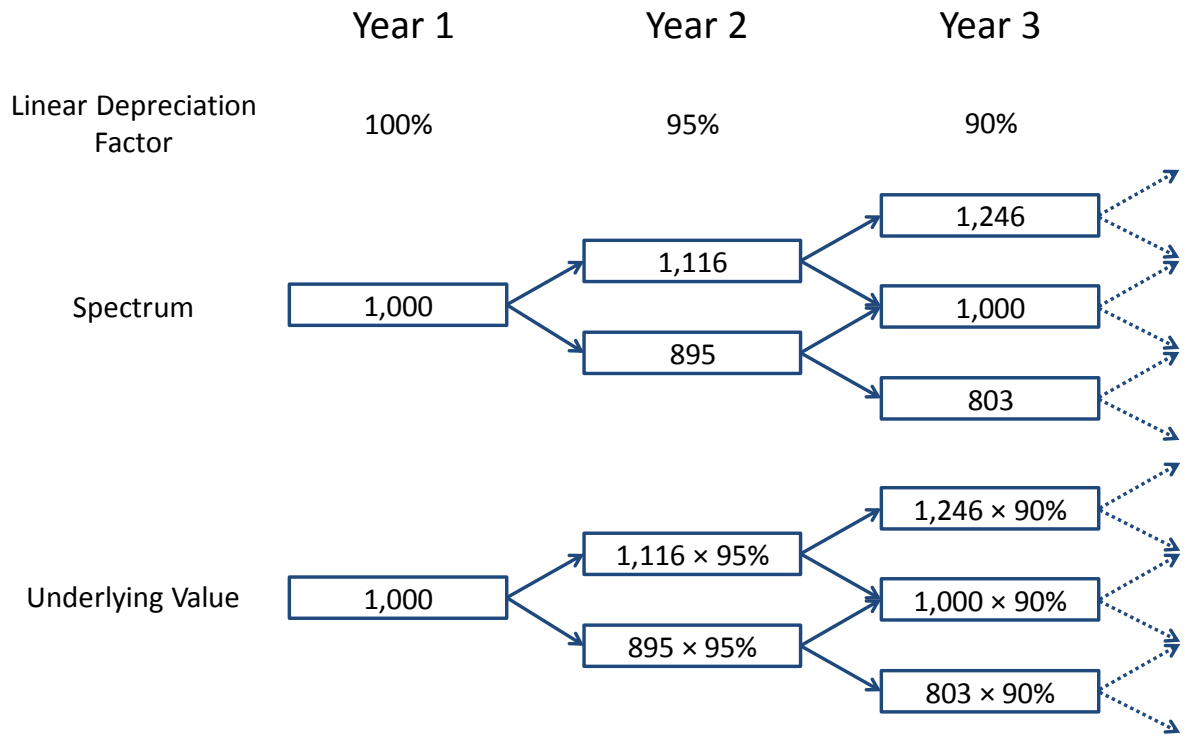
Based on Equation 7 and Equation 8, the volatility (together with the risk-free rate) defines the size of the up- and down-movements and the risk neutral probabilities – the key inputs to any option analysis. In each period, the value of spectrum can go up by a multiple of 1.12 or down by a multiple of 0.9. The risk neutral probabilities consistent with a volatility of 11% and a risk-free rate of 0% are 47% for the up-movement and 53% for the down-movement.

The up- and down-multiples as well as the risk-neutral probabilities of the up and the down state describe the possible evolution of the value of spectrum during each of the 20 years of the reference period. However, the value of the underlying in the option model is the right to use the spectrum over 20 years and therefore the value of the underlying must converge to zero as the lifetime of the contract draws to its end. We incorporate this feature in our binomial tree by applying a linear discount factor that takes the value of 100% at the beginning of period 1 and decreases by 5 percentage points every period, such that it takes the value of 5% at the beginning of period 20. We illustrate the combination of the binomial tree with linear depreciation in Figure A.1 for the first 3 of 20 periods.

[63] See Cox, J.C., S.A. Ross and M. Rubinstein (1979). Options Pricing: A Simplified Approach," Journal of Financial Economics, No. 7, No. 3, pp. 229- 264.

[64] When t and n are equal to 1 the formula simplifies to $up = e^{\sigma}$.

Figure A.1
Implementation of a Linear Depreciation Factor in the Binomial Tree



Source: NERA Illustration

A.4. Backward induction

In this section, we provide more detail on valuation by backward induction. At the beginning of the last period, the value of the put option is equal to (only) the payoff of the put as it no longer holds any optionality value: If the option is not exercised, there will be no possibility to exercise it later.

Hence, Equation 2 simplifies to:

Equation 9: $\text{Payoff Put} = \text{Max}[K-S; 0]$,

where

- K is the strike price, i.e. the payment received upon exercise; and
- S is the price of the underlying.

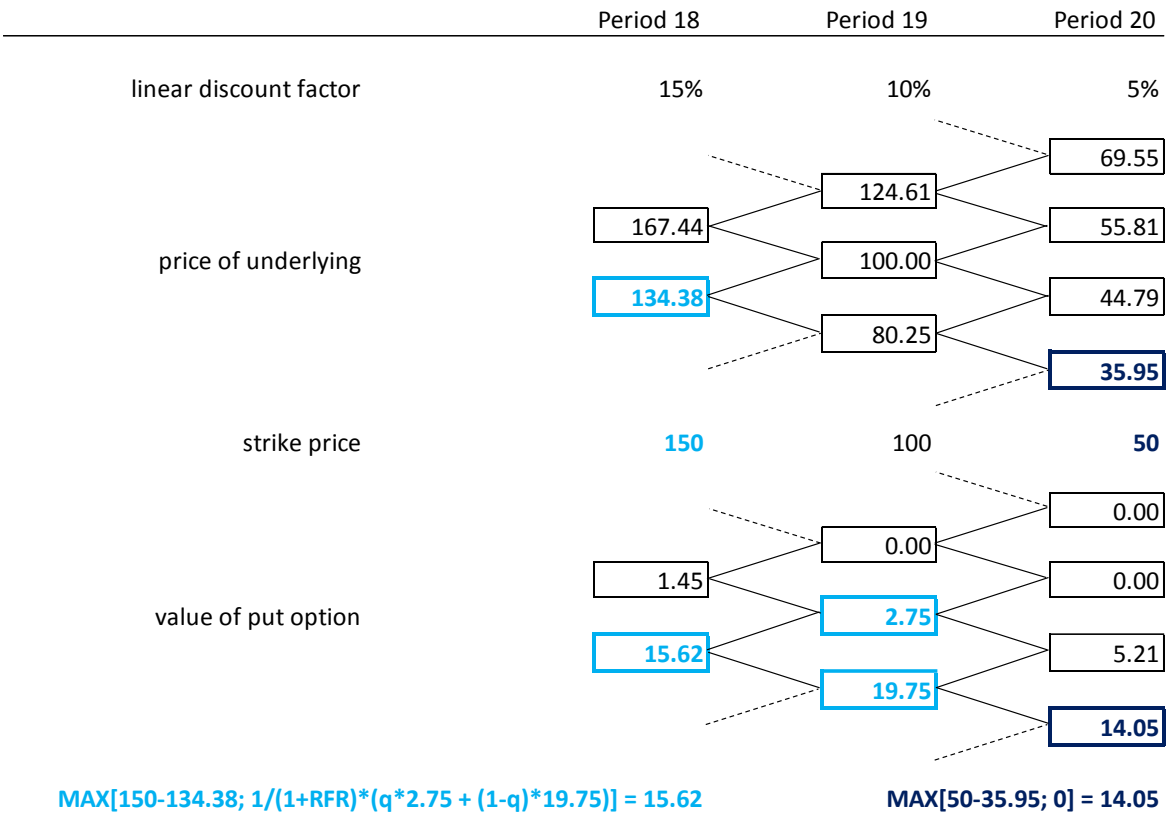
Equation 9 can be interpreted as the option holder having the following choices compared to the default course of action that is paying the ALF and enjoying profits from using the spectrum:

- Exercise the option and sell the spectrum (with market value S) at the strike price K thus realising K-S as a benefit; thus, offsetting the payoffs from the default course of action to end up with a value of zero; or
- Do not exercise the option and receive a zero benefit in addition of the default course profit of S-K.

The holder of a put option will only exercise the option if the price of the underlying (S) is below the strike price (K), because in that case the payoff from exercising the option is greater than the payoff from not exercising.

A rational investor will factor these impending outcomes into the decision-making process at the penultimate stage when deciding whether to exercise the option or to keep hold of it. This process can be repeated at each earlier stage in order to value the option at these stages. We illustrate the concept of backward induction from period 20 through earlier periods for a subset of the binomial tree in Figure A.2 below.

Figure A.2
Valuation of the put option by backward induction



Source: NERA Illustration

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NERA
ECONOMIC CONSULTING

NERA Economic Consulting
Marble Arch House
66 Seymour Street
London W1H 5BT, UK
Tel: +44 20 7659 8500 Fax: +44 20 7659 8501

Unter den Linden 14
10117 Berlin, Germany
Tel: +49 30 700 150 601
www.nera.com