5 The Weighted Average Cost of Capital (WACC)

5.1 Introduction and main goals of the section

WACC is generally recognised as the best way to evaluate the allowed return on the capital invested.[1] It is relevant for regulatory purposes as it is one of the main elements in defining cost oriented prices, carrying out price/margin squeeze tests[2] and implementing the regulatory accounting obligations. It is relevant as a benchmark on return on investment and for applying claw-back mechanisms in state aid procedures.

The WACC plays an important role in setting cost-oriented regulated prices because it determines the reasonable rate of return on the capital employed. Regulated prices should provide the regulated firm with the opportunity to finance (efficient) investment and provide access seekers with efficient "build-vs-buy" price signals. An increase (decrease) in WACC will, other things equal, increase (decrease) regulated prices. Even minor changes in the WACC can influence the regulated prices significantly given that the telecommunications sector is very capital intensive[3].

The WACC estimation is forward looking even when based on historical information. As such, estimating the WACC requires regulatory judgement to assess whether current or historical evidence is more relevant on a forward-looking basis.

This implies that when calculating the WACC for wholesale price regulation purposes, NRAs cannot focus only on theory; a practical view on the estimation process is also necessary to take into account regulatory objectives and previous regulatory decisions.

It is possible to estimate the parameters in the WACC formula in different ways, and NRAs may take different approaches according to elements such as national economic conditions, availability of data, the degree of wholesale and retail competition, regulatory goals/strategy etc. BEREC considers that NRAs should have flexibility to take a practical approach to estimating WACC that supports national circumstances

When NRAs calculate the WACC they may take into account general regulatory principles[4] such as predictability, transparency, and consistency, sending efficient price and investment signals etc..

Predictability limits uncertainty and thereby risks to the industry that is characterized by long term investment.

Transparency helps to obtain acceptance from the industry. In practical terms, this means the use of

- reliable and well documented data sources,

[1] Commission Recommendation on 20 September 2010 on regulated access to Next Generation Networks (NGA).
[2] BoR (14) 190.
[3] For the local access market, for example, a 1% change in the WACC could change regulated wholesale prices by 5-10%.
[4] 2009/140/EU

- proven methodologies that can be verified and
- financial theory that is established and accepted by the market.

Consistency ensures that the calculation of the parameter values is in line with both theory, empirical findings and regulatory frameworks which helps WACCs converging methodologies across countries.

BEREC acknowledges that the WACC is not only a matter of wholesale price regulation; it can provide, together with the regulatory framework in charge and the overall remedies imposed a signal directly to investors who invest in multiple EU-countries. In such a sense, a more homogenous WACC methodology estimation process can increase confidence of investors providing a better signal - in this case limiting the risk of distorting investments in telecommunications infrastructure between member states.

Specifically, in relation to the last relevant element a question arises on the advantages of a strong harmonisation of the parameters used for WACC estimation among European countries. To this respect, a cost/benefit trade-off should be carefully weighed against the desired consistency over time and stability within a member state. It needs to be assessed whether the costs of adjustment due to a change of methods within a country are higher than the potential benefit of a harmonised/common methodology.

Over the years BEREC has collected information about the way WACC is estimated by all NRAs in regulated markets. In BoR (13) 110, an extensive survey has been carried out on the subject of WACC confirming that nearly all NRAs use the CAPM (Capital Asset Pricing Model) to evaluate the equity rate of return from which they derive the WACC as a weighted average of the cost of debt and the cost of equity focusing the analysis on the fixed and mobile markets i. e. Market 4/2007 and Market 7/2007.[5] In general, NRAs that estimate the WACC for fixed markets also use the same values for fixed termination markets and leased lines with any differences usually the result of timing differences between market reviews.

In the Regulatory Accounting Report 2016 (BoR (16) 159) BEREC decided to update and expand the information collected for the WACC section in terms of quality, quantity and scope, providing an update of the 2013 Annex report as well as providing new benchmarks about WACC parameter estimation and methodologies.

Before going to go into 2017 analysis BEREC would like to briefly mention the Brattle study. On 18 July 2016 the Commission published a study carried out by The Brattle Group and titled “Review of approaches to estimate a reasonable rate of return for investments in telecoms networks in regulatory proceedings and options for EU harmonisation”.[6] This study analyses in detail the approaches NRAs use to determine the rate of return in regulatory environments providing guidance to a “converging” methodological approach for estimating parameters.

The study has been thoroughly examined by BEREC since one of the main goals of EC in tendering the research has been to promote a methodological approach in Europe to estimate WACC avoiding high discrepancies that could lead to weakening the single market.

Chapter 5 of the 2017 RA report will survey WACC values, benchmarking final rates, and methodologies of single parameters within the WACC formula computed by NRAs for the estimation of

[5] Annex to the 2013 RA Report “Cost of Capital in Europe – Cost of Capital Parameters in 27 European Countries” (Data as of 1st January 2012)
[6] https://publications.europa.eu/it/publication-detail/-/publication/da1cbe44-4a4e-11e6-9c64-01aa75ed71a1

legacy WACC specifically in market 3a and more in general in fixed markets.[7] It will also provide information about the evolution of the WACC value over time.

Different values may be detected among countries. Single parameter analysis was agreed to be relevant in understanding differences in WACC among NRAs. Parameters has indeed been classified among those which may be detected as those that NRAs interpret in light of country specific evidence or, conversely, that are less relevant in explaining differences in WACC values among NRAs. The last classification refers to correlation between single parameters values and final WACC values on an historical basis. Each parameter has been indeed correctly identified in terms of NRAs approach to the estimation. Each single parameter has been analysed, for benchmarking purposes, in terms of methodology used by single NRAs, values evolution overtime and guiding principles. Analysis refers to the general leading principles, in order to depict how those principles are practically taken into account by NRAs in their WACC calculation. For each parameter it is possible to highlight differences in values, differences in methodologies, if any, or evaluating if methodologies are sufficiently aligned and converging. According to this analysis it is possible to highlight the more critical parameters with respect to a likely methodological harmonization process among NRAs.

It is important to mention that when NRAs exercise their regulatory discretion by taking into account general principles as well as the objectives of the ECS framework when choosing how to calculate the WACC their decisions are not arbitrary as also the data collected show. Thus, in a mix of theory and regulatory practice used consequently in taking WACC decisions, the analysis shows that differences can be explained by country specificity and would not lead to investment distortion.

The following analysis is based on an updated questionnaire targeted to collect information on:

- parameter values to evaluate the WACC;
- main methodologies currently used to estimate each parameter (based on predefined options);
- evolution over time of methodologies and parameters values used by NRAs.

The WACC formula

The rate of return allows service providers to obtain the necessary funds from capital markets to finance infrastructure investments and satisfy both shareholders and debt holders.

The WACC equals the weighted average of financial market costs. Specifically, it may be evaluated through the sum of two components: the cost of equity and the cost of debt. The weights represent the percentage of the equity and debt respectively with regard to the total value of the company. The WACC can be expressed in nominal and real terms, post- and pre-tax.

[7] The information collected and presented in the report refer to market 3a, in some cases due to country specificity issue data provided can refer to fixed market (i.e. market 1, market 3b, market 4). In the text will be highlighted when different data set have been provided by NRAs.

$$WACC_{post-tax\ nominal} = \frac{r_e \times E}{D+E} + \frac{r_d \times (1-T) \times D}{D+E}$$

$$WACC_{pre-tax\ nominal} = \frac{WACC_{post-tax\ nominal}}{1-T}$$

$$r_e = return\ on\ equity\ (post\ tax)$$
$$r_d = cost\ of\ debt\ (pre-tax)$$
$$E = equity; D = debt; T = tax$$

A nominal WACC includes the impact of inflation. The conversion from a nominal WACC to a real one should be done by using the well-known *Fisher equation*:

$$WACC_{real} = (1+Wacc_{nominal})/(1+Inflation\ rate)-1.$$

The choice of a nominal or real WACC is related to the used price base. Generally, NRAs, when using bottom-up models, can include inflation via price evolution of assets, in that case a real WACC is required for estimating the cost of capital, whereas in the opposite case a nominal WACC is needed to avoid double counting of the inflation.

It is relevant to consider that the conversion from nominal to real WACC should be consistent with the estimation of a pre– or post-tax calculation of the WACC. In line with the concept that taxes are always paid in nominal terms, a pre-tax WACC should be derived from an after tax WACC expressed in nominal terms and not in real terms. So a pre-tax real WACC should be derived from nominal pre-tax WACC.

A first methodological element in the WACC calculation to be considered is how the cost of equity is determined. The most common approach used by NRAs is the **Capital Asset Pricing Model (CAPM)**[8], which is a linear single factor model that provides a measure of the relationship between perceived market risk and expected returns from the point of view of the market investor. The CAPM makes the assumption that the rate of return should be positively correlated with a market risk.

The rate of return of a market stock can be expressed as the sum of the Risk Free Rate (r_f) plus a Market Risk Premium. The model explains that the equity risk of a stock market can be expressed as a linear relation between the beta of the market stock and the Equity Risk Premium ($r_m - r_f$).

$$r_E = r_f + \beta * (r_m - r_f)$$

The beta provides an estimation of the component of non-diversifiable risk of a market stock assuming the investor has a perfectly diversified portfolio. The beta of a market stock is expressed as the ratio between the co-variance of the rate of return of the market stock with respect to the rate of return of the whole market portfolio and the variance of the market portfolio itself: cov(Ri,Rm)/σ^2(Rm). When beta is equal to 1, then the rate of return of a stock market is equal to the rate of return of the whole market portfolio. A beta grater (lower) than one means that the rate of return of a market stock has a greater (lower) systematic risk with respect to the whole market portfolio.

The following analysis focuses on CAPM since this is the methodology NRAs use. Other methods for estimating the cost of equity have not been considered (such as: Arbitrage Pricing Theory (APT); Fama-French model[9]; Empirical capital asset pricing model[10]; Market derived CAPM[11]; Total Market Return (TRM)).

[8] William F. Sharpe "Capital Asset Prices: A theory of Market Equilibrium under Conditions of Risk" Vol. 19, No. 3 (Sep., 1964), pp. 425-442

[9] The Fama and French is a three-factor model that can be thought of either as a special case of APT or as an enhancement of CAPM. The model has three factors: market factor, company size factor, and book/market value factor. While this model has been, to some extent, supported by the results of certain empirical studies, there has been a con-

The questionnaire asked NRAs to provide information on the following main parameters: i) Risk Free Rate; ii) Cost of Debt; iii) Beta; iv) Equity Risk Premium; v) Gearing; vi) Tax. Information was collected both on methodologies and values, for decisions currently in force as well as past decisions. Specifically, the questionnaire relates to WACC decisions in market 3a of the Recommendation; in case "not applicable/not available", data related to other fixed markets have been considered (fixed termination or market 3b).

Table 1 – WACC parameters

	Parameters
1	Risk Free Rate
2	Equity Risk Premium
3	Beta
4	Cost of debt
5	Gearing
6	Tax rate
7	Wacc Nominal pre-tax

Source: BEREC 2017

In table 2 the year of information provided about WACC calculation is reported for each country as well as their frequency of updating.

31 NRAs replied to the questionnaire providing information on WACC methodologies and values applied to market 3a in the 2008-2017 period.[12] Most of the NRAs (21) update WACC in line with their market analysis or when pricing decision are taken. In this case, market-specific WACCs may be in force for 2 or more years . Some NRAs update yearly (10), but in some cases the update comes into force only when new pricing decisions are taken.

The dataset used for the following analysis takes into consideration 65 observations on all 7 parameters previously listed. Specifically 10 NRAs provided one WACC updates, 8 NRAs provided two WACC updates and 13 NRAs provided three WACC updates.

All values provided by NRAs are consistent with their final nominal pre-tax WACC calculation meaning that in some cases parameters contain also some country specific premium added to the cost of Equity and attributed mainly to RFR, ERP or Beta in line with the information provided to the RA-EWG.

siderable debate on whether the risk premium associated with the two additional factors (company size and book/market value) are statistically significant.

[10] Jensen, Michael C. and Black, Fischer and Scholes, Myron S., The Capital Asset Pricing Model: Some Empirical Tests. Michael C. Jensen, STUDIES IN THE THEORY OF CAPITAL MARKETS, Praeger Publishers Inc., 1972. Available at SSRN: https://ssrn.com/abstract=908569

[11] J. McNulty, T.D. Yeh, W.S. Schulze, M. H. Lubatkin "What's your real cost of capital?" Harvard Business Review 2002

[12] Only EE said that the final WACC value is obtained using a benchmark from other NRAs, not applying directly a formula.

Table 2 – WACC database and frequency update

	2017	2016	2015	2014	2013	2012	2011	2010	2009	2008	FREQUENCY UPDATE
AT			X			X			X		MARKET ANALYSIS/REGULATORY PERIOD
BE			X					X		X	MARKET ANALYSIS/REGULATORY PERIOD
BG		X			X						MARKET ANALYSIS/REGULATORY PERIOD
CH	X				X					X	YEARLY
CY	X		X				X				MARKET ANALYSIS/REGULATORY PERIOD
CZ		X									MARKET ANALYSIS/REGULATORY PERIOD
DE	X							X			MARKET ANALYSIS/REGULATORY PERIOD
DK	X	X	X								YEARLY
EE											MARKET ANALYSIS/REGULATORY PERIOD
EL			X		X						MARKET ANALYSIS/REGULATORY PERIOD
ES		X			X				X		YEARLY
FI	X				X				X		MARKET ANALYSIS/REGULATORY PERIOD
FR		X			X	X					MARKET ANALYSIS/REGULATORY PERIOD
HR		X			X						MARKET ANALYSIS/REGULATORY PERIOD
HU	X	X	X								YEARLY
IE	X*				X				X		MARKET ANALYSIS/REGULATORY PERIOD
IS		X									-
IT			X					X			MARKET ANALYSIS/REGULATORY PERIOD
LI				X							MARKET ANALYSIS/REGULATORY PERIOD
LT			X								YEARLY
LU		X									MARKET ANALYSIS/REGULATORY PERIOD
LV											
ME											
MK											
MT						X					MARKET ANALYSIS/REGULATORY PERIOD
NL			X		X						MARKET ANALYSIS/REGULATORY PERIOD
NO	X**				X						MARKET ANALYSIS/REGULATORY PERIOD
PL	X										YEARLY
PT	X	X	X								YEARLY
RO					X						MARKET ANALYSIS/REGULATORY PERIOD
RS		X	X	X							YEARLY
SE	X***										MARKET ANALYSIS/REGULATORY PERIOD
SI				X							MARKET ANALYSIS/REGULATORY PERIOD
SK		X			X						YEARLY
TR											
UK	X**			X					X		MARKET ANALYSIS/REGULATORY PERIOD
Number of observations Totals	12	12	11	4	12	3	1	3	5	2	65

*Confidential ** Under consultation ***Mobile

Source: BEREC 2017

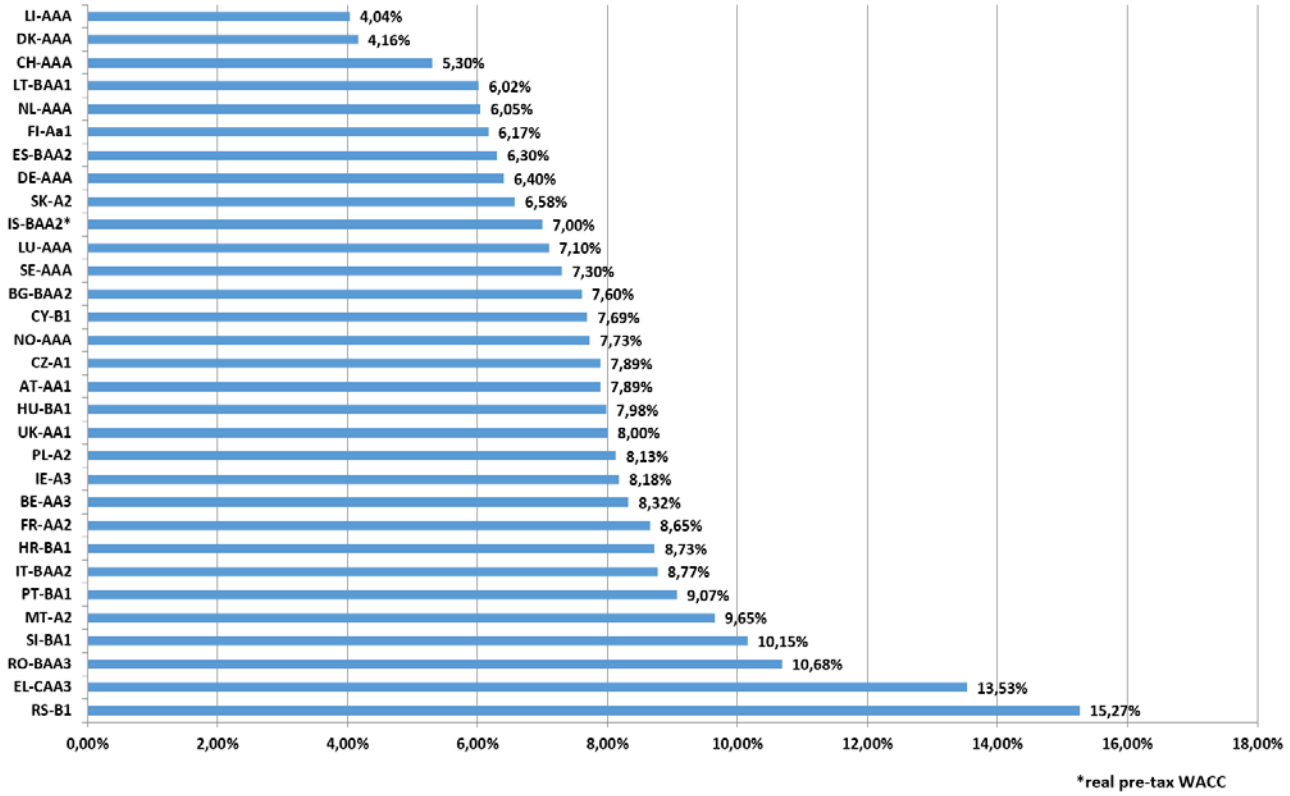
5.2 WACC Nominal Pre-tax synthetic value

The table reports the main statistics currently in use to estimate the nominal pre-tax WACC.

	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
WACC Nominal pre tax	**7,98%**	**7,89%**	**2,34%**	**29,3%**	**15,27%**	**4,04%**

In Figure 1 WACC values have been sorted by increasing order and country credit rating information is provided.

Figure 1 – WACC-Nominal Pre-tax[13]

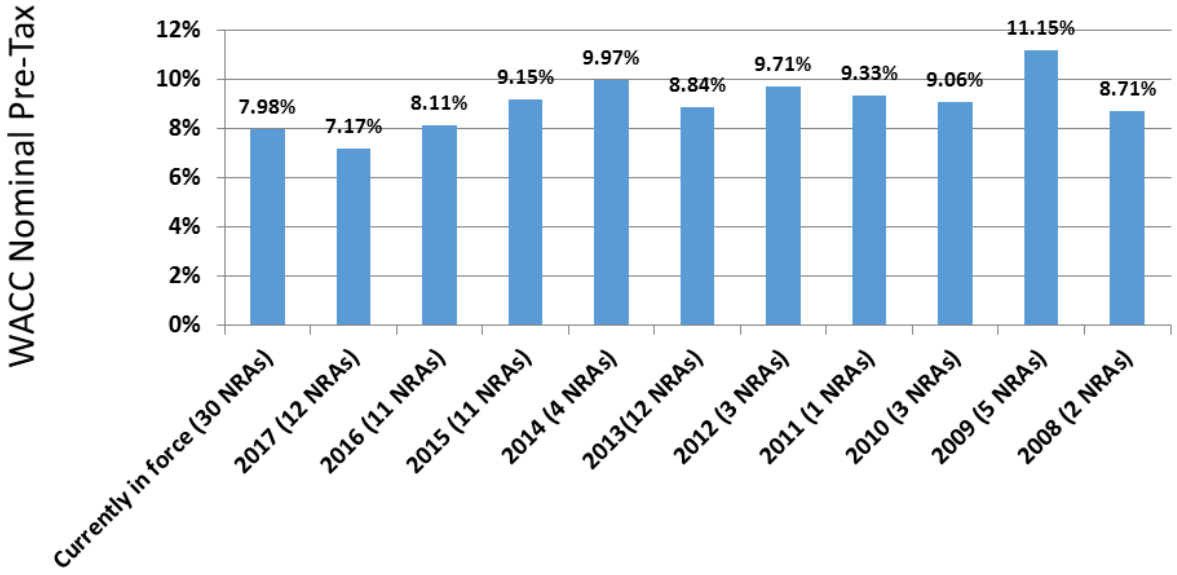


Source: BEREC 2017

In figure 2 the average year-by-year adopted nominal pre-tax WACC values are shown to have a better understanding on the influence of the time when the decisions were taken on the estimation on the nominal WACC values. The currently in force average value comes from averaging values that are in use at the date of questionnaire's replies (independent from the year of the decision).[14]

[13] UK WACC for 2017 comes from March 2017 WLA Consultation. This caveat applies to each parameter.
[14] For DE the WACC for 2017 is the corresponding real pre-tax WACC equal to 5.76%.

Figure 2 – WACC-Nominal Pre-tax 2008-2017



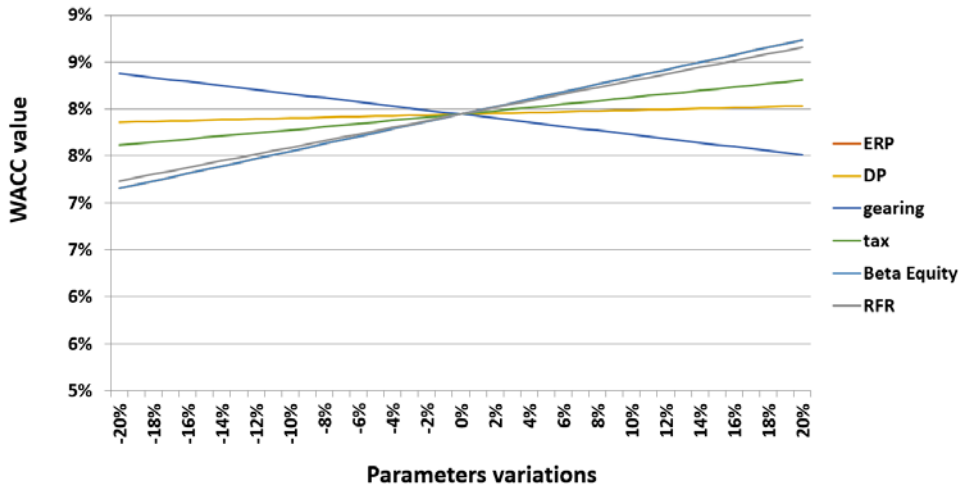
Source: BEREC 2017

We note a reduction over time of the average WACC estimation for the last four years (only NRAs that updated WACC values from 2014 were considered).

In order to explore the WACC parameters relevance with respect to the WACC values according to the formula and the dataset collected by NRAs, we carried out i) a sensitivity analysis and ii) a regression exercise.

Figure 3 shows the outcomes of the sensitivity analysis (Beta and ERP lines overlie since they have the same coefficient)[15].

Figure 3 – Sensitivity analysis on WACC formula



[15] The sensitivity analysis is as follows. We take, for each parameter the arithmetic average of the survey, which is described in the next Sections. We let each parameter vary by keeping constant the others. Each parameter in the picture may vary by +/- 20%. We may conclude that, in a realistic parameter space, linear approximation of variation (i.e. a constant partial derivative also for tax parameter) is accurate. Just when varying taxes more than +100% the WACC curve may exhibit a nonlinear trend on this single parameter variation.

Source: BEREC 2017

In Figure 4 the coefficients of the linear approximation of the variation of each parameter (i.e. partial derivatives) in the WACC formula are shown.

Figure 4 – Partial derivative of the WACC formula

beta	ERP	RFR	gearing	taxes	DP
0.000395	0.000395	0.000356	-0.000217	0.000173	0.000043

Source: BEREC 2017

ERP and BETA are the parameters which may, potentially, have a greater (positive) impact on the final WACC value (followed by RFR, gearing, taxes and debt premium).
On the other hand, the regression exercise is useful to consider (in terms of causal inference) the historical and currently in force data on single parameters collected through questionnaires. Results from the regression highlight that the most part of the variability in WACC values is due to the RFR estimation and, to a far lesser extent, to ERP. All other parameters provide a much lower explanation to the variation of the final WACC (see Annex 2 for details). RFR and ERP are the parameters to which NRAs refer most for assessing their country-specificity[16].

This is to say that RFR, even if it is not the parameter with the absolute highest weight on WACC formula, is the one which explain better differences in regulatory WACC decisions.

In what follows, we explore the single parameter values and methodologies, used for estimating them, and where available the reasoning behind regulatory choices by NRAs.

From data and information provided, it comes out that NRAs do not apply a mechanistic approach for WACC estimation, but theory is applied with judgment in order to address the country specific situation, in the light of a predictable and consistent regulatory path overtime. Besides the regulatory approach, the availability of (public) data also plays an important role for the choice of the methodology mainly for transparency reasons.

Elements collected allow to conclude that where differences among NRAs approach result in different final WACC values, this are mainly due to country specific evidence and, to a less extent, to different methodological assumptions (e.g. time windows).

In the following section, for each WACC parameter, the output of the survey is presented accompanied by definitions and general financial theory.[17] The survey summarizes, where available, also main "motivations/priorities" declared by NRAs behind the chosen methodologies.[18]

[16] The methodology benchmarking, reported in the following paragraphs, highlights in fact that beta and gearing are estimated mainly by applying a "notional" approach, while for RFR and, to a less extent, ERP we don't find such preference in estimation.
[17] General financial theory is also included, without the claim to be exhaustive, to provide the reader a self-consistent document for easier understanding of the *benchmark* result proposed.
[18] The NRAs' responses stating "stability" are included as "predictability".

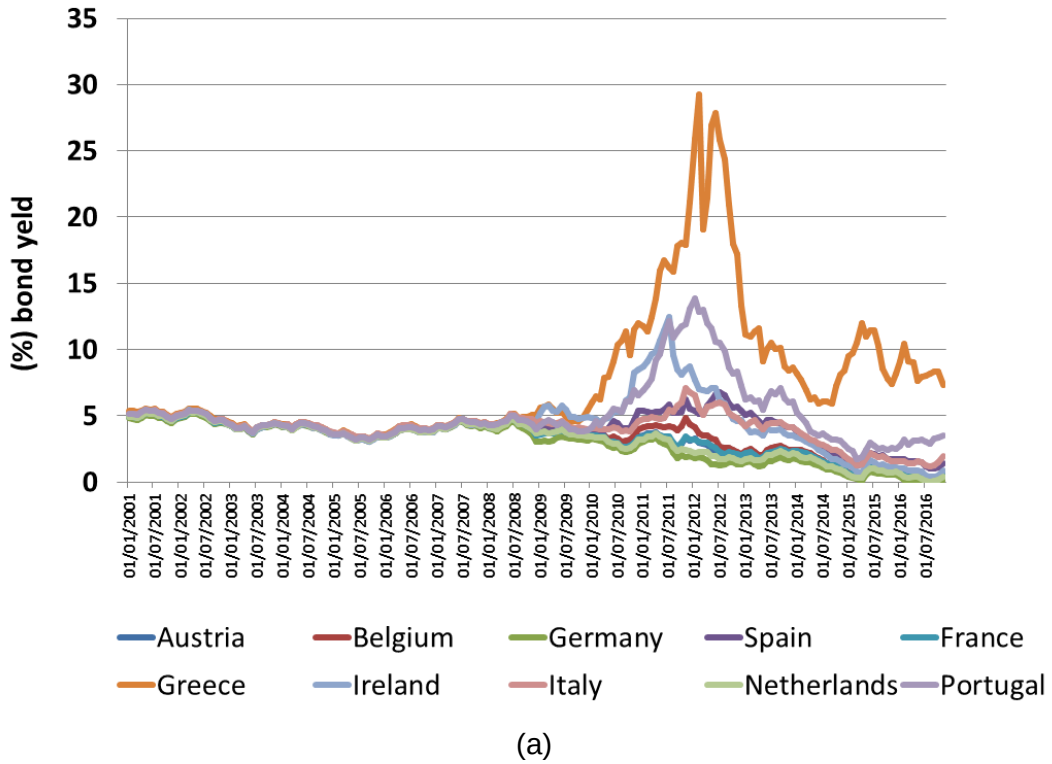
5.2.1 Risk Free Rate

Definition and general financial theory

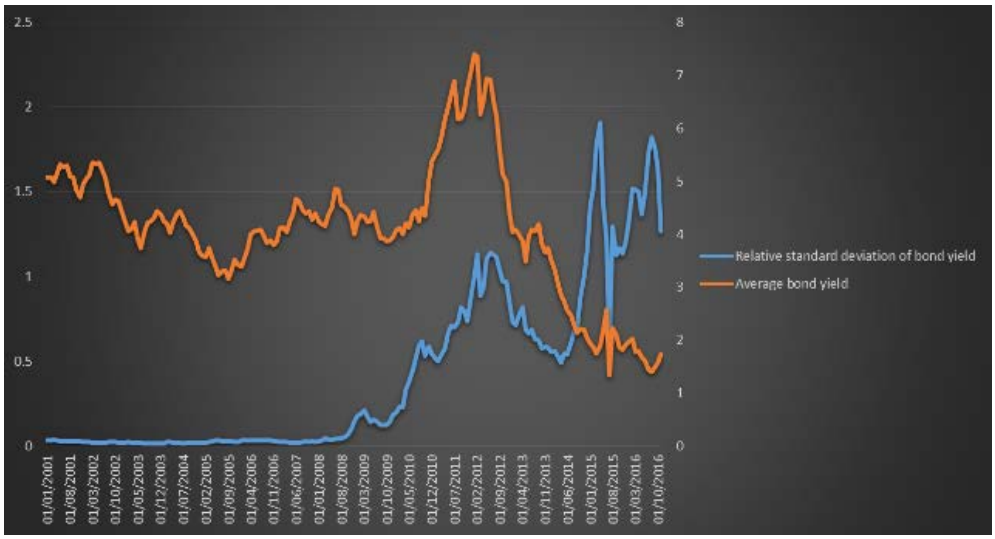
The risk free rate is the return which an investor can expect to gain from investments which do not carry any risk: it measures the expected return on an investment free of default and systematic risk, it reflects the time value of money understood as the compensation that investors require in order to invest today in favour of future consumption. The risk free rate is a relevant element for estimating the cost of equity in the CAPM model.

RFR is generally informed by reference to government bond yields. The nominal RFR can be informed by yields on nominal government bonds while the real RFR can be informed by yields on index-linked government bonds. A real RFR can be translated into a nominal RFR by using the Fisher equation and an assumption about inflation. From the introduction of the Euro up until the crisis of 2009, nominal government bond yields in the Eurozone economies have been at similar levels – see Figure 5(a). This trend changed from 2009 onwards when, due to the global financial crisis, the difference between country bond yields increased. In figure 5(b) the relative standard deviation of the average for 10 year spot rate bond for all countries is represented, showing a significant increase. At the same time, the Quantitative Easing Policy of BCE reduced the average level of the bond yields from mid-2012 onwards.

Figure 5 – Yield difference average yield (a) / average and standard deviation (b)



(a)



(b)

Source: BEREC 2017 on ECB publicly available data

It is generally recognised that the domestic bond yield is the correct approach to include a country risk premium in the cost of equity, moreover, it provides a good approximation of the nominal Risk Free Rate considering the fact that the domestic bond yield reflects inflation expectations in a forward looking perspective.

The inclusion of a country specific risk premium in the risk-free rate seems may be one way to capture the specific effect that the financial crisis had on the required return for regulated assets, as it incorporates part of the additional country risk premium that may be required by equity investors with regards to the macro environment of a specific country. The domestic bond yield will generally compensate for country specific (incl. regulatory) risks. Also, in the event of an economic downturn or crisis the risk of increased default payments, bad debt and network abandonment can increase the systematic and non-diversifiable risk.

In financial theory different approaches are applied for estimating a country risk premium in order to determine the cost of equity: i) using a government country bond yield for the RFR; ii) using a spread between company bond working in national market that suffers a financial crisis and company bond working in market that doesn't suffer a financial crisis;[19] iii) adjusting the ERP estimated in normal conditions through the ratio of equity market volatility of a country suffering a financial crisis and equity market volatility of a market that doesn't suffer a financial crisis.

The use of domestic bonds is generally not recommended in case of illiquidity, in fact in this case the spread between the real risk free rate (i. e. German Government Bonds) cannot represent a compensation of the systematic risk (non-diversifiable risk) due to macroeconomic conditions of the country, but just an illiquidity premium. Illiquidity measures can be obtained using trading volume, trading frequency (the number of trades executed within a specified interval, without regard to trade size, etc.). However, "relatively" simple indicators of market activity based on trading volumes

[19] While the cost of equity compensates investors for a different set of risks than the cost of debt, using data from debt markets can still provide some insight on the country risk premium. Intuitively, the country risk premium on equity would be expected to be at least as big as the country risk premium on debt, since equity-holders are the residual claimants on a firm's cash flows (Oxera http://www.autorita.energia.it/allegati/docs/15/275-15oxera.pdf).

and the number of transactions can be used to estimate market depth, i. e. the capacity of a given market to absorb buy and sell orders involving large quantities. Liquidity can also be gauged through measures of: - bid-ask spreads posted by banks and brokers, which proxies the ex-ante cost of executing a trade; - price impact, which proxies the share of the execution cost linked to execution itself (i. e. post-trade).

Domestic bonds are not recommended in case the NRA's MS have a significant risk of default e. g. in case a credit rating is below investment grade (BBa3 or below), or the yields are above the yields on bonds issued by large firms operating and earning most of their revenues in the country.

Other elements to take into consideration are the: i) bond maturity; ii) the averaging period; iii) Quantitative Easing adjustments.

Regarding bond maturity, a choice can be made considering the following elements: the regulatory period taken into account; the volatility; the liquidity; the Equity Risk Premium estimation. Taking all these elements into consideration, as a rule of thumb, long term bonds (10/20 years) seem to be a better choice for estimating a country's RFR because they are less volatile, more liquid, and generally consistent with the Equity Risk Premium estimation based on historical DMS time series.

	3Years	5Years	10Years	20Years
Regulatory Period	++	+	-	-
Volatility	-	-	++	++
Liquidity	-	-	+++	++
Consistency with ERP	-	-	+	++

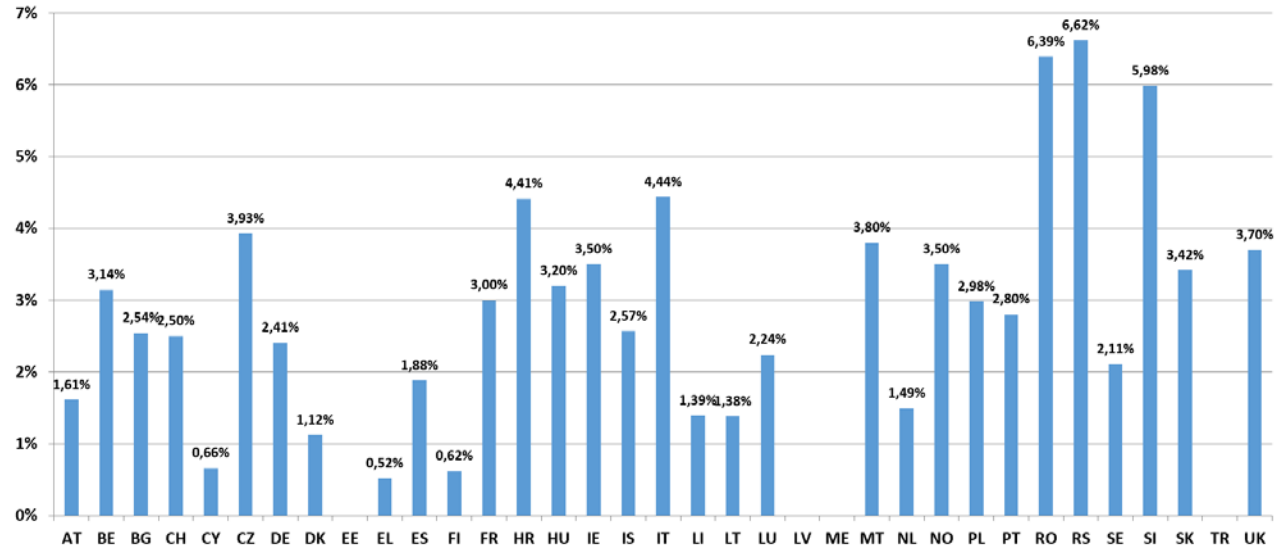
Regarding the averaging window some trade-offs between a forward looking estimation and a reduced volatility of the bond yields in light of the predictability principle is generally taken into account.

Main output from the survey.
From the replies of to the 2017 questionnaire the following statistics were derived.[20]

2017	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
Nominal RFR (30 NRAs)	**3.04%**	**2.89%**	**2.03%**	**66.74%**	**0.52%**	**10.67%**

[20] The data represented include a country risk premium in RFR, from the values provided by the NRAs to be consistent with the final WACC estimation. In case of IS real risk free rate is provided. For RS the data reported in figure 6 doesn't include inflation.

Figure 6 – Nominal Risk Free Rate



Source: BEREC RA database 2017

The following table compares the main approaches used by NRAs to estimate the RFR (the answers were based on a set of pre-defined alternatives as reported in the table). As an example for the "main methodology" indicator, the following assumptions have been considered.

Main methodology	
Domestic bond	Refers to the use of own country bond
Country specific bond	Refers to the use of a specific bond from a different country
Other	A mix of methodologies and judgement is used to derive an estimate
Benchmarking	the RFR is estimated by referenced to RFR values used by other NRAs

Table 2 – RFR methodology survey RA Report 2017

	Do you evaluate the Real Risk Free Rate in order to compute the Nominal Risk free Rate?		Methodology/Country bond		Bond length		Sampling period used		Averaging window		Average methodology		Quantitative Easing		-if benchmarking is indicated in the methodology section please indicate the average used from other countries	
Nominal Risk Free Rate (in %)	Yes	7	domestic bond	20	1 year	0	daily	16	Spot rate	1	Arithmetic average	23	Yes	1	Arithmetic average	0
	No	23	country specific bond	4	3 years	0	weekly	1	3 months	2	Geometric Average	0	No	20	Geometric Average	0
	in red the value with the highest frequency		other	7	5 years	0	montly	9	6 months	2	Moving Average	1	Comment	2	Moving Average	0
			benchmarking	0	10 years	25	Other	3	1 Year	6	Median	0			Median	0
					20 years	0			2 Years	2	Other	2			Other	0
					Other	5			3 Years	5						
									5 Years	7						
									10 Years	3						
									Others	1						

Source: BEREC 2017

Next we provide some highlights from the questionnaires. As a preliminary output, most of NRAs use a nominal estimation of the RFR without evaluating a real risk-free rate. A real risk-free rate is estimated by 7 NRAs (CH, IE, IS, LU, NO, PL, UK).

All the indicators identified by the questionnaire show a quite consistent approach in terms of the main methodology used for estimating the RFR. The averaging window is the only factor where a variety of approaches are taken by NRAs.[21]

Combining the approaches in terms of general methodology (geographical scope) and time windows, i. e. the more differentiated parameters to estimate the RFR, the following statistics emerged (figure 7).

[21] In table 2, replies of "7 years" (SE, LU) have been included in the closer category "5 years".

Figure 7 – RFR: Main methodology and time windows (frequency, NRAs, values)

		Methodology			
		Domestic Bond	Country specific	Others	Total
Time windows	<=1 year	8	1	2	11
	<=3 years	2	0	5	7
	>=5 years	9	2	0	10
	Total	18	3	7	28

		Methodology			
		Domestic Bond	Country specific	Others	Total
Time windows	<=1 year	BG,CH,ES,FI,HU,LT,PL,SK	EL	RS, SI	11
	<=3 years	MT,PT		AT,BE,HR,NL,RO	7
	>=5 years	CZ,DE,DK,FR,IS,IT,SE,LU,UK	CY,LI		10
	Total	18	3	7	28

		Methodology			
		Domestic Bond	Country specific	Others	Average
Time windows	<=1 year	2.31%	0.52%	8.33%	3.24%
	<=3 years	3.30%		3.41%	3.38%
	>=5 years	2.87%	1.03%		2.50%
	Average	2.67%	0.86%	4.81%	

Source: BEREC 2017

Note that when “country specific” is chosen as main category the country risk premium on the cost of equity is generally included in ERP (EL, CY); time windows are less relevant in this case.

When “Other” is chosen as the main methodology combined with a short time window (<=1 year), generally the RFR includes some country specific risk premium (SI, RS) that is more relevant for the final value of the RFR; in this case, the relevance of time windows is lower.

Most NRAs that have used an average window between 1 and 3 years do this in conjunction with “other” as the main methodology. In this case the averaging window seems to have been chosen to reflect a consistent approach with theory such as lower standard error. In case of financial crisis, some countries stated that they use German government bonds as a benchmark: these bonds are in fact less affected by fluctuations in short-term interest rates which may influence price control for 3 to 5 years.

Two main groups (8 and 9 NRAs respectively) use domestic bonds and time windows that are: i) less than 1 year (BG, CH, ES, FI, HU, LT, PL, SK) or greater than 5 years (CZ, DE, DK, FR, IS, IT, SE, LU, UK). In the first group, some countries also added a country specific risk premium to the RFR (CZ, SK) for their final estimation of the cost of equity.

In general, NRAs that use domestic bonds as a methodology for estimating the RFR together with a less than one-year time window motivated the choice in terms of consistency with a forward looking approach with respect to the financial situation. In this case the deviation from the spot rate is a way to overcome short term volatility. It should be considered that the frequency of updating the WACC can have an influence on the approach used: among the 8 NRAs that use short time windows, 5 update the WACC yearly (ES, HU, LT, PL, SK). On the other end, out of the 8 NRAs that use a longer time window only one NRAs updates the WACC yearly (DK).

NRAs that use domestic bonds and a time window average of more than 5 years explained as their motivations the imposition of some "regulatory objective", thus granting predictability, consistency and transparency, and overcoming the effects of quantitative easing.[22]

In the last case, the choice of averaging bond windows seems to be related to adjusting the level of the risk-free rate (by including a country risk premium when this is not included in other way). That is to say, within the current period of very low yields, the aim is to place more emphasis on longer data series aiming at mitigating the risk of underestimating the WACC.

In summary, the main motivations behind the choice of averaging windows are: i) to maintain regulatory predictability (e.g. consistent approach over time, or taking long term averages to limit variations between market reviews); ii) to avoid putting too much weight on factors which may distort current yields (e.g. QE); iii) consistency with regulatory period; iv) consistency with investment life cycle.

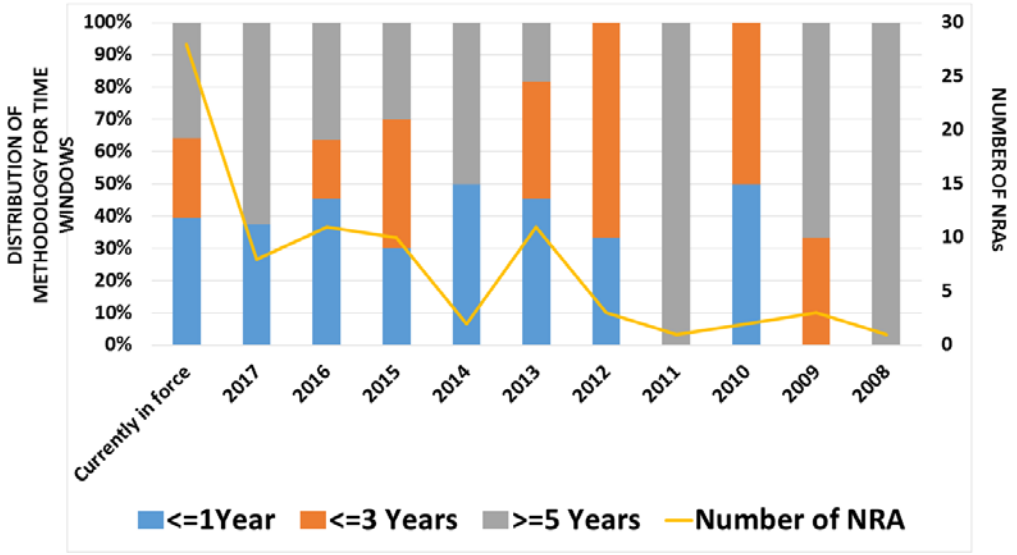
In order to see how predictability and consistency principles are interpreted by NRAs in practical terms, the questionnaire asked about the motivation behind the change (if any) of main methodologies in recent years. Only few NRAs stated to have changed their approach over the years for estimating the RFR (FI, FR, IT). The motivation for changing was to overcome instability in the final value of the WACC that could have occurred from the application of previous methodologies due to the low level of the domestic bond rate (FI) with respect to previous regulatory periods, or the volatility experienced due to the global financial crisis (FR and IT).

Looking at the distribution of the "time windows" used by NRAs in 2013-2017, the period when the number of NRAs that have updated their WACC is higher, it seems that there is a growth in preference with respect to a time windows >=5 years.

At the same time the average Risk Free Rate estimated in the same period shows higher values than European bonds leading to more stable values than the ones obtainable from the spot estimation of the parameter at the basis of RFR estimation (fig 9).

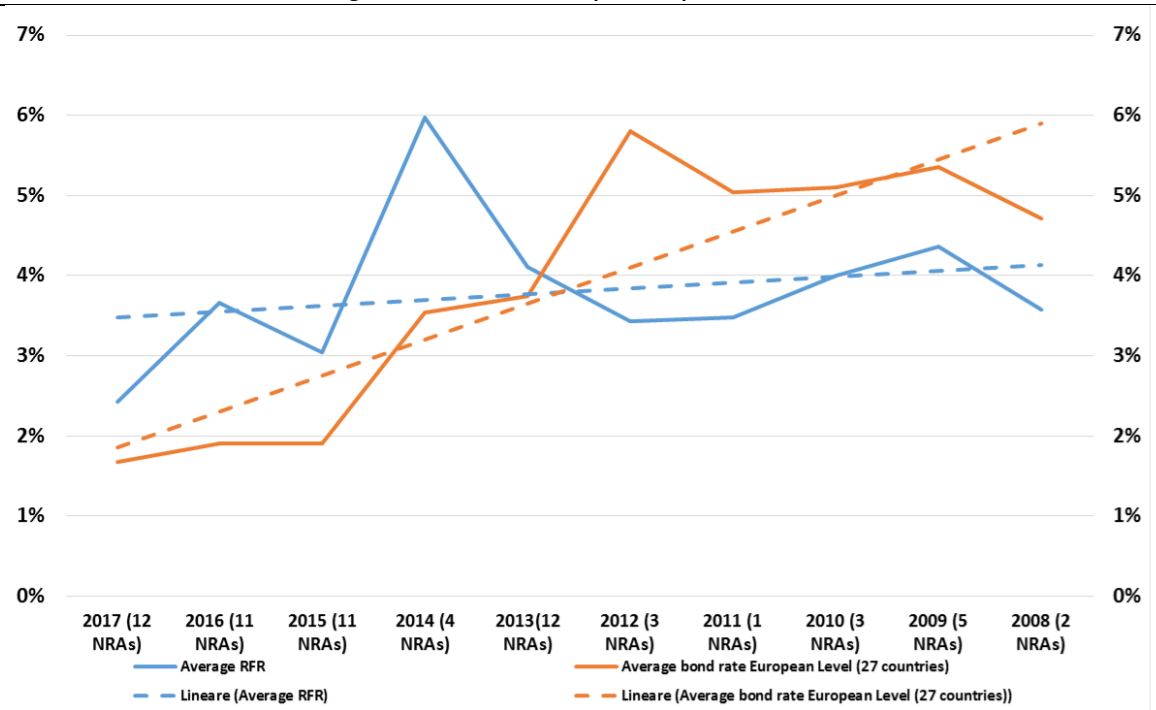
[22] One NRA (DE) declared that a high fluctuation of the regulatory WACC over time is not in line with the requirements of the law. Therefore an exponential smoothing procedure has been used since 2009. The procedure's goal is to achieve fairness in the long run without having instability and unpredictability while, in the short run, it allows the regulator to stick to the chosen estimation procedures for the WACC even in years when the procedure leads to unexpected results. This exponential smoothing consist in weighting the current estimation by 30%, while 70% is the weight attributed to the WACC estimated in previous period.

Figure 8 – RFR: distribution of methodology



Source: BEREC 2017

Figure 9 – RFR/European spot bond rate



Source: BEREC 2017

Looking at Quantitative easing, only one NRA takes this explicitly into account (BE)[23]. In two other cases (FR and UK) quantitative easing is indirectly taken into account without an explicit adjustment.. One NRA (UK), even without making an explicit adjustment to time windows for this effect, explains that QE is one reason for preferring longer term average yields rather than spot rates.

[23] The RFR in this case is based on a composed Bloomberg index.

5.2.2 Equity Risk Premium (ERP)

Definition and general financial theory

The Equity Risk Premium represents the additional return over the risk free rate that investors require as compensation from an investment in a perfectly diversified portfolio of common stocks. The ERP reflects the equilibrium price of equity market risk.

The estimation of the Equity Risk Premium is difficult as "there is no single figure for the risk premium that theory says is correct".[24]

The main elements to take into account are the geographic scope of the estimation (notional or country specific) and the effective methodology (historical vs forward looking or mixture of these methods).

Concerning the geographical scope of the ERP the use of a notional approach is in line with a view that investors can diversify equity investment, in the sense that a notional approach can take into account the fact that equity investment can be diversified investing in different countries.

When estimating ERP at a single country level a mix of methodologies based on historical and forward-looking approaches may be used.

The standard data source for historical ERP estimates is based on the Dimson, Marsh and Staunton (DMS) database. The DMS data set calculates the average excess return of stocks over bonds (consistent with the RFR estimation)[25] over more than 100 years for a large group of world markets. The underlying idea to use this measure is that the future is expected to be like the past.

Specifically, the historical perspective provided by the DMS data (more than 100 years of data analysis) are based on the fact that strong volatility in short time series are detected also considering 10 years' time series. In the view of the DMS approach the historical equity premium should be based on very long-time series to provide consistent results.[26] Using a longer time series is the only way in which a standard error on historical risk premiums estimation will be reduced.

One of the main elements of the estimation of the historical Equity Risk Premium is related to how the average returns on stocks and treasury bonds, are computed. The arithmetic average return measures the simple mean of the series of annual returns, whereas the geometric average considers the compounded return. There is a general consensus about the fact that in a forward looking perspective the arithmetic average is the best estimate of the equity risk premium. In fact, if annual returns are uncorrelated over time, and our objective is to estimate the risk premium for the next year, the arithmetic average is the best and most unbiased estimate of the premium. On the other hand, there are also arguments that favour the use of geometric averages: empirical studies seem to indicate that returns on stocks are negatively correlated over time such as positive years follow negative years and vice-versa (mainly in five-year perspective)[27]. In this case, the arithmetic average return is likely to over-state the premium. Taking into account that the regulatory period gener-

[24] E. Dimson, P. Marsh, M. Staunton, "The worldwide Equity premium: a smaller puzzle" (2006)

[25] The expected return on stocks can be compared to either short-term government securities (treasury bills) or long term government securities (treasury bonds) and the risk premium for stocks can be estimated to either.

[26] Stock returns are so volatile that it is hard to measure the mean historical premium with precision. Without long-run data, the task is impossible, and even with over a century of data, the standard error remains high—even if we assume that the underlying series is stationary.

[27] Fama, E.F. and K.R. French, 1992, The Cross-Section of Expected Returns, Journal of Finance, Vol 47, 427-466.

ally is multi-year and much longer than one year, arguments for geometric average premiums may become stronger. So the use of arithmetic, geometric or hybrid approaches can all be supported by financial theory in order to obtain reliable information on the country's market risk premium.

Another method for evaluating the ERP is based on a survey done via interviews with investors and CEOs about their expectations and their forward-looking perspective of market stock premiums. There is a widespread view that this methodology may have some drawbacks concerning its reliability when estimate the ERP for regulatory purposes. Specifically, replies collected in surveys might have been affected too much by recent outcomes of the stock market providing an overestimate or an underestimate of the ERP due to short term events. Moreover, the survey approach, in some cases, can be less consistent with the estimation of the RFR as it takes into account a general view on premium that weights expectation on both treasury bill (short term) and bonds (long terms).

An alternative approach is to use a dividend growth model (DGM) that is based on the estimation of actual share prices and returns per share. The use of the DGM is a common technique for estimating the cost of equity for a company or an index making use of short-run data. In its simplest form the DGM can be written as follows.

The DGM estimates the cost of equity by computing the discount rate that equates a stock's current market price with the present value of all future expected dividends. In a simple (one-stage) DGM it is assumed that there is a constant expected growth rate of dividends for all future years.

Given this assumption, the stock is valued at a price P0 derived as follows:

$$R = D0*(1+g)/P0+g \quad (1)$$

Where:

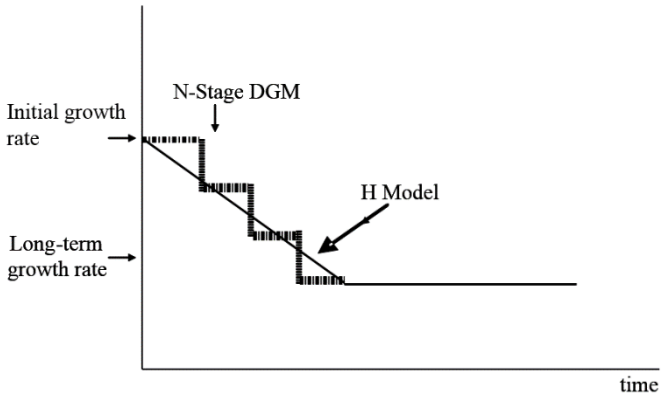
- D0 is the dividend per share at period 0;
- R is the post-tax cost of equity;
- g is the dividend per share growth rate (assumed constant); and
- P0 is equal to the share price at period 0 (measured at ex-dividend date).

Equation (1) states that a firm's cost of equity is equal to: i) its prospective dividend yield (expected next period dividend per share divided by stock price on the ex-dividend date of the previous dividend paid out) plus ii) the long-term expected rate of growth in its dividend.

The ERP is obtained subtracting from the cost of equity (R) an estimation of the Risk Free Rate.

In the described model a single stage of growth rate is assumed.

A more complex approach is a multi-stage DGM with the hypothesis that the growth rate cannot be constant over time: the growth rate of a company may be higher at the early stage and stabilising in the future (see figure below).



In case of a linear H-model the implied cost of equity can be written in a closed formula:

$$R = \frac{D_0}{P_0} \cdot \left[(1+g_n) + H \cdot (g_a - g_n)\right] + g_n$$

In this case two different growth rates have to be estimated at the beginning of the period (g_a) and after 2H years (g_n).

The estimation of the growth rate is mainly based on the view of financial analysts and in this respect is more of a subjective analysis, in line with the one provided in the survey approach.

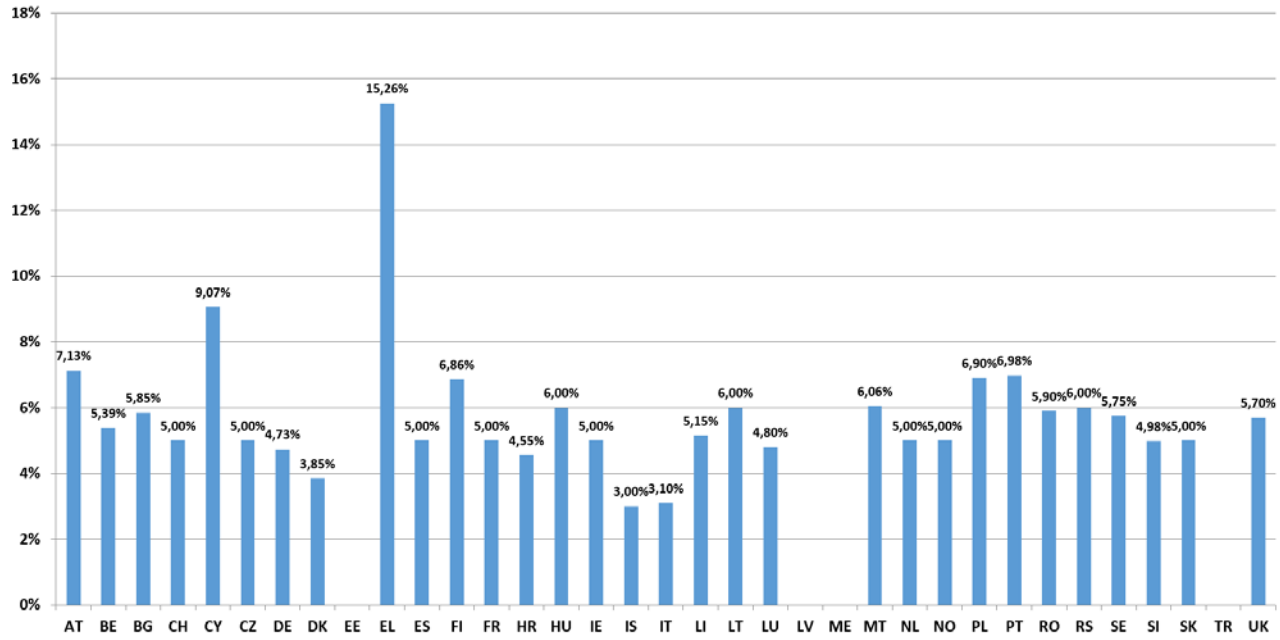
Main output from the survey.

From the replies to the 2017 questionnaire the following statistics emerge. [28]

2017	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
Equity risk premium ERP (31 NRAs)	**5.77%**	**5.15%**	**2.12%**	**36.82%**	**15.26%**	**3.00%**

[28] The data represented include a country risk premium in ERP value provided by NRAs to be consistent with the final WACC estimation (CY, IE, EL).

Figure 10 – Equity Risk Premium



Source: BEREC 2017

The following table compares the main approaches used by NRAs to estimate the ERP (the answers were based on a set of pre-defined alternatives as reported in the table).

Table 3 – ERP Methodology Survey from RA 2017

	Methodology (General)		Methodology Specific		-If historical data Average methodology		-if benchmarking is indicated in the methodology section please indicate the average used from other countries	
Equity risk premium	Notional value	10	Historical data	14	Arithmetic average	11	Arithmetic average	1
	country specific	8	Dividend grow model	0	Geometric Average	2	Geometric Average	0
	other	7	Historical+DGM	2	Moving Average	0	Moving Average	0
	benchmarking	1	Historical+DGM+Suvey	3	Median	0	Median	0
			Survey	4	Other	5	Other	0
			Historical+Survey	4				

Source: BEREC 2017

In terms of general methodology, no clear-cut preference emerges. Roughly one third of NRAs adopt a notional approach mixing evidence from different countries, one third of NRAs choose a country-specific ERP, one third opts for a methodological mix – i.e. “other”).

According to some NRAs, a notional approach is generally preferred due to unreliable/missing country-specific data and also because it can provide more stable results.

One NRA uses a benchmarking approach based on ERP values in accordance with the risk premium used by other European NRAs (BG).

In terms of the weight given to past data, the ERP estimation by NRAs generally derives from a combination of data and judgement.

In the questionnaire of the RA Report 2017 more predefined options on the specific methodologies used have been included: i) Historical data (HD); ii) Dividend Growth Model (DGM); iii) HD+DGM; iv) HD+DGM+Survey; v) HD+Survey; vi) Survey (forward looking).

Most NRAs use historical data alone (14); the second largest group uses historical data together with a survey and/or a DGM-Survey approach (9 NRAs); a third group estimates ERP only through a survey approach (4 NRAs).

In the following tables we compare the main indicators on the “geographical scope” (notional vs country specific) and the kind of information used in terms of weight given to the past or the future. Note that not all NRAs have provided specific information on each methodological category.

Figure 11– ERP Methodology in use

	Historical data	HD + Other Methods (DGM+Survey)	Survey	Total
Notional value	5	3	2	10
country specific	4	2	1	7
other	2	3	1	6
Total	11	8	4	23

	Historical data	HD + Other Methods (DGM+Survey)	Survey	Total
Notional value	BE, FR, HR, RO, LU	MT,NL,DK	RS	8
country specific	AT, IT, LI, SK	UK,ES	FI, PT	8
other	DE, NO	SI, CY, HU	CZ	6
Total	11	8	4	23

	Historical data	HD + Other Methods (DGM+Survey)	Survey
Notional value	5.13%	4.97%	6.49%
country specific	5.10%	5.35%	6.86%
other	4.87%	6.68%	5.00%

Source: BEREC 2017

From this analysis relatively weak correlations may be observed.
NRAs that use only historical data generally take into account long-time series.[29]
Where a mixed approach is declared (other) the estimation process generally takes into account many sources, also from different European countries.

[29] More than 100 years taking as source of notice DMS time series, Damoradan, Duff & Phelps, Pictet, as well as national bank source. In some cases more than a source of notice is used.

Summing up, the main motivations behind NRAs methodological choices in defining ERP, are the following: i) Regulatory predictability; ii) Consistency with RFR estimation and overall Total Market Return (TMR); iii) Reflect country specific conditions; iv) Consistency with market index used to estimate beta; v) Availability of evidence; vi) Other regulatory decisions.

Predictability and transparency objectives are the main motivations behind a stronger emphasis on historical data. According to some NRAs, a notional approach is in fact generally preferred in case of unreliable/missing country-specific data. When a notional approach is used in conjunction with historical data and other methodologies (DGM/Survey) this is in general motivated by the desire to combine predictability with a forward-looking perspective inside the ERP estimation. The use of a pure forward-looking approach on ERP estimation is generally motivated by trying to include more country specificity in terms of macroeconomic conditions.

To obtain a deeper insight- into the motivations for choosing the parameters that contribute to the cost of equity, the approaches behind ERP and RFR are provided in Figure 12.

Figure 12 – ERP-RFR main methodologies in use

		ERP				
		Notional value	country specific	other	benchmar king	Tot al
RFR	domestic bond	6	5	4	1	16
	country specific bond	0	1	2	0	3
	other	5	1	1	0	7
	Total	11	7	7	1	26

		ERP				
		Notional value	country specific	other	benchmar king	Total
RFR	domestic bond	Dk, FR, LT, LU, MT,PT	ES, FI, IT, SK, UK	CZ,HE,H U,NO	BG	16
	country specific bond		LI	CY, EL	0	3
	other	BE,HR,NL, RO,RS	AT	SI	0	7
	Total	11	7	7	1	26

Total market return (TMR=RFR+ERP)		ERP			
		Notional value	country specific	other	bench markin g
RFR	domestic bond	7.84%	7.94%	8.44%	8.39%
	country specific bond		6.54%	12.75%	
	other	10.59%	8.74%	10.96%	

Source: BEREC 2017

Figure 12 shows that some NRAs that use their own country specific ERP also estimate RFR with domestic bonds, providing the same geographical scope for the Equity component (RFR and ERP). In case of a financial crisis some countries considered to include the country risk premium on ERP (CY and EL). Others consider notional ERP in conjugation with domestic bond estimation.

Another relevant point is the relation between the "time windows" considered for estimating the RFR and the "data source" (historical vs forward-looking approach) for ERP estimation. This is relevant in order to understand if there is a clear picture about the preference of NRAs for a forward-looking approach on RFR estimation (shorter time windows) rather than on ERP.

Figure 13 – ERP-RFR time windows methodology in use

		ERP			
		Historical data	HD + Other Methods (DGM+Survey)	Survey	Total
RFR	<=1 year	3	3	2	8
	<=3 years	4	2	1	7
	>=5 years	5	4	1	10
	Total	12	9	4	25

		ERP		
		Historical data	HD + Other Methods (DGM+Survey)	Survey
RFR	<=1 year	CH, PL, SK	ES, HU, SI	FI, RS
	<=3 years	AT, BE, HR, RO	MT,NL	PT
	>=5 years	DE, FR, IT, LI, LU	SE, CY, DK	CZ

Total market return		ERP		
		Historical data	HD + Other Methods (DGM+Survey)	Survey
RFR	<=1 year	8.60%	9.01%	12.08%
	<=3 years	9.63%	8.17%	9.78%
	>=5 years	7.25%	7.99%	8.93%

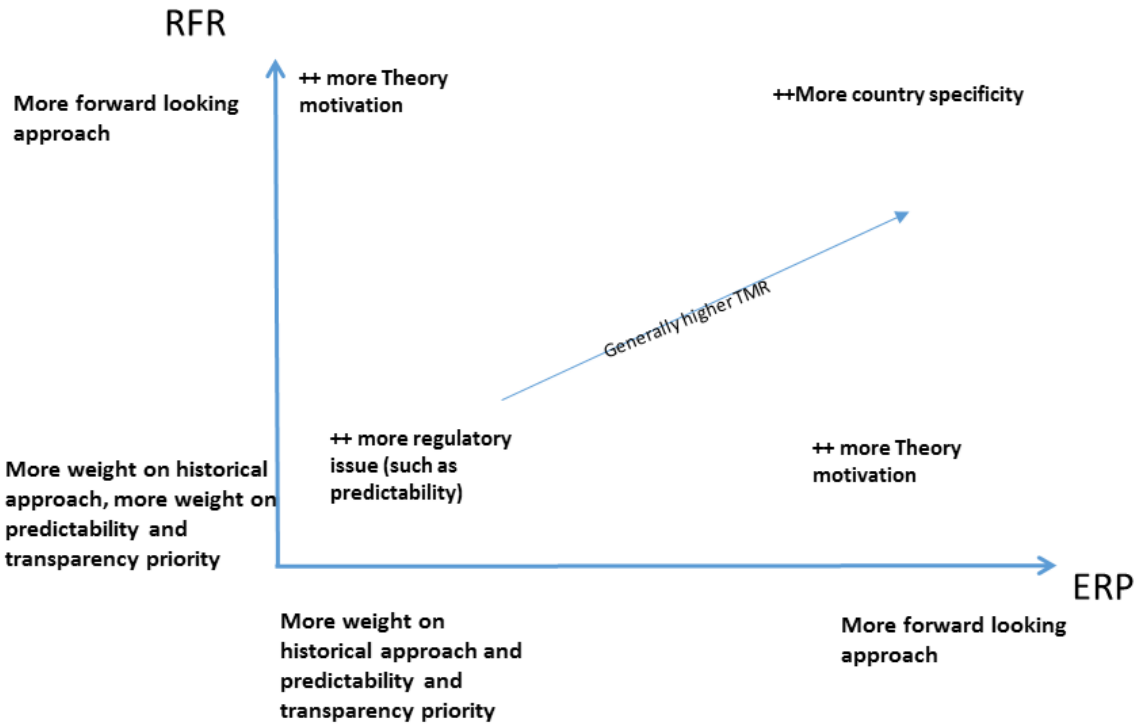
Source: BEREC 2017

From Figure 13 we can derive that there is no a clear common approach. The most frequent approach, which represents just one-fifth of the sample, is to have both the RFR with a long time windows and the ERP based on historical time series. NRAs that have chosen this approach show a clear priority on predictability and consistency with their past WACC decisions. Deviations on the ERP are mainly due to the choice of adding more sources of evidence ("sanity check") in order to estimate the WACC.

In Figure 14 a pattern of motivation and methodology is shown. In the picture on x-axis and y-axis, the ERP and RFR time windows are respectively reported: in extreme cases, such as 1 year for RFR and historical data on ERP or long time windows on RFR and forward looking approach on ERP the main motivation is explained by the willingness to be as consistent as possible with a theoretical approach (i.e. ++ Theory). In case more historical data are used both for ERP and RFR, motivations are mainly related to regulatory issues such as predictability.

Cases “in between” are motivated mainly by a mix of a theoretical consistent approach/country specificity and consistency with past decision.

Figure 14 – ERP-RFR (time windows/motivations relation)



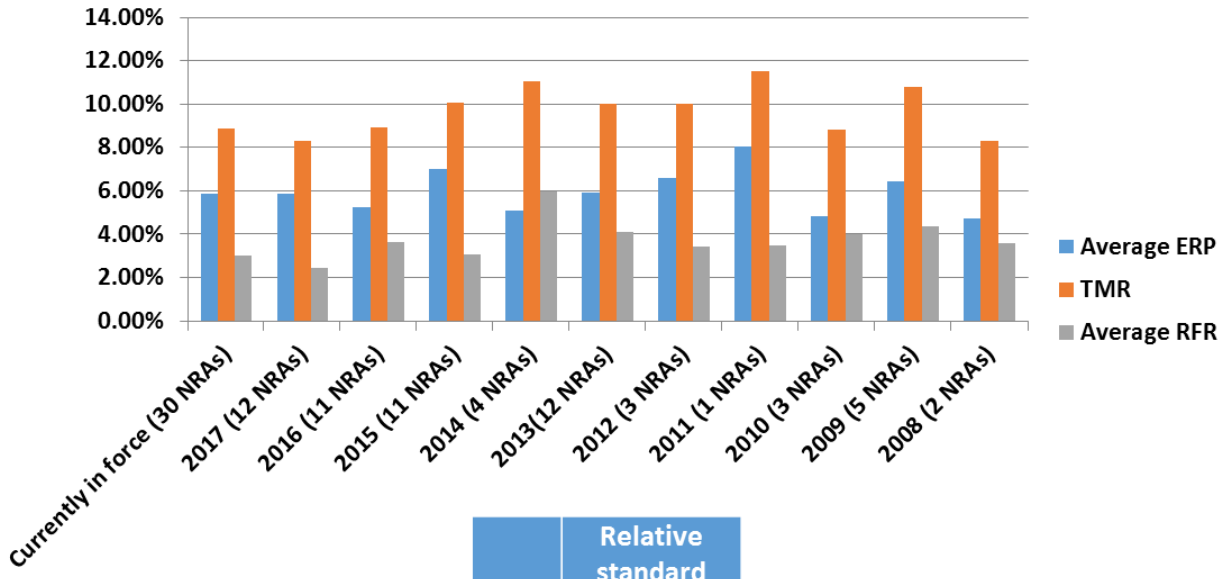
Source: BEREC 2017

As a further element of priority for methodological consistency with past decisions, only two NRAs declared to have changed their main methodology for the ERP estimation during the years (BG, FI).[30]

Figure 15 considers the average evolution over time of ERP-RFR and TMR (ERP+RFR). TMR has a lower relative standard deviation over time (more stable values) with respect to the two distinct components ERP and RFR. The outlined evidence could be interpreted as a sort of compensation between the RFR and ERP providing a more stable result for the total cost of equity.

[30] In the first case the motivation was due to the relatively recent launch of data on the Bulgarian Stock Exchange, and due to this a benchmarking approach was used (previously the approach was notional based on historical and DGM methodology). In the second case the methodology moved from historical data to Survey approach, it is needed to say that when historical data had been declared it takes into account only short range time series (10 years length).

Figure 15 – ERP-RFR-TMR over time



	Relative standard deviation during years
RFR	24.65%
TMR	11.57%
ERP	17.72%

Source: BEREC 2017

Another element analysed in the questionnaire is the type of averaging method used when historical data is applied.

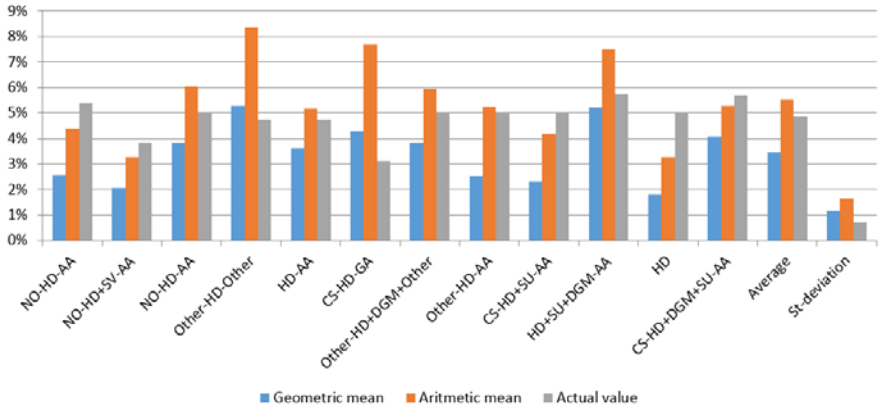
Most NRAs use an arithmetic average (11 NRAs), while a second group of NRAs use a mix of arithmetic and geometric average (5). Only two NRAs use a pure geometrical average.

A basic exercise of sensitivity analysis shows that the choice of the "average" significantly affects the ERP value. The figure below shows the comparison of ERP actual values and the ones obtained "if" other kind of average would have been applied (data from the DMS database 1900-2005 publicly available[31] were used applied to some European countries).[32]

The data in the figure 16 cannot be directly compared. When geometric and arithmetic average is presented, data refer to the DMS database updated until 2005, whereas the actual value is the one provided by the NRAs for the RA EWG survey 2017. The figure compares the actual values of ERP with ERP values depending on main methodologies used, and with respect to relevant public reference data.

[31] THE WORLDWIDE EQUITY PREMIUM: A SMALLER PUZZLE, Dimson, Marsh, Stauton (2007)
[32] HD refers to use of "Historical data"; NO refers to notional approach; AA refers to Arithmetic Average; GA refers to geometric average; CS refers to Country Specific.

Figure 16 – ERP value from sub set of countries



Source: BEREC 2016 and Dimson, Marsh, Stauton 2007

We observe that ERP values vary substantially according to the choice of the kind of average type when historical data is considered.

5.2.3 Beta

Definition and general financial theory

The equity Beta is a measure of the level of investment risk in a specific stock market with respect to a perfectly diversified market portfolio. It quantifies the systematic and not the diversifiable risk. The higher the value of the beta, the higher the uncertainty about the returns on a firm's equity.

The main elements to estimate the equity beta are: i) the methodology (Bottom-up/notional vs SMP operator); ii) time horizon and sampling period; iii) market index; iv) adjustment of the beta; and v) the unlevering formula.

A notional asset beta can be evaluated as an average among a number of European operators that comprise a peer group.

Regarding criteria in choosing the peer group of companies generally are: i) the liquidity of the traded stock should be high (volume and frequency)[33]; ii) the volumes of the company stocks should not exceed an amount of volume stocks of the compared index in which they are quoted (less than 10%); iii) investment credit rating (from AAA to BBB-); iv) they should not be involved in M&A processes; v) they should be active in network investments and not only as a reseller.

Sampling frequencies are usually daily, weekly or monthly and time horizons between 1 and 10 years. There is often a trade-off between having enough data points to be sufficiently robust and ensuring the beta is a reasonable estimate on a forward looking basis. (i.e. with about 500 data points, in case of 2 years time windows and daily estimation, can ensure an accepted trade-off between a forward looking perspective (short time frame) and statistical significance of the beta estimation).

[33] One suggested criteria is to look the frequency of the traded stock with respect to the available day of index in which the stock is traded that should be greater than 90%. The average daily values of shares traded, and the average volume of shares traded as a percentage of shares issued, exceed certain thresholds.

In general, using daily sampling data is a better solution (when all other parameters are kept unchanged, i. e. time windows, level of confidence) to reduce the standard error and thus reach a higher confidence interval of the beta estimation. At the same time, daily sampling can be affected by the failure of the hypothesis of independency and identical distributed assumptions about each sample included in the regression analysis (heteroscedasticity). In that case, due to a correlation between consecutive samples in time, both estimations of standard error and beta can be biased. In this case general literature addresses the problem recommending to estimate the standard error through the Newey-West procedure[34] and adjust the beta by using the so called "Dimson" methodology by which the beta estimation is done following a multiple regression of the stock return of the firm with, at least, the current, lagged and forward value of the return on the market:

$$R_{it} = \alpha + \beta_1 R_{mt} + \beta_2 R_{mt-1} + \beta_3 R_{mt+1} + e_{it}$$

Where Rmt-1 is the return on day t-1 and Rmt+1 is the return on day t+1, and the CAPM beta is then β1+ β2+ β3.

The idea behind this method is that: i) for stocks that are extensively traded it is conceivably to take a while for the general market to catch up with news which is reflected in the stock's price almost instantly (including Rmt+1); ii) for stocks that are thinly traded it is conceivable to take a while for the price of the individual stock to adjust to the market (including Rmt-1).

Other adjustments, which aim to improve the accuracy of the final estimation of the equity beta, and that are commonly used are "Blume", "Bayesian" and "Vasicek". The first two methods provide an adjustment with the presumption that the beta estimated through the CAPM model should be adjusted in a way that the final value will approach one. The Bayesian adjustment can be expressed as followings:

$$\beta_{adj} = \beta_{OLS} \times \frac{Var(\beta_{pop})}{Var(\beta_{pop}) + SE^2(\beta_{OLS})} + 1 \times \frac{SE^2(\beta_{OLS})}{Var(\beta_{pop}) + SE^2(\beta_{OLS})}$$

With SE^2(βOLS) being the squared standard error of the OLS estimate of beta and Var(βpop) being the variance of beta across the sample of firms for whom average beta is equal to one. The logic behind the adjustment is as follows: much greater is the magnitude of the standard error than greater will be the weight for an estimation of beta equal to one.

The Blume and Vasiecek adjustments are special cases of the Bayesian adjustment. The Blume adjustment is evaluated through the following formula βadj =0.67 βOLS+0.33. In this case the adjustment is independent of how much of the estimation done through the OLS is unreliable.

The Vasicek adjustment is similar to the Bayesian adjustment with the difference that the beta of the peer group is not supposed to be equal to "one" but to a different value.

The equity beta will depend on the financial leverage or 'gearing' of the firm. In case the beta is estimated from a peer group of companies it is common to unlever the equity beta of each firm by determining the asset beta from which the average asset beta is evaluated. Based on the average asset beta it is relevered through an average gearing value obtained from the gearing of the selected peer group, thus obtaining an equity beta for determining the cost of equity in the WACC

[34] Newey e West "A Simple Positive Semi-definite Heteroskedasticity and Autocorrelation Consistent Covariance Estimator" (1987)

formula. Through this procedure the obtained beta highlights only differences in underlying business risk rather than financial leverage conditions.

There are many variations of the unlevering formula the most well-known and used is the Miller formula,[35] including or excluding a certain level of beta debt.

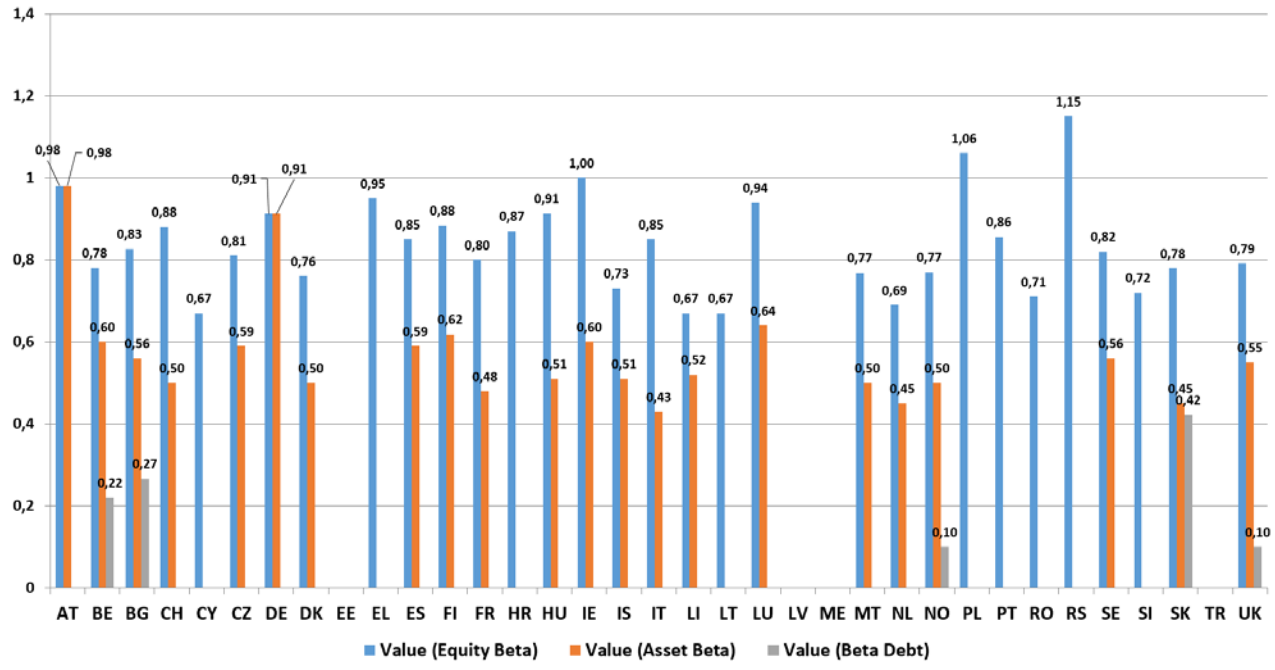
$$\beta_{asset} = \beta_{equity}/(1-g) + \beta_{debt}\, g$$

where *g* is the gearing ratio of the company equal to Debt/(Equity+Debt).

Main results of the survey.
From the replies of to the 2017 questionnaire the following statistics emerge.[36]

	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
Equity beta (31 Nras)	0.83	0.82	0.12	0.14	1.15	0.67
Asset beta (22 NRAs)	0.57	0.54	0.13	0.24	0.98	0.43
Beta debt (5 NRAs)	0.22	0.22	0.13	0.60	0.42	0.10

Figure 17 – Beta values currently in force



Source: BEREC 2017

The following table summarises the different approaches used by NRAs to estimate Beta.

[35] Refered also as Modigliani-Miller formula when taxation is included.
[36] Asset betas/Equity betas are calculated with reference to different market indices, thus comparison should be considered in the light of this fact.

Table 4 – Beta Methodology

	Methodology		-if notional/others (if applicable) please indicate the average used (average to get the asset/equity beta from the comparable)		Sampling period		Time window		Adjustment Used		Market reference index used		Do you unlever your beta?		- if yes which formula do you apply?		-if benchmarking is indicated in the methodology section please indicate the average used from other countries	
Beta (equity)	notional (generic operator)	16	Arithmetic average	3	daily	9	1 week	0	Dimson	0	Own Country	2	yes	21	Modigliani-Miller	15	Arithmetic average	1
	SMP Operator	6	Geometric Average	0	weekly	7	1 month	0	Bayesian	4	European	13	no	4	Miles & Ezzell	0	Geometric Average	0
	Other	6	Moving Average	0	montly	3	3 month	0	Blume	4	World	6			Hamada	2	Moving Average	0
	benchmarking	3	Median	2	other	2	6 months	0	Vasicek	2					Other	4	Median	1
			Other	7			12 months	1	others	2							Other	0
							2 years	6	No Adjustment	9								
							3 years	5										
							5 years	7										
							10 years	0										
							others	5										

Source: BEREC 2017

The most frequent methodology used by NRAs is to estimate a notional beta based on an analysis of telecom comparators (16 NRAs). When "Other" is declared (6 NRAs) it generally refers to a hybrid approach that takes into account different sources of estimation; it can be closer to a notional approach or to an estimation of an SMP Beta[37].

[37] For example, different market indexes are considered (BE); in one case a TMI telecom stoxx index is regressed as dependent variable with respect to general TMI stoxx index (DE), or the comparison between the SMP and own countries operators are benchmarked with other group of comparable (UK, NO); in one case long term beta is set with regard to a sample of 5-10 European operators (FR).

Figure 18 – Beta Methodology for fixed access market (mainly market 3a)

Methodology	Equity beta (average)	Asset beta (average)	NRAs
notional (generic operator)	0.86	0.59	AT,CH,CY,CZ,ES,FI,HR,HU,IS,IT,LU,PL,PT,RO,RS,SI
SMP Operator	0.78	0.49	BG,DK,EL,LT,NL,SK
Other	0.81	0.60	BE,DE,FR,NO,SE,UK
benchmarking	0.84	0.56	IE,LT,MT

Source: BEREC 2017

When a notional approach is declared the number of comparable operators varies between 10 and 34, mainly European. Some NRAs choose the peer group in line with the main business: fixed, mobile or broadcasting.

The way the average beta is estimated from the peer group can differ accordingly to a different kind of average.

Figure 19 – Beta methodology

	Number of comparable	Average
CH	12 Telco companies in UE	Arithmetic average
CZ	34 Telecom companies, world spread	Median
ES	16 comparable operators, with similar business mix and listed in the stock exchange	Arithmetic average
FI	15 telecom companies	Median
HR	20 Eropean telecom companies.	
HU	20, European operators listed on the stock exchanges	
IT	10 comparable (European SMP operators)	Arithmetic average
RO	17 countries peer group of operators based in Europe with shares traded on stock exchanges	Other
RS	10 comparable companies . All of them are in the telecommunication industry and offer similar products/services.	
SI	28 European telecommunication companies	

Source: BEREC 2017

Concerning the sampling period, daily and weekly sampling are the most frequent approaches used. In general, the choice of the sampling period doesn't seem to be correlated with the time window approach used as reported in Figure 20. On the other hand the choice of a weekly data sampling period seems to be related to overcoming the heteroscedasticity of the time series at the

expense of a greater confidence interval of the beta estimation. This is in line with the missing application of the “Dimson” adjustment.

Figure 20 – Beta Methodology

		Time windows			
		<=2Years	<=3 Years	>=5 Year	others
Sampling period	daily	3	3	1	2
	weekly	3	1	3	0
	montly	0	0	3	0
	other	0	1	0	1

Country	Methodology	Sampling period	Time windows
CH	notional (generic operator)	weekly	2 years
CY	notional (generic operator)	daily	others
CZ	notional (generic operator)	weekly	2 years
ES	notional (generic operator)	weekly	5 years
FI	notional (generic operator)	weekly	3 years
HR	notional (generic operator)	other	3 years
HU	notional (generic operator)	weekly	5 years
IT	notional (generic operator)	daily	2 years
LU	notional (generic operator)	daily	3 years
PT	notional (generic operator)	montly	5 years
RO	notional (generic operator)	daily, weekly	12 months, 3 years
SI	notional (generic operator)	weekly	2 years
BE	Other	daily	3 years
DE	Other	daily	5 years
FR	Other	other	others
SE	Other	weekly	5 years
UK	Other	daily	2 years
DK	SMP Operator	daily	others
LT	SMP Operator	montly	5 years
NL	SMP Operator	daily	3 years
SK	SMP Operator	montly	5 years

Source: BEREC 2017

Concerning the time windows chosen for the estimation of the beta the approach is more variable between NRAs with three main clusters of two, three and five years.

The motivation behind these choices is related to the importance given to a theoretical approach with respect to the opportunity to provide a reliable estimation of the beta, or to be consistent with the approach used to estimate other parameters such as the RFR, or the availability of data from referenced sources such as Bloomberg.

The RFR time windows and the time windows for the beta estimation are chosen accordingly in 11 cases out on 21 (where information is available for all indicators), (Figure 21).

Figure 21 – Beta-RFR (time windows)

		Beta time windows			
		<=2 years	<=3 years	>=5 years	Total
RFR	<=1 year	3	1	4	8
	<=3 years		3	1	4
	>=5 years	3	1	5	9
	Total	6	5	10	21

		Beta time windows			
		<=2 years	<=3 years	>=5 years	Total
RFR	<=1 year	SI, CH, PL	FI	SK,ES,HU,LT	8
	<=3 years		BE,HR,NL	PT	4
	>=5 years	IT,CZ,UK	LU	DE,DK,FR,CY,SE	9
	Total	6	5	10	21

Source: BEREC 2017

If the choice of time window for beta differs from the one of the RFR and when the option chosen is >=5 years, it is mainly motivated by predictability, reliability and transparency objectives; it can also be motivated by main theoretical aspects or by an effort to provide enough data to reduce the standard error in the estimation.

Concerning the adjustment used for estimating the equity beta of SMP or comparable companies, the most part of NRAs use a Bayesian/Blume adjustment. Some NRAs apply the Blume adjustment explaining their choice by a motivation to report evidence from an academic study,[38] or remarking that in case of "off the shelf" data provided by Bloomberg, the Blume adjustment is applied, or that the Blume adjustment reflects future risks. Other NRAs (9 NRAs), do not make any adjustment considering that there is no reason for applying it. Generally, the application of an adjustment is done when a shorter time windows for beta estimation is in use; this is consistent with the idea that with less data the estimation of the equity beta can be less reliable.

[38] Pablo Férnandez, Beta used by professors: A survey with 2500 answers, IESE CIIF, Business School, University of Navarra, Working Paper, WP-822, September, 2009.

Figure 22 – Time windows-Adjustment for Equity beta

		Time windows			
		<=2 years	<=3 years	>=5 years	Total
Kind of adjustment	No Adjustment	1	0	8	9
	Blume	2	1	1	4
	others	1	1	0	2
	Vasicek	0	2	0	2
	Bayesian/Blume	0	0	0	0
	Total	4	4	9	17

Source: BEREC 2017

Most NRAs apply an unlevered beta before estimating the final equity beta (21 NRAs).

Concerning the unlevering formula the most widely used is the Modigliani-Miller formula (Miller being the same formula without tax[39]) such as the one reported as:

$$\beta_{asset} = \beta_{equity} * (1 - g)$$

$$\beta_{asset} = \beta_{debt} * g + \beta_{equity} * (1 - g)$$

$$\beta_{asset} = \beta_{equity} / (1 + (1 - t) * (\frac{D}{E}))$$

Only few NRAs apply a beta debt in the levering procedure and un-levering formula. Generally, this is done when an "SMP" beta is estimated, rather than a notional one.

Concerning the market index, most NRAs (13 NRAs) use a European index (STOXX Europe TMI Telecommunications; STOXX Europe TMI, MSCI Europe Index). Sometimes the equity beta for each comparable is estimated on a specific country index (e.g. every comparable beta is estimated on its own country market index). In case of a World index the MSCI is used by several NRAs (6 NRAs). A country specific index is typically used when the beta is evaluated by reference to the SMP operator (2 NRAs).

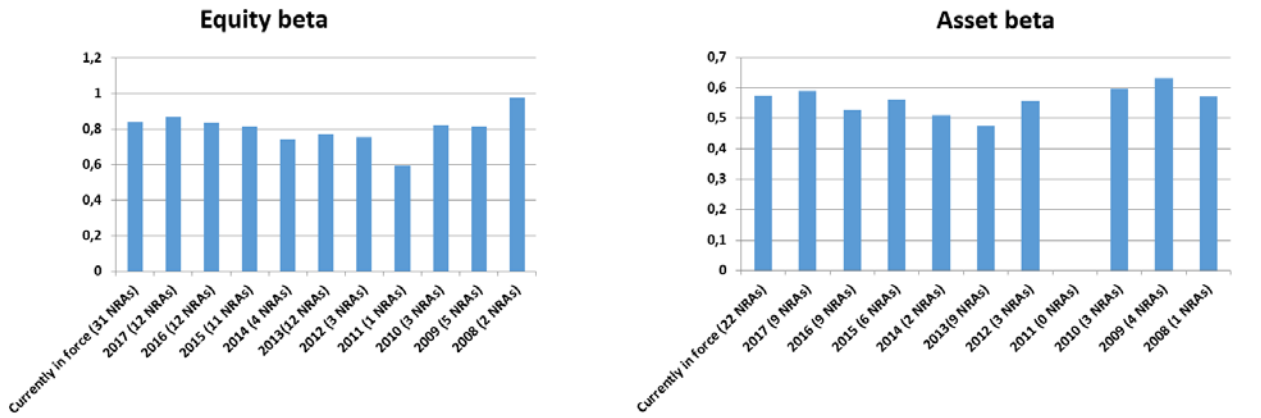
The approach is generally motivated by the fact that an index provides a reliable data source and is consistent with earlier decisions.

Sensitivity analysis on the time windows, adjustment and market index shows a relevant variability of the estimation; different results can be obtained using different market indexes, time windows and adjustments (see annex 1). A notional approach, in any case, can reduce a certain level of variability.

Overall, in the period covering 2008-2017 estimated beta values have been relatively stable.

[39] Sometimes the same formula is referred to as "Hamada formula" or "Fernadez practioners".

Figure 23 – Evolution over time of the Equity beta and Asset beta estimation



Source: BEREC 2017

5.2.4 The cost of debt

Definition and general financial theory

The cost of debt is generally evaluated by adding a debt premium to the RFR or directly from company bond yields.

Cost of debt= RFR+ Debt Premium

The main factors that should be taken into account for the estimation of the debt premium/ cost of debt are; i) the "geographical scope" of the estimation (notional or SMP target); ii) the source data (book value/market value); iii) time windows and the maturity of bonds used.

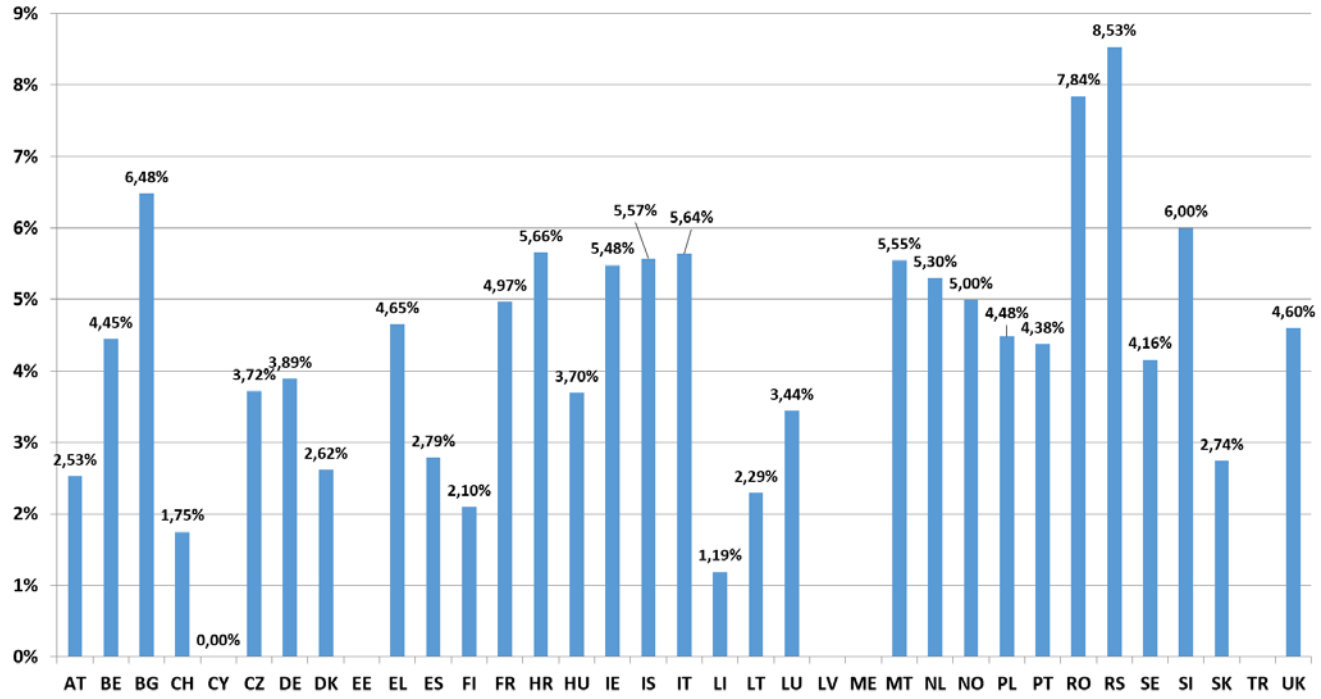
Generally a higher gearing percentage for a company implies an increase of the interest rate paid on debts in form of wider spread. On the other hand, the level of the debt premium is also related to the main market in which the firm operates and so linked to the credit rating of the company.

Main output from the survey.

From the replies to the questionnaire 2017 the following statistics come out:

2017	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
Cost of debt (31 NRAs)	**4.22%**	**4.45%**	**1.85%**	**43.92%**	**8.53%**	**0.00%**

Figure 24 – Cost of debt



Source: BEREC 2017

The following tables summarises the different approaches used by NRAs to estimate the cost of debt component.

Table 5 – Cost of debt methodology

	Methodology		Cost of debt/debt-premium		Market/book value		-if "Market value"/"Other" (if applicable) Source data		-if "Market value"/"Other" (if applicable) bond window		-if "Market value"/"Other" (if applicable) Average window		-if "Market value"/"Other" (if applicable) Average methodology (with respect to the hystorical series included in the Average window)		-if benchmarking is indicated in the methodology section please indicate the average used from other countries	
Cost of debt (RFR+ Debt premium)	notional (generic operator)	13	Debt premium	19	Book value	2	Secondary traded market	4	1 year	1	Spot rate	4	Arithmetic average	11	Arithmetic average	1
	SMP Operator	7	Cost of Debt	11	Market Value (Company bond)	19	Nominal bond yield	10	3 years	0	3 months	0	Geometric Average	1	Geometric Average	0
	Other	10			Other	6	Other	3	5 years	0	6 months	1	Moving Average	0	Moving Average	0
	benchmarking	1							10 years	8	1 Year	4	Median	1	Median	0
									20 years	0	2 Years	1	Other	1	Other	0
									Hybrid	3	3 Years	1				
									Other	5	5 Years	1				
											10 Years	2				
											Others	2				

Source: BEREC 2017

Coming to the methodologies the most frequent approach used by NRAs is a notional approach (13 NRAs), the second category chosen by 10 NRAs is “Other” which means a mix of approaches

(SMP+ notional). This is followed by an estimation of the SMP cost of debt (7 NRAs). Most NRAs estimate a debt premium instead of estimating the cost of debt directly and this is done most frequently when a notional approach is used (Figure 25). Instead, when the cost of debt refers to the SMP operator, a direct cost of debt is generally estimated. Within a notional approach NRAs generally use peer groups according to credit rating (at least BBB-).[40]

Figure 25 – Methodology of cost of debt

Methodology	Values	NRAs	
Debt premium	4.47%	19	AT,BE,DE,DK,FI,FR,HR,HU,IE,IS,LI,LU,MT,NO,PT,RO,RS,SE,UK
Cost of Debt	4.17%	11	BG,CH,CZ,EL,ES,IT,LT,NL,PL,SI,SK

	Value	NRAs	
notional (generic operator)	4.56%	13	CH,FI,FR,HR,HU,IS,LI,LU,PT,RO,RS,SI,SE
SMP Operator	4.51%	7	AT,BG,EL,IE,IT,LT,NL
Other	3.72%	10	BE,CY,CZ,DE,ES,MT,NO,PL SK,UK
Benchmarking	2.62%	1	DK

	Debt premium	Cost of Debt
notional (generic operator)	11	2
SMP Operator	2	5
Other	5	4
benchmarking	1	0

Source: BEREC 2017

With reference to the data source used, most NRAs use a market value of peer group companies' nominal bond yield. A book value approach is used generally chosen in case a SMP cost of debt is used.

Concerning the bond windows, the most common approach is to use 10 year bonds in line with the bond windows used to estimate RFR (figure 26).

[40] One NRA declared that the level of debt of the SMP operator is negligible and for this reason it is considered equal to 0.

Figure 26 – Bond windows on cost of debt- RFR bond windows

		Cost of debt						
		1 year	3 years	5 years	10 years	20 years	Hybrid	Other
RFR	1 year	0	0	0	0	0	0	0
	3 years	0	0	0	0	0	0	0
	5 years	0	0	0	0	0	0	0
	10 years	1	0	0	8	0	1	4
	20 years	0	0	0	0	0	0	0
	Other	0	0	0	0	0	2	1

Source: BEREC 2017

With respect to the choice of the time windows, most NRAs choose them in accordance with their choice for the RFR (figure 27).[41]

Figure 27 – RFR- Cost of Debt time windows

		Cost of Debt			
RFR		<=1 year	<=3 years	>=5 years	Total
	<=1 year	6	0	0	6
	<=3 years	2	1	2	5
	>=5 years	1	1	3	3
	Total	9	3	5	16

		Cost of Debt			
RFR		<=1 year	<=3 years	>=5 years	Total
	<=1 year	BG,SK,RS,ES,PL ,HU	0	0	5
	<=3 years	MT,RO	PT	BE,HR	5
	>=5 years	IT	LU	SE,FR,UK	3
	Total	9	2	5	16

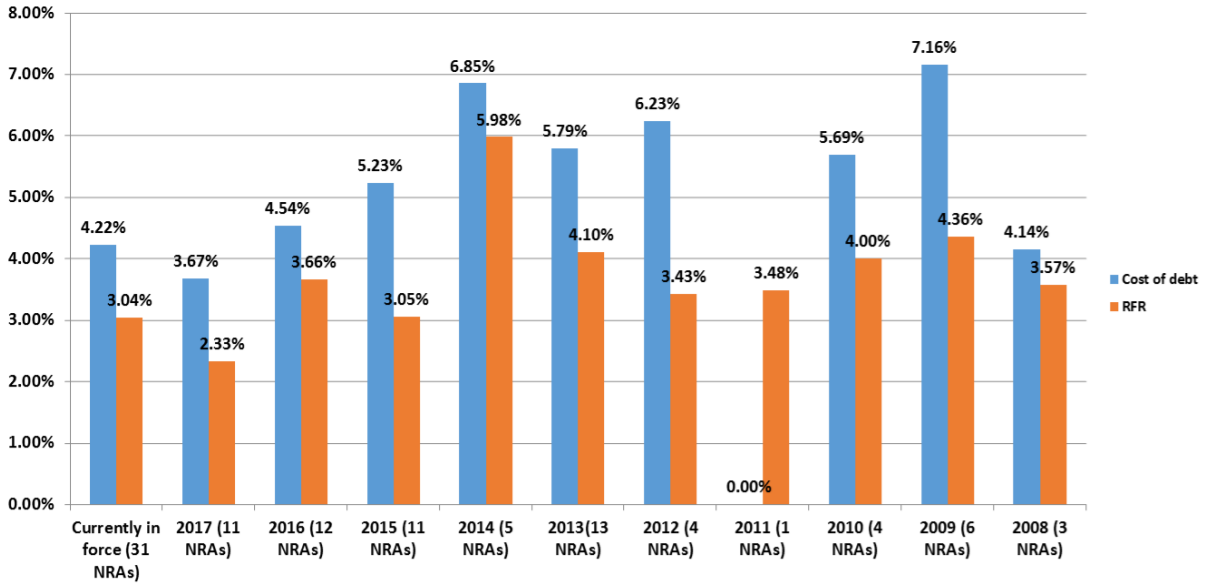
Source: BEREC 2017

Where differences emerge they have been motivated by the general availability of data, simplicity, characteristic of the SMP operator, country specifics as well consistency with time windows used for beta estimation.

[41] The information reported are based on which NRAs place most weight.

Figure 28 shows the evolution over time of the cost of debt and the RFR.

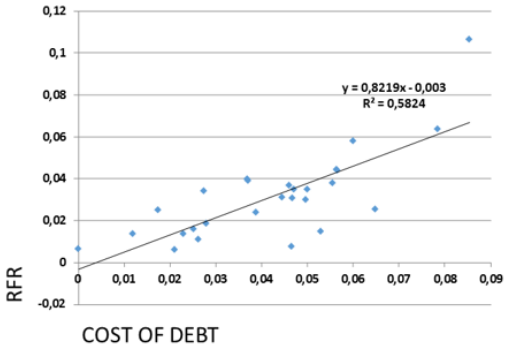
Figure 28 – RFR- Cost of Debt over time



Source: BEREC 2017

In figure 29 we observe a relevant correlation between the RFR and cost of debt.

Figure 29 – RFR- Cost of Debt RFR-Debt premium



Source: BEREC 2017

5.2.5 Gearing Ratio

Definition and general financial theory

The gearing ratio in the WACC calculation refers to the proportion of the debt with respect to the entire financing of the company. Specifically, it is defined as the ratio between the debt and the value of the company (Equity + Debt).

$$g = \frac{D}{E + D}$$

It is relevant because it appears directly in the WACC formula, but it is also required to derive the asset beta previously described.

It is important to emphasise that the gearing ratio included in the equation to evaluate an unlevered beta (described in the previous paragraph within the levering/unlevering formula) is specific for each comparable company used for estimating the asset beta. In that case, we refer to the final gearing used in the WACC formula that should overlap with the gearing used to relever the asset beta.
The elements that should be considered are: i) the main methodology used consistently with the beta estimation (notional vs SMP operator); ii) the source of data to evaluate each component of Debt and Equity (book value vs market value).

NRAs generally estimate the gearing consistently with the estimation of the asset beta when it is relevered. In that case the gearing can be the one of the SMP operator when the beta is SMP targeted, otherwise notional when beta is notional.

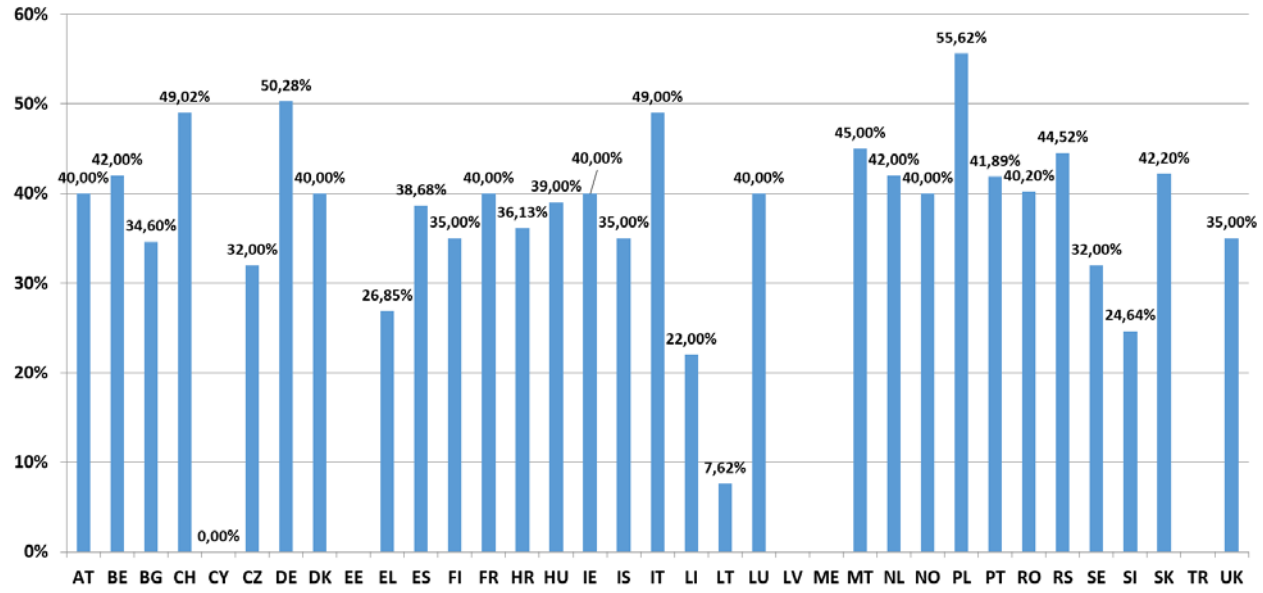
With reference to the source of data, for the equity component the market value is obtained from the number of shares in the market multiplied by their price.

An estimation of the debt component at market value is difficult as not all debts are traded and general underestimation of debt through this approach can occur; when book value is used generally it should include all long term financial and capital leases. In every case the credit rating of the company should be at investment level (e.g. >= BBB+) to be taken into account in the general methodology.

Main results of the survey.
From the replies to the questionnaire 2017 the following statistics emerge:

	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
Gearing (30 NRAs)	**36.78%**	**40.00%**	**11.38%**	**30.93%**	**55.62%**	**0.00%**

Figure 30 – Gearing values



Source: BEREC 2017

The following tables summarise the different approaches used by NRAs to estimate the gearing component.

Table 6 – Gearing methodology survey from RA 2016

	Methodology		Debt component (if applicable)		Equity component (if applicable)		-If notional value "Average methodology"		Other remarks (i.e explain how you evaluate the debt, explaining how you treat the cash)	-If benchmarking is indicated in the methodology section please indicate the average used from other countries	
Gearing	notional (generic operator)	16	Book value	9	Book value	3	Arithmetic average	5		Arithmetic average	0
	SMP Operator	6	Market Value	6	Market Value	10	Geometric Average	0		Geometric Average	0
	Other	5	Other	1	Other	2	Moving Average	0		Moving Average	0
	benchmarking	0					Median	3		Median	0
							Other	4		Other	0

Source: BEREC 2017

Generally NRAs that have indicated “notional”, generally don’t adjust the gearing with national circumstances; instead they take the value of the notional gearing used to unlever the beta. The gearing is generally evaluated taking into account the same time windows used for beta estimation.

According to 2017 data, most NRAs use a notional approach in line with the one used for estimating the Beta. Concerning their data source, most NRAs also use book value for the debt component and a market value for the equity component. When the SMP operator gearing is considered the estimation of the equity component is sometimes done using the book value (figure 31).

Figure 31 – Gearing methodology

NUMBER OF NRAS

	Debt component			Equity component		
	Book value	Market Value	Other	Book value	Market Value	Other
notional (generic operator)	4	4	1	1	5	2
SMP Operator	3	1	0	2	2	0
Other	2	1	0	0	3	0
benchmarking	0	0	0	0	0	0
Total	9	6	1	3	10	2

NRAs

	Debt component			Equity component		
	Book value	Market Value	Other	Book value	Market Value	Other
notional (generic operator)	AT,FR,HR,IE	ES,HU,IT,LU	CH	AT	ES,FR,HR,HU,IT	CH,IE
SMP Operator	DK,LI,NL	BG,	0	DK,LI	BG,NL	0
Other	DE,UK	SK	0	0	DE,SK,UK	0
benchmarking	0	0	0	0	0	0
Total	9	5	1	2	10	2

GEARING AVERAGE VALUES

	Debt component			Equity component		
	Book value	Market Value	Other	Book value	Market Value	Other
notional (generic operator)	39.03%	41.67%	49.02%	40.00%	40.56%	44.51%
SMP Operator	34.67%	34.60%		31.00%	38.30%	
Other	42.64%	42.20%			42.49%	
benchmarking						

Source: BEREC 2017

When the debt component is estimated via the book value, generally long term and short term debt without netting off the cash is considered.[42]

From figures 32 and 33 we can understand that the gearing methodology is influenced mainly by the main methodology in use for the beta estimation, while gearing also influences the debt premium estimation.

Looking in parallel at the methodologies in use by all NRAs for the cost of debt, gearing and beta it becomes apparent that the gearing estimate is important since it determines the weight placed on the cost of equity and cost of debt, it is used to unlever and re-lever the beta and it influences the size of the cost of debt.

[42] Cash is considered useful to operate the business (rather than available to pay off debt)

Figure 32 – Gearing Cost of debt Methodology

		Cost of debt				
		notional (generic operator)	SMP Operator	Other	benchmarking	Total
Gearing	notional (generic operator)	11	3	2	0	16
	SMP Operator	1	3	1	1	6
	Other	0	0	5	0	5
	benchmarking	0	0	0	0	0
	Total	12	6	7	1	27

		Cost of debt				
		notional (generic operator)	SMP Operator	Other	benchmarking	Total
Gearing	notional (generic operator)	CH,FI,FR,HR,HU,LU,PT,RO,RS ,SE,SI	AT,IE,IT	CZ,ES	0	16
	SMP Operator	LI	BG,LT,NL	PL	DK	6
	Other	0	0	BE,DE,MT,SK,UK	0	5
	Benchmarking	0	0	0	0	0
	Total	12	6	7	1	27

Source: BEREC 2017

Figure 33 – Gearing - Beta Methodology

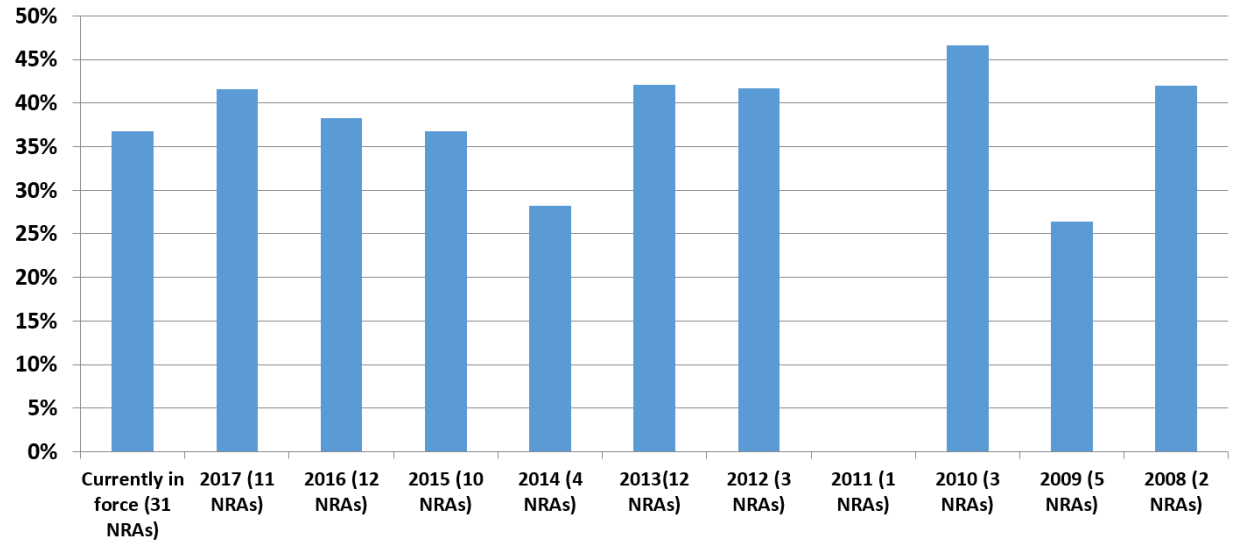
		Beta				
		notional (generic operator)	SMP Operator	Other	benchmarking	
Gearing	notional (generic operator)	13	0	2	1	16
	SMP Operator	1	4	0	1	6
	Other	0	1	3	1	5
	benchmarking	0	0	0	0	0
	Total	14	5	5	3	27

		Beta				
		notional (generic operator)	SMP Operator	Other	benchmarking	
Gearing	notional (generic operator)	AT,CH,CZ,ES,FI,HR,HU,IT, LU,PT, RO, RS, SI	0	FR, SE	IE	16
	SMP Operator	NL	BG,DK,LT,NL	0	LI	6
	Other	0	SK	BE,DE,U K	MT	5
	benchmarking	0	0	0	0	0
	Total	14	5	5	3	27

Source: BEREC 2017

The evolution over time of gearing estimation is reported in figure 34.

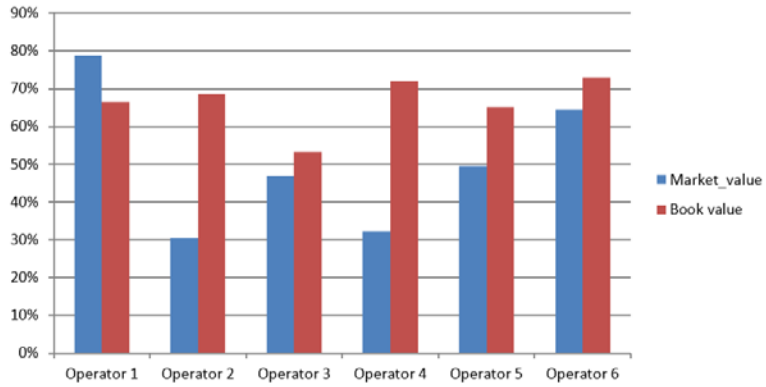
Figure 34 – Gearing over time



Source: BEREC 2017

In the figure below, a spot gearing evaluation is presented for a sub-set of SMP operators, by comparing the gearing evaluated modifying the Equity component estimation in the gearing: i) for market value Equity is evaluated as stock capitalization (number of shares multiplied by the price of the share), and ii) in the other case directly at book values. For the debt component a book estimation is done including: i) Long term debt; ii) short term debt and iii) capital lease.[43] From the figure, an estimation at book value of the gearing can underestimate the final WACC value.

Figure 35 – Sensitivity Analysis (spot) Gearing



Source: BEREC 2017 based on Bloomberg public available data

5.2.6 Tax rate

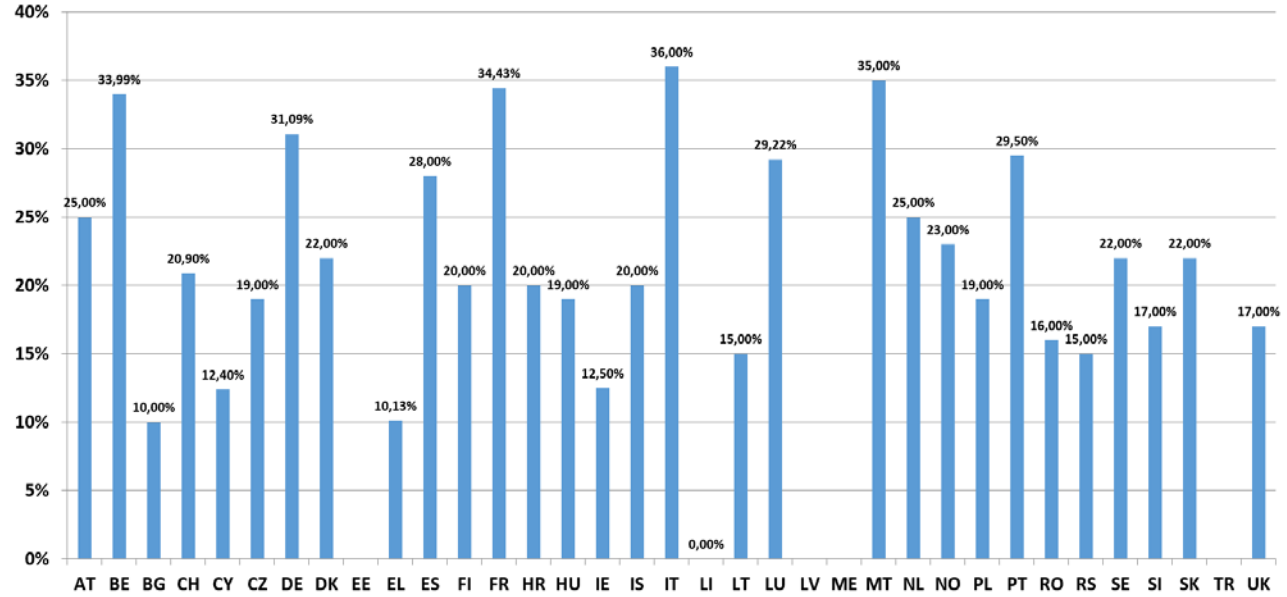
Concerning the corporate tax rate in use the following statistics emerge.

	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
Tax rate	21.26%	20.00%	8.30%	39.05%	36.00%	0.00%

[43] Bloomberg Source

As already reported Tax is also an important parameter to explain WACC variation between NRAs and it represents a typical country specific parameter.

Figure 36 – Tax rate current in use

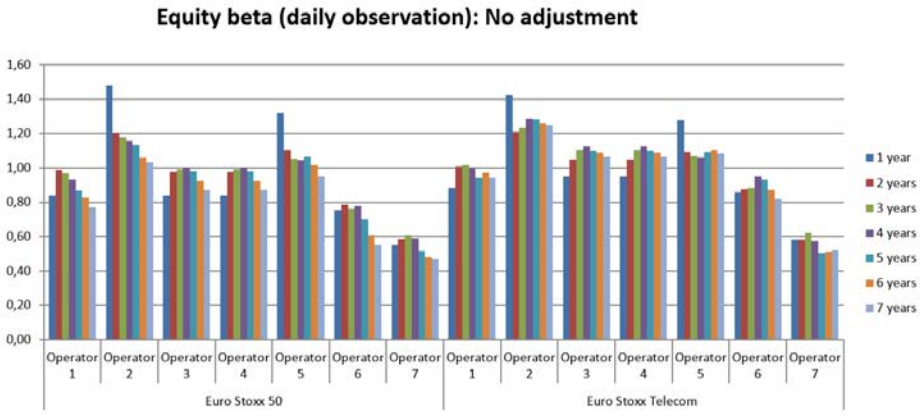


Source: BEREC 2017

5.2.7 Appendix

Annex 1
Beta sensitivity analysis

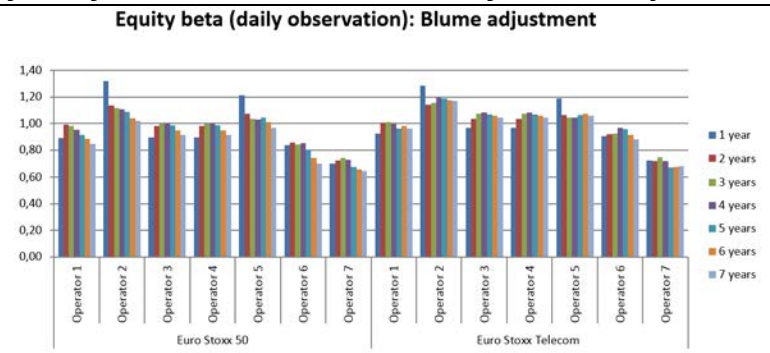
Figure 1 – Sensitivity analysis on Beta estimation: daily, no adjustment



	Euro Stoxx 50							Euro Stoxx Telecom						
	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7
1 year	0,84	1,48	0,84	0,84	1,32	0,76	0,55	0,88	1,42	0,95	0,95	1,28	0,86	0,58
2 years	0,99	1,20	0,97	0,97	1,11	0,79	0,58	1,01	1,21	1,05	1,05	1,09	0,88	0,58
3 years	0,97	1,18	0,99	0,99	1,05	0,76	0,61	1,01	1,23	1,10	1,10	1,07	0,88	0,62
4 years	0,93	1,16	1,00	1,00	1,04	0,78	0,59	1,00	1,29	1,13	1,13	1,06	0,95	0,57
5 years	0,87	1,13	0,98	0,98	1,06	0,70	0,51	0,94	1,28	1,10	1,10	1,09	0,93	0,50
6 years	0,82	1,06	0,92	0,92	1,01	0,61	0,48	0,97	1,26	1,09	1,09	1,11	0,87	0,51
7 years	0,77	1,03	0,87	0,87	0,95	0,55	0,47	0,94	1,25	1,06	1,06	1,09	0,82	0,52

Source: BEREC 2017 on public available data

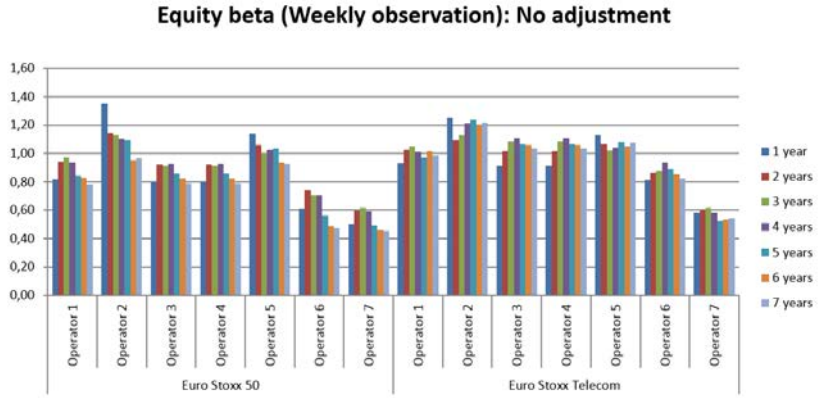
Figure 2 – Sensitivity analysis on Beta estimation: daily, Blume adjustment



	Euro Stoxx 50							Euro Stoxx Telecom						
	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7
1 year	0,89	1,32	0,89	0,89	1,21	0,84	0,70	0,92	1,28	0,97	0,97	1,19	0,91	0,72
2 years	0,99	1,14	0,98	0,98	1,07	0,86	0,72	1,00	1,14	1,03	1,03	1,06	0,92	0,72
3 years	0,98	1,12	0,99	0,99	1,03	0,84	0,74	1,01	1,16	1,07	1,07	1,04	0,92	0,75
4 years	0,95	1,11	1,00	1,00	1,03	0,85	0,72	1,00	1,19	1,08	1,08	1,04	0,97	0,71
5 years	0,91	1,09	0,99	0,99	1,04	0,80	0,67	0,96	1,19	1,07	1,07	1,06	0,95	0,67
6 years	0,88	1,04	0,95	0,95	1,01	0,74	0,65	0,98	1,17	1,06	1,06	1,07	0,91	0,67
7 years	0,84	1,02	0,91	0,91	0,97	0,70	0,64	0,96	1,17	1,04	1,04	1,06	0,88	0,68

Source: BEREC 2017 on public available data

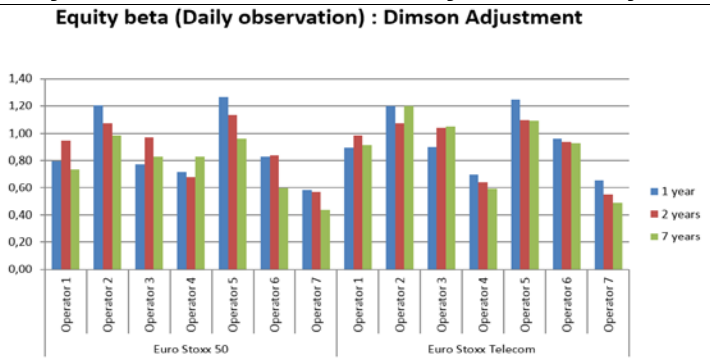
Figure 3 – Sensitivity analysis on Beta estimation: weakly, no adjustment



	Euro Stoxx 50							Euro Stoxx Telecom						
	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7
1 year	0,82	1,35	0,80	0,80	1,14	0,61	0,50	0,93	1,25	0,91	0,91	1,13	0,81	0,58
2 years	0,94	1,15	0,92	0,92	1,06	0,74	0,60	1,03	1,10	1,02	1,02	1,07	0,86	0,60
3 years	0,97	1,13	0,91	0,91	1,00	0,71	0,62	1,05	1,13	1,09	1,09	1,02	0,88	0,62
4 years	0,94	1,10	0,93	0,93	1,02	0,71	0,59	1,01	1,22	1,11	1,11	1,04	0,94	0,58
5 years	0,84	1,09	0,86	0,86	1,04	0,56	0,49	0,97	1,24	1,06	1,06	1,08	0,89	0,52
6 years	0,83	0,95	0,82	0,82	0,94	0,49	0,46	1,02	1,21	1,06	1,06	1,05	0,85	0,53
7 years	0,79	0,97	0,79	0,79	0,93	0,47	0,46	0,99	1,22	1,04	1,04	1,08	0,82	0,54

Source: BEREC 2017 on public available data

Figure 4 – Sensitivity analysis on Beta estimation: daily, Dimson adjustment



	Euro Stoxx 50							Euro Stoxx Telecom						
	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7
1 year	0,80	1,20	0,77	0,71	1,27	0,83	0,58	0,90	1,20	0,90	0,70	1,25	0,96	0,65
2 years	0,94	1,07	0,97	0,68	1,14	0,84	0,57	0,99	1,07	1,04	0,64	1,10	0,94	0,55
7 years	0,74	0,99	0,83	0,83	0,96	0,60	0,44	0,91	1,20	1,05	0,59	1,10	0,93	0,49

Source: BEREC 2017 on public available data

Annex 2
WACC parameter quantitative analysis

Thanks to the availability of longer time series and a larger number of countries that have provided data, it is possible to use them not for predictive purposes, but for causal inference analysis. In the latter case, the independent variables (parameters for estimating WACC) are regarded as causes of the dependent variable (WACC values). Causality exploration aims to determine whether a particular independent variable actually influence the dependent variable, and to estimate the magnitude of the effect, if any.
In order to identify parameters that more explain the WACC variations on historical basis, we use the following regression model, which links the WACC values to main six parameters:

$WACC\_i\_k = Constant + \beta_1 RFR\_i\_k + \beta_2 Equity\ Beta\_i\_k + \beta_3 ERP\_i\_k + \beta_4 gearing\_i\_k + \beta_5 Debt\ premium\_i\_k + \beta_6 Tax\_i\_k$ (where *i* is the year of the data and *k* identifies countries involved).

Regression analysis can provide a deep understanding and numerical information on causation relation between dependent variable and each independent variable, taking into account information provided by other independent variables. This feature cannot be addressed by simple correlation analysis between each independent and the dependent variable as in this case, only a measure on the extent the two variables move together is considered, independently with respect to the information on variation provided by all other independent variables (missing, in this way, to prove real causality relation).
Several checks are needed to validate the use of a linearized model in order to infer or predict[44]. In case of panel data analysis with linear regression model, it is necessary, *inter alia*, to address the following main elements: i) linearity validity of the relationship between dependent and independent variables; ii) multicollinearity between independent variables; iii) homoscedasticity (constant variance) of the errors; iv) normality of the error distribution.
In the following, "sanity checks" on the proposed linear model have been addressed analysing the residual output of the model before addressing the relevance of variables that better explain observed WACC values.

Linearity
A first verification of the validity of the linear approximation is to detect if some path can be identified in the residual plot (y-axis) with respect to the expected values (x-axis). Points should be distributed symmetrically, around a horizontal line in relation to an intercept equal to zero. Different trends indicate at first point the presence of some non-linearity in the model (figure 1).[45] The assumption that the average error E(ε) is everywhere zero implies that the regression surface accurately reflects the dependency of Y on the X's.

[44] "Statistics for business and economics" Heinz Kohler 1994.
[45] The residual of an observed value is the difference between the observed value and the estimated value of the quantity of interest.

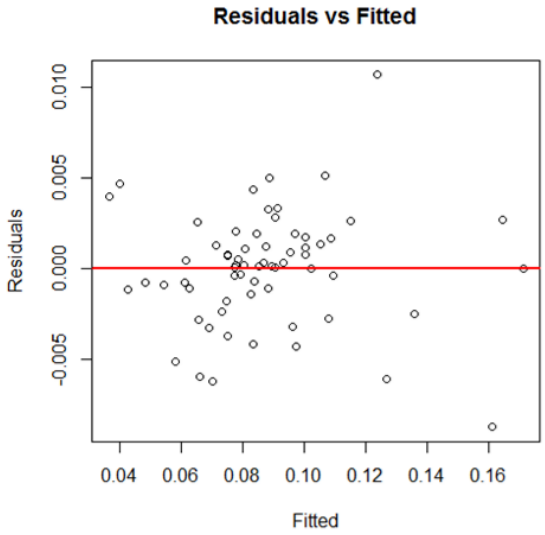


Figure 1

Moreover, a deeper analysis on each regressor should be considered plotting the residual previously represented with each independent variable. Also in this case non-linear effects could be detected when paths deviate from "random" shape (visible in the residual plots).

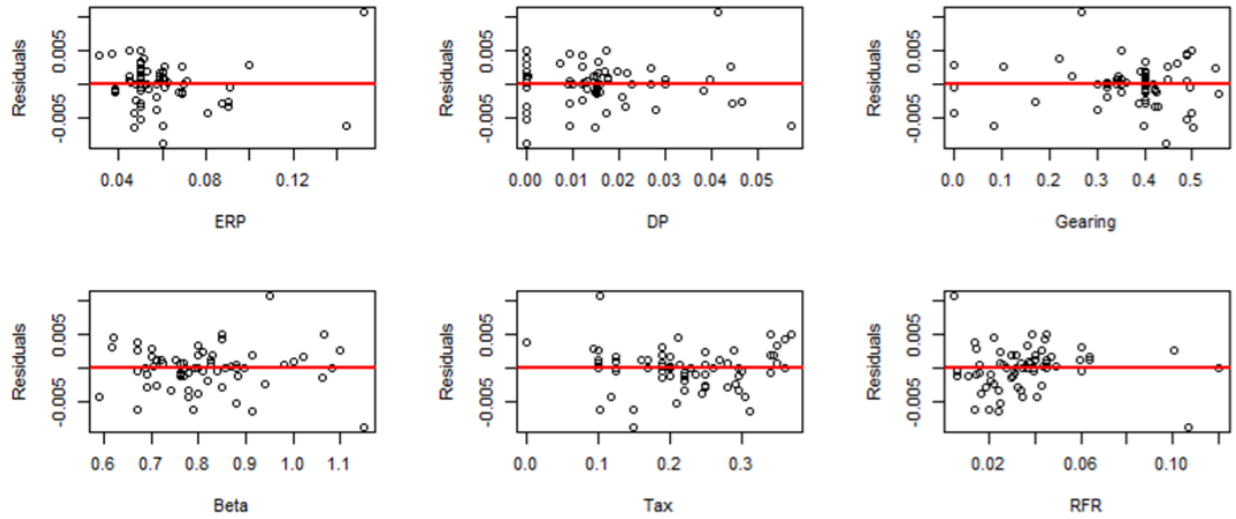


Figure 2

Another relevant measure to detect non-linearity in the model is provided through the use of the partial residual plot[46] (figure 3), which in case of multiple regression show the relationship between a given independent variable and the response variable, given that other independent variables are also in the model. Since in our case dependent variable depends on six main parameters, the use of partial residual plot is therefore more correct than simple single-variables scatter plot[47] (correlation measure). In Figure 3 a nonparametric fitting (green line) helps assess whether the linear trend adequately captures the partial relationship between Y and X. The partial residual plot highlights that linear approximation is good for each parameter.

[46] Partial residual plot includes E_ij=(residual_i + beta_j*x_ij) vs x_ij. This simply adds the linear component of the partial regression between Y and x_i (which may be characterised by a nonlinear component) to the least squares residuals. The "partial residuals" E(j) are plotted versus Xj, meaning that beta_j is the slope of the simple regression of E(j) on X_j. Through this plot both monotone and non-monotone non linearity can be detected.

[47] Regressing each independent variable with the dependent variable like a bi-variate model.

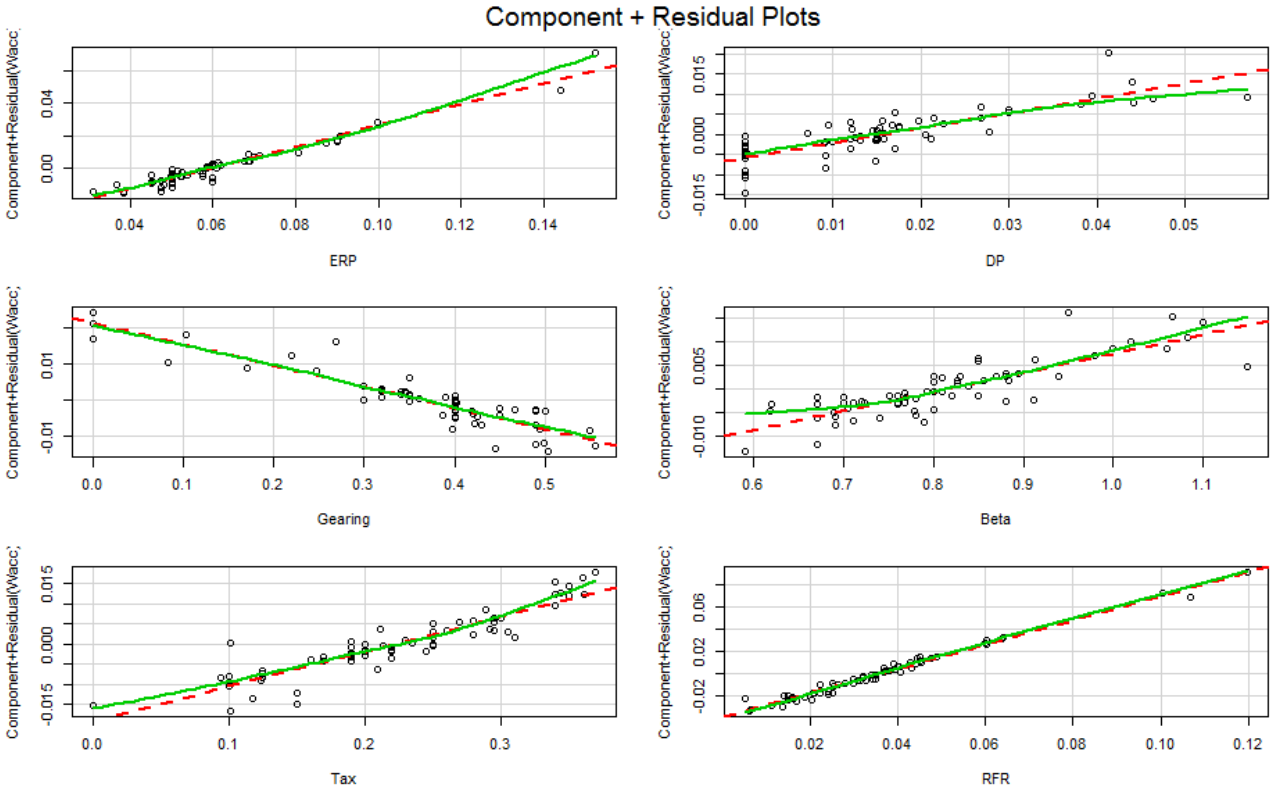


Figure 3

Normality, multicollinearity, homoscedasticity

In the Figure 4, summarised statistics are provided showing that all regressors are statistically significant with an adjusted R squared of 0.98. Moreover, standard variance inflation factor (VIF) show no multicollinearity among variables, thus further validating the model. We show hence (i) the residual graph against theoretical values, which looks completely casual, thus not revealing the existence of a residual systemic dependence among variables (already shown also in figure 1); (ii) the normal Q-Q plot of the standardized residues, which graphically verifies the assumption of normality of the erratic component of the linear model; (iii) the chart of square roots of standardised residues against theoretical values, and (iv) the graph of Cook distances, which let us identify three observations as possible outliers. We hence show the same model without the three possible outlier observations, by still founding similar results, as shown in Figure 5.

Figure 3 – WACC - Nominal panel data statistics[48]

```
Residuals:
      Min         1Q     Median         3Q        Max
-0.0087334 -0.0012361  0.0001443  0.0016849  0.0106608

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.025597   0.003614  -7.083 2.31e-09 ***
ERP          0.641597   0.026164  24.522  < 2e-16 ***
Tax          0.086944   0.005794  15.007  < 2e-16 ***
Beta         0.039954   0.003915  10.205 1.78e-14 ***
DP           0.364855   0.037048   9.848 6.57e-14 ***
RFR          1.083112   0.020882  51.867  < 2e-16 ***
Gearing     -0.058548   0.004653 -12.582  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.003309 on 57 degrees of freedom
Multiple R-squared:  0.986,     Adjusted R-squared:  0.9845
F-statistic: 667.6 on 6 and 57 DF,  p-value: < 2.2e-16
```

Variance Inflation Factor

```
     ERP      Tax     Beta       DP      RFR  Gearing
1.746507 1.355789 1.329712 1.385023 1.160953 1.839210
```

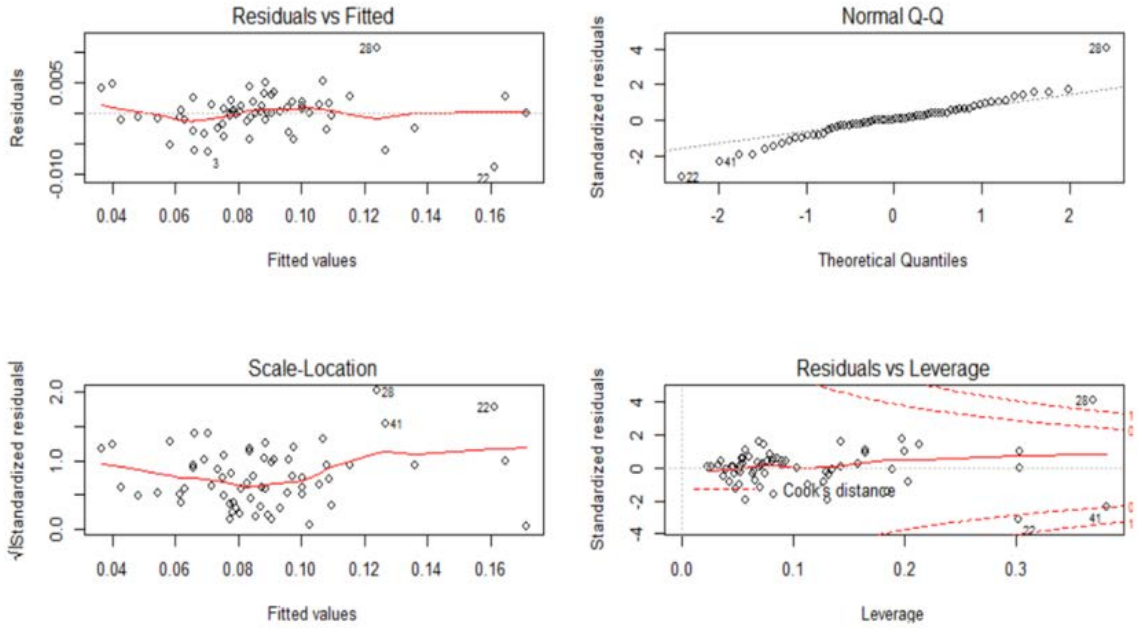


Figure 4

[48] IS is not included in the analysis due to the fact that no information have been provided on the nominal pre-tax wacc.

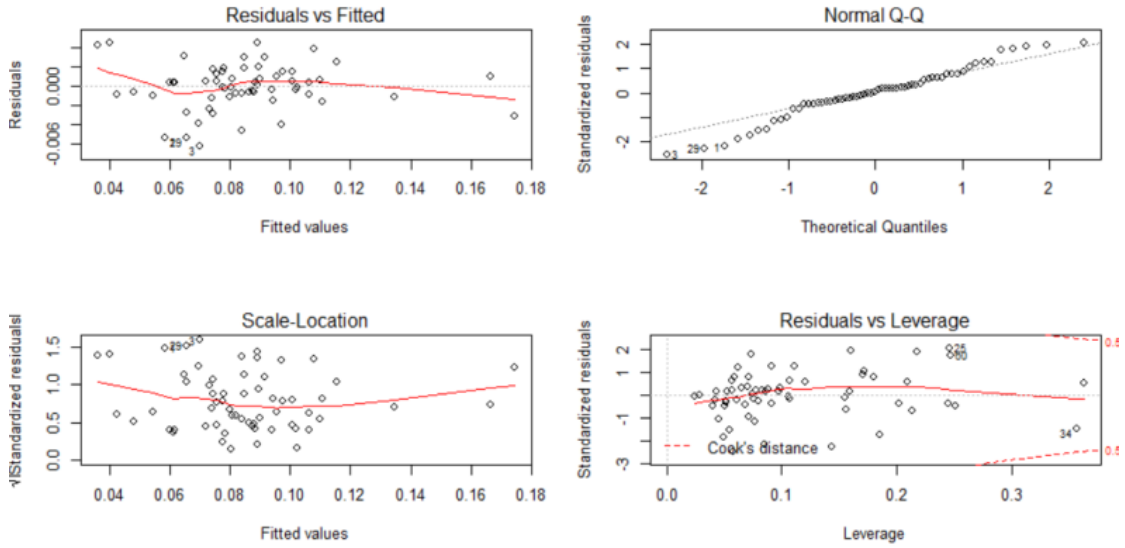
```
Residuals:
       Min         1Q     Median         3Q        Max
-0.0061688 -0.0009759  0.0001067  0.0014471  0.0045206

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.024840   0.003275  -7.585 4.63e-10 ***
ERP          0.607494   0.028916  21.009  < 2e-16 ***
Tax          0.087558   0.004553  19.232  < 2e-16 ***
Beta         0.040434   0.003167  12.766  < 2e-16 ***
DP           0.340241   0.029749  11.437 4.77e-16 ***
RFR          1.120781   0.017568  63.795  < 2e-16 ***
Gearing     -0.059279   0.003862 -15.349  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.002531 on 54 degrees of freedom
  (3 observations deleted due to missingness)
Multiple R-squared:  0.9905,    Adjusted R-squared:  0.9895
F-statistic: 942.8 on 6 and 54 DF,  p-value: < 2.2e-16
```

Variance Inflation Factor

```
     ERP      Tax     Beta       DP      RFR  Gearing
1.514770 1.316490 1.276499 1.154611 1.105611 2.126386
```



Source: BEREC 2017

Figure 5

Figure 6 shows the contribution to the increase in R-squared that each parameter produces when it is added to a model that already contains all of the other variables. Specifically, we include all N-1 variables in the model and we evaluate how well they fit in the model, like in a Backward elimination selection rule in a stepwise regression, and comparing the results with the Model specified with the N independent variable.

Since the change in R-squared analysis considers each variable as the last one entered into the model, the change represents the percentage of the variance one single variable explains that the other variables in the model cannot explain. In other words, this change in adjusted R-squared represents the amount of *unique* variance that each variable explains above and beyond the other

variables in the model. We further estimate the Akaike Information Criterion,[49] comparing the value obtained with a model with N independent variables and the values obtained with models composed by N-1 variables. This analysis confirms what the R-square analysis already highlighted, in terms of relevance of the parameters and provides that no model overfitting problem comes out. In figure 6 we report statistics from the two analysis done, when all the observations are taken into account (n=64) and when the possible 3 "outliers" have been deleted (n=61).

Figure 6 – WACC - Nominal pre-tax R^2 adjusted variations / AIC variations

Observations N=64	Total	RFR	ERP	Tax	gearing	beta	DP
R^2 adjusted (variations)	0.9845	0.719	0.1605	0.0599	0.0421	0.0276	0.0257
AIC (variations)	-724.45	-246.02	-154.59	-100.38	-83.06	-64.51	-61.61
Observation N=61	Total	RFR	ERP	Tax	gearing	beta	DP
R^2 adjusted (variations)	0.9895	0.7773	0.0841	0.0705	0.0448	0.0309	0.0248
AIC (variations)	-722.9	-262.47	-133.9	-123.68	-100.9	-82.83	-73.05

Source: BEREC 2017

The conclusion that most part of the variability is explained by RFR estimation and, to a far less extent, to ERP, is statistically significant. All other parameters provide a much lower explanation to the variation of the final WACC value.

[49] The Akaike information criterion (AIC) is a measure of the relative quality of statistical models for a given set of data. Given a collection of models for the data, AIC estimates the quality of each model, relative to each of the other models. Hence, AIC provides a means for model selection. Given a set of candidate models for the data, the preferred model is the one with the minimum AIC value. AIC rewards goodness of fit (as assessed by the likelihood function), but it also includes a penalty that is an increasing function of the number of estimated parameters. The penalty discourages overfitting, because increasing the number of parameters in the model almost always improves the goodness of the fit.