5 The Weighted Average Cost of Capital (WACC)

5.1 Introduction and main goals of the section

Chapter 5 of the 2017 RA report surveyed legacy WACC values, benchmarking final rates and methodologies for single parameters estimation within the WACC formula computed by NRAs specifically in market 3a and, more in general, in fixed markets.[1] It also provided information about the evolution of the WACC value over time.

The 2018 RA report mainly provides an update of the information reported in BoR (17) 169 both for parameter values and methodologies.

Theoretical and practical issues concerning WACC are also covered in the opinion BoR (18) 167 issued by BEREC in response to the public Consultation launched by the European Commission.

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 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 clearly 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) and adjustments that NRAs may apply to their standard approach in order to take into account country specificity
- evolution over time of methodologies and parameter values used by NRAs.

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; vii) pre-tax WACC. Information was collected both on methodologies and values, and is valid for decisions currently in force as well as past decisions. Specifically, the questionnaire relates to WACC decisions in market 3a of the Recommendation[2].

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

32 NRAs replied to the questionnaire providing information on WACC methodologies and values applied to market 3a in the 2008-2018 period[3]. 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.

[1] The information collected and presented in the report refers to market 3a. In some cases, due to country specificity issues, data provided can refer to the fixed market (i.e. market 1, market 3b, market 4). Where different data sets have been provided by NRAs this will be highlighted in the text.
[2] In case "not applicable/not available" has been chosen for market 3a, data related to other fixed markets have been considered (fixed termination or market 3b).
[3] Only EE states that the final WACC value is obtained using a benchmark of other NRAs, rather than applying a formula.

The dataset used for the following analysis takes into consideration 79 observations on all 7 parameters previously listed. The data collected refer to information provided by NRAs both from last year's report and the updated 2018 questionnaire with a cut-off date of 1st April 2018.

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 according to the information provided in the questionnaire. Information about technical adjustments are also reported.

For the first time, the 2018 report will provide also WACC values for the mobile markets.

Table 2 – WACC (fixed market) database and frequency update/calculation[4]

	2018	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					X	YEARLY
CY	X	X		X				X				MARKET ANALYSIS/REGULATORY PERIOD
CZ			X									MARKET ANALYSIS/REGULATORY PERIOD
DE	X	X							X			MARKET ANALYSIS/REGULATORY PERIOD
DK	X	X	X	X								YEARLY
EE												MARKET ANALYSIS/REGULATORY PERIOD
EL	X			X		X						MARKET ANALYSIS/REGULATORY PERIOD
ES	X		X			X				X		YEARLY
FI		X				X				X		MARKET ANALYSIS/REGULATORY PERIOD
FR	X		X			X	X					MARKET ANALYSIS/REGULATORY PERIOD
HR			X			X						MARKET ANALYSIS/REGULATORY PERIOD
HU	X	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			X								YEARLY
LU			X									MARKET ANALYSIS/REGULATORY PERIOD
LV												
ME												
MK	X											
MT							X					MARKET ANALYSIS/REGULATORY PERIOD
NL				X		X						MARKET ANALYSIS/REGULATORY PERIOD
NO	X	X				X						MARKET ANALYSIS/REGULATORY PERIOD
PL		X										YEARLY
PT		X	X	X								YEARLY
RO						X						MARKET ANALYSIS/REGULATORY PERIOD
RS	X		X	X	X							YEARLY
SE	X	X *										MARKET ANALYSIS/REGULATORY PERIOD
SI					X							MARKET ANALYSIS/REGULATORY PERIOD
SK			X			X						YEARLY
TR												
UK	X	X**			X					X		MARKET ANALYSIS/REGULATORY PERIOD
Number of observations Totals	15	12	11	11	4	12	3	1	3	5	2	79

Source: BEREC 2018

[4] For RS the WACC provided in the 2018 questionnaire is in charge for 2017.

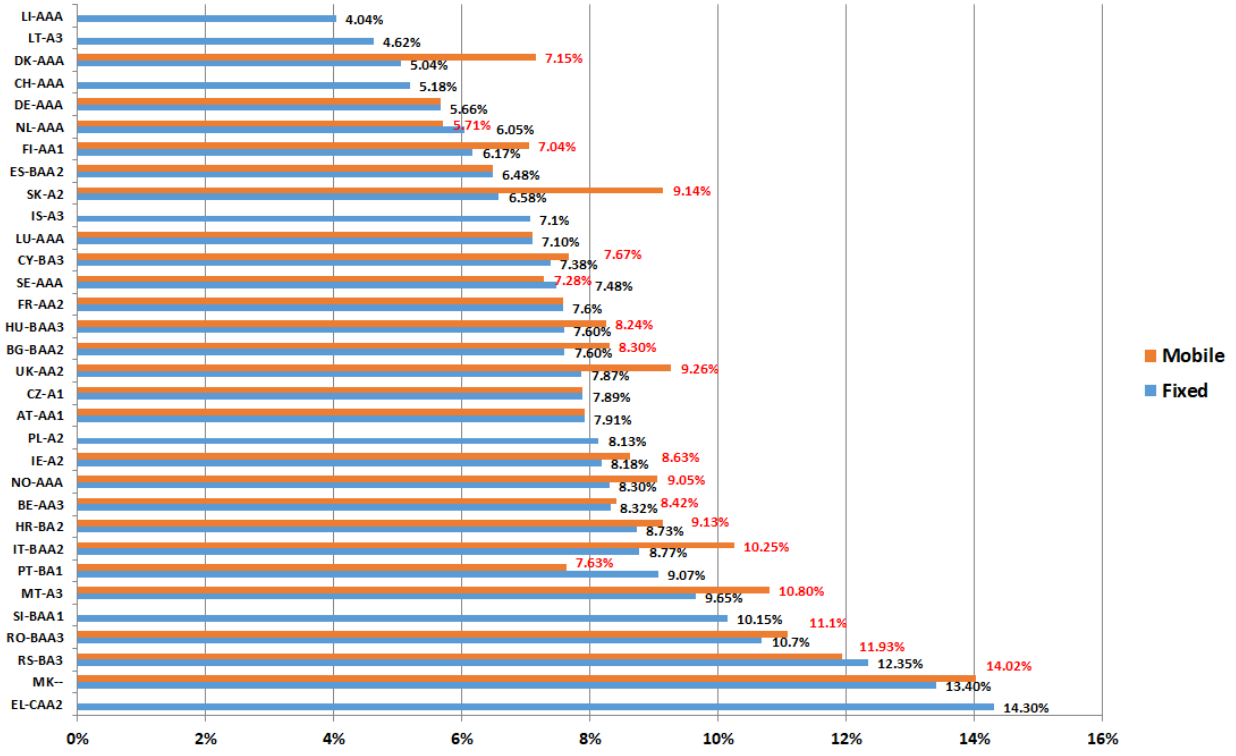
5.2 WACC Nominal Pre-tax synthetic value

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 (fixed) Nominal Pre-tax (32 NRAs)	**7.98%**	**7.73%**	**2.33%**	**29.22%**	**14.30%**	**4.04%**
WACC (mobile) Nominal Pre-tax (25 NRAs)	**8.54%**	**8.24%**	**1.93%**	**22.62%**	**14.02%**	**5.66%**

The average value of WACC currently in force for fixed markets did not change from the previous year. In Figure 1 WACC values for fixed and mobile markets have been sorted (from lowest to highest) and country credit rating information is provided. With respect to 32 NRAs that evaluate WACC for the fixed market, 25 also provided information with reference to the WACC for the mobile market. Among the 25 NRAs that evaluate a mobile market WACC, 6 NRAs estimate a single WACC for fixed and mobile markets; 15 NRAs estimate a higher WACC for the mobile market (on average +0.93%); and 4 NRAs estimate a lower mobile market WACC with respect to fixed services (on average -0.60%).

Figure 1 – WACC - Nominal Pre-tax (fixed and mobile markets)

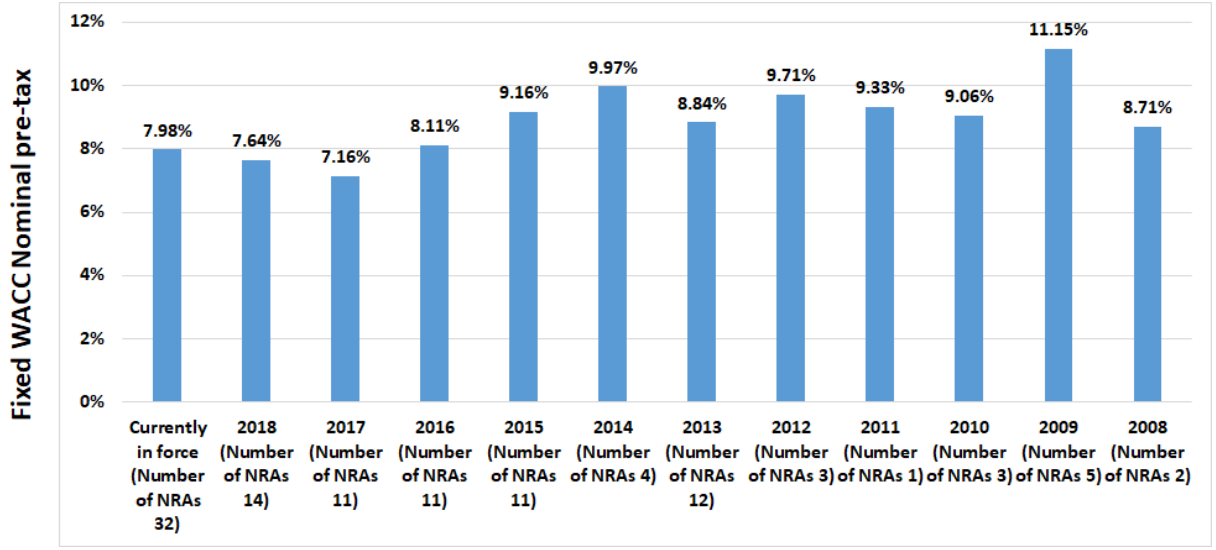


Source: BEREC 2018

In figure 2 the average year-by-year nominal pre-tax WACC values adopted are reported.

The average value currently in force comes from averaging values that are in use at the date of questionnaire's replies (independent of the year of the decision).[5]

Figure 2 – Fixed WACC-Nominal Pre-tax 2008-2018[6]



Source: BEREC 2018

In order to explore the WACC parameters weight with respect to the final WACC values according to the dataset collected by NRAs, we updated the regression exercise presented in BoR (17) 169 (page 9 and Annex 2). As last year data showed that main differences in final WACC values were mainly explained with respect to parameters in the WACC calculation that are more "country specific" than "sector specific" such as the RFR, ERP and Tax, with a less relevant role for parameters such as beta, gearing and debt premium. This is also in line with the replies provided in the survey about methodologies that confirm that beta, gearing and debt premium are estimated on a "notional" basis.

5.2.1 Risk Free Rate

see BoR (17) 169[7] and BoR (18) 167[8] for definition and general financial theory

Main output from the survey.

From the replies of the 2018 questionnaire the following statistics were derived.[9]

2018	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum

[5] For DE the real WACC is in force, for 2018 the corresponding real pre-tax WACC (after exponential smoothing) equals 5,20% for fixed and 5,26% for mobile. In Denmark (DK) a real pre-tax WACC of 5.25% is used in the LRAIC mobile model and not 7,15% which refer to nominal pre-tax WACC. For BE there exists (due to tax reform in 2006) a system of tax deduction for capital risk: deduction of fictitious interest (notional interest) calculated on the basis of a company's equity and which may be deducted up to a certain maximum the tax base of this company. The main aim of this measure was to reduce tax discrimination between loan financing and equity financing. Taking this into account the nominal Pre-tax for BE is 8,13% (both for fix and mobile).

[6] These average values are based on the WACC calculated in the respective year. If they had been calculated based on all the values applicable in a respective year, the average would have been different.

[7] https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/7316-berec-report-regulatory-accounting-in-practice-2017.

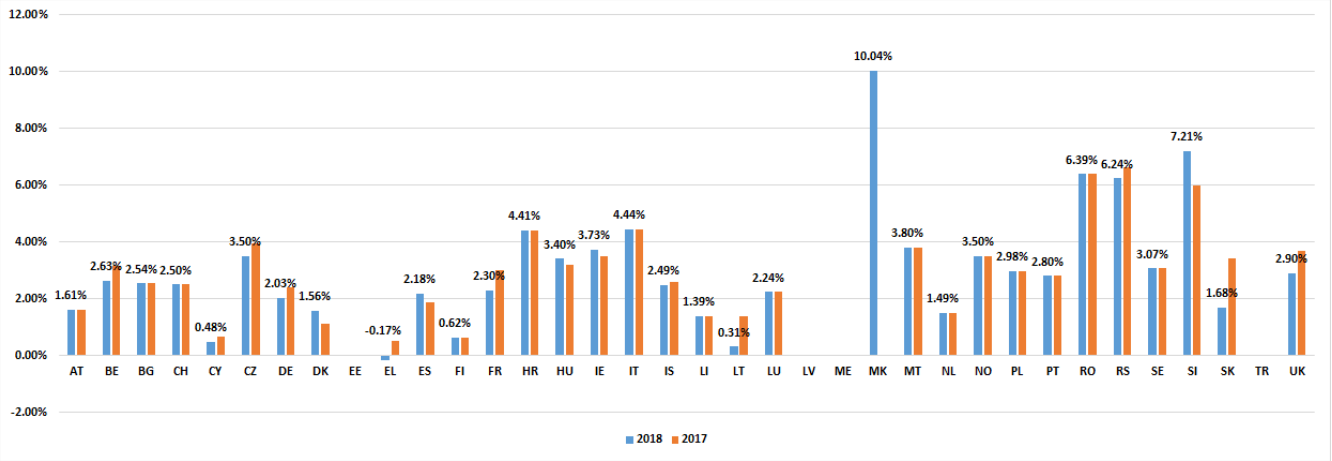
[8] https://berec.europa.eu/eng/document_register/subject_matter/berec/opinions/8257-berec-position-paper-input-to-the-commission8217s-wacc-consultation-2018.

[9] The data represented include adjustments that can be attributed to RFR, as declared by NRAs, consistent with the final WACC estimation.

Nominal RFR (fixed market (32 NRAs)	**3.01%**	**2.59%**	**2.11%**	**70.29%**	**10.04%**	**-0.17%**
Nominal RFR (mobile market) (25 NRAs)	**3.25%**	**2.80%**	**2.04%**	**62.71%**	**10.04%**	**0.48%**

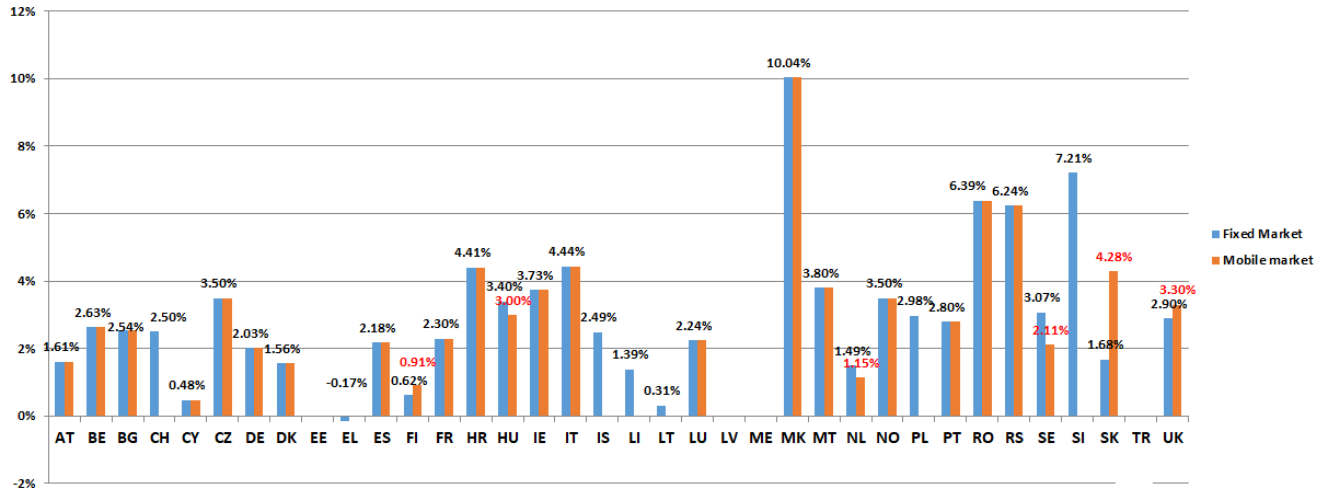
The average value of Nominal RFR currently in force is in line with the 2017 survey. In Figure 3 the nominal risk free rate is reported for 2017 and 2018.[10]

Figure 3 – Nominal Risk Free Rate Fixed Market[11]



Source: BEREC 2018

Figure 4 – Nominal Risk Free Rate Fixed and Mobile Markets currently in force



Source: BEREC 2018

Differences in RFR calculation between fixed and mobile markets are due to a time lag of the estimation between market analysis.

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

Main methodology	

[10] The label in figures that compares 2017 and 2018 data report only data for 2018 information.

[11] Specifically for CZ the 2017 value reported in BoR (17) 169 include country risk premium, not included in RFR data for 2018 report. Country risk premium for CZ is highlighted separately as adjustment to the cost of equity as reported in the next section.

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**

In Table 3 the RFR methodology approach used by NRAs for estimating the RFR for the fixed market is reported. Red figures report the most frequent approach (for comparison, 2017 data in brackets). In Table 4 the RFR methodology approach used by NRAs for estimating the RFR for the mobile market is reported.

Table 3 – RFR for *fixed market* methodology survey RA Report 2018

	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	Yes	7 (7)	domestic bond	21 (20)	1 year	0	Daily	14 (16)	Spot rate	1 (1)	Arithmetic average	23 (23)	Yes	2 (1)	Arithmetic average	0
	No	23 (23)	country specific bond	4 (4)	3 years	0	Weekly	1 (1)	3 months	2 (2)	Geometric Average	0	No	21 (20)	Geometric Average	0
			other	7 (7)	5 years	0	Montly	10 (9)	6 months	2 (2)	Moving Average	2 (1)	Comment	2 (2)	Moving Average	0
			benchmarking	0	10 years	26 (25)	Other	3 (3)	1 Year	7 (6)	Median	1 (0)			Median	0
					20 years	0			2 Years	3 (2)	Other	2 (2)			Other	0
					Other	5 (5)			3 Years	5 (5)						
									5 Years	7 (7)						
									10 Years	3 (3)						
									Others	1 (1)						

Source: BEREC 2018

Table 4 – RFR for *mobile market* methodology survey RA Report 2018

	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	Yes	5	domestic bond	16	1 year	0	Daily	11	Spot rate	1	Arithmetic average	18	Yes	2	Arithmetic average	0
	No	18	country specific bond	2	3 years	0	Weekly	1	3 months	1	Geometric Average	0	No	17	Geometric Average	0
			other	7	5 years	0	Montly	7	6 months	2	Moving Average	2	Comment	2	Moving Average	0
			benchmarking	0	10 years	21	Other	2	1 Year	3	Median	1			Median	0
					20 years	0			2 Years	3	Other	1			Other	0
					Other	3			3 Years	5						
									5 Years	4						
									10 Years	3						
									Others	2						

Source: BEREC 2018

Next, we provide further clarifications derived from the questionnaires.
As a preliminary output, most NRAs use a nominal estimation of the RFR without evaluating a real risk-free rate. A real risk-free rate is estimated in the fixed market by 7 NRAs (CH, IE, IS, MT, NO, PL, UK).

All 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 there is no clear "most frequent" choice by NRAs.[12] At the same time it is not possible to attribute differences in the RFR estimation to this methodological issue, but rather to country specific issues, related mainly to currency and expected inflation.[13]

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 (Table 5).[14]

[12] In table 2, replies of "7 years" (SE) and "6 years" (DK) have been included in the closer category "5 years".
[13] Regressing categorical variables analysed through the survey and final value of RFR no statistical significance can be detected between different methodologies used and the RFR final value. On the other hand it is possible to observe that RFR is influenced by currency issues between Eurozone and non-Eurozone.
[14] In red are NRAs that provided a different approach with respect to previous year's report.

Table 5 – RFR: Main methodology and time windows (frequency, NRAs, arithmetic average values) for fixed market[15]

RFR		Geographical scope			
		Domestic bond	Country specific	Other	Total
Time windows	<=1	8	1	1	10
	<=3	3	1	5	9
	>=5	9	2	0	11
	Total	20	4	6	30

RFR		Geographical scope			
		Domestic bond	Country specific	Other	Total
Time windows	<=1	BG,CH,ES,FI,LT,PL,RS,SK	EL	SI	10
	<=3	HU,MT,PT	IE	AT,BE,HR,NL,RO	9
	>=5	CZ,DE,DK,FR,IT,IS,LU,SE,UK	CY,LI		11
	Total	20	4	6	29

RFR		Geographical scope			
		Domestic bond	Country specific	Other	Average
Time windows	<=1	2.38%	-0.17%	7.21%	2.61%
	<=3	3.33%	3.73%	3.31%	3.36%
	>=5	2.73%	0.94%		2.40%
	Average	2.68%	1.36%	3.96%	2.76%

Source: BEREC 2018

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, LT, PL, RS, SK) or greater than or equal to 5 years (CZ, DE, DK, FR, IS, IT, SE, LU, UK).

Note that when "country specific" is chosen as the main category, a "country risk premium" is generally included in the cost of equity, e.g. 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), the RFR generally includes some country specific risk premium (SI) that is more relevant for the final value of the RFR; in this case, the relevance of time windows is lower.

Most NRAs that use an average window between 1 and 3 years do this in conjunction with "other" as the main methodology. In case of a heavy impact of the financial crisis, some countries state that they use

[15] In the matrix tables (e.g. table n. 5, 9, 10 etc.), the NRAs listed in RED have declared a different category with respect to the previous year.

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.

Some countries apply some adjustments to the estimation of the RFR as reported in the following table. The year of update is also provided.

Table 6 – RFR: Adjustment applied to RFR methodology in fixed market

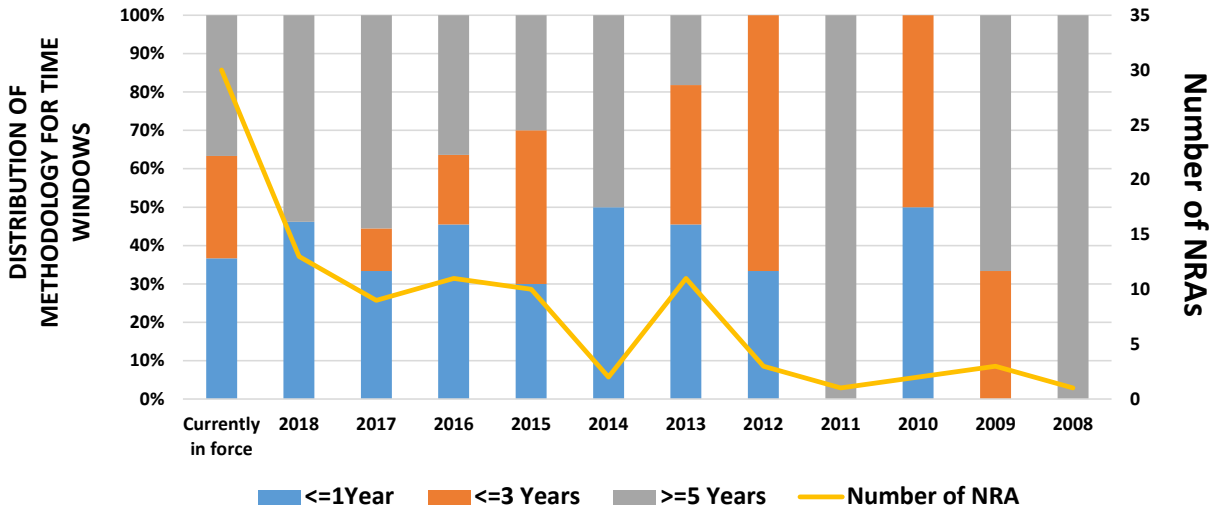
	Nominal RFR	Nominal risk free rate without adjustment	Country risk premium (%)	Size premium value (%)	Consistency with ERP estimation (hystorical data on ERP on different bond length)	Other adjustment: Size of adjustment (%)	Description of adjustment and how the adjustment was made
DK (2018)	1.56%	1.10%			0.40%	0.07%	QE
ES (2018)	2.18%	1.18%				1%	QE
IE (2013)	3.73%	3.63%				0.10%	Aiming up
RO (2013)	6.39%	3.19%	3.20%				Damodaran
MK (2009)	10.04%	4.49%	4.19%	1.36%			
SI (2014)	7.21%	2.10%	4.00%	1.11%			Duff&Phelps 2014-medium-sized company

Source: BEREC 2018

In figure 3 the average year-by-year nominal Risk Free Rate adopted is reported including in the average only NRAs that update the WACC value with respect to previous information reported. The average value currently in force stems from averaging values that are in use at the date of the questionnaire's replies (independent of the year of the decision).
Specifically there is a slight tendency of reduction over the last three years in line with the experience of lower yields of own country bonds, also due to QE purchase programs. Looking at quantitative easing, two NRAs that have updated the WACC last year took this explicitly into account (DK, ES). In two other cases (FR and UK) quantitative easing has been indirectly taken into account without an explicit adjustment[16]. 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.
Looking at the distribution of the "time windows" used by NRAs in 2013-2018, the period where the number of NRAs that have updated their WACC is higher, it seems that there is a growth in preference with respect to time windows >=5 years.

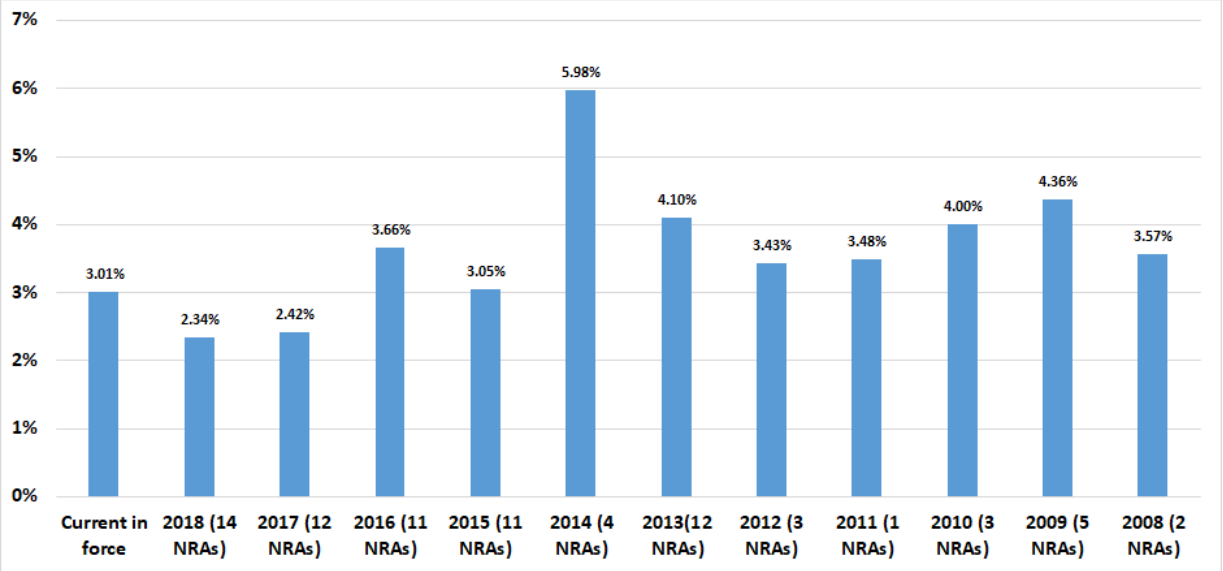
[16] In France this has been done by using a long averaging period (10y) for estimating RFR.

Figure 3.1 – RFR fixed market: distribution of methodology



Source: BEREC 2018

Figure 3.2 – RFR fixed market evolution over time



Source: BEREC 2018

In conclusion, NRAs that use domestic bonds as a methodology for estimating the RFR together with a less than one-year time window explain their approach 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)[17].

NRAs that use domestic bonds and a time window average greater than 5 years explained their approach with the pursuing of "regulatory objectives" - thus granting predictability, consistency and transparency - and overcoming the effects of quantitative easing.[18] The choice of longer averaging bond windows seems

[17] On the other side, out of the 8 NRAs that use a longer time window only one NRA updates the WACC yearly (DK).

[18] 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

to reflect the aim of estimating a "country risk premium" when this cannot be included in any other way. That is to say, within the current period of very low yields, the emphasis on longer data series aims at mitigating the risk of underestimate the WACC.

In summary, the main motivations behind the choice of the averaging windows are: i) to maintain regulatory predictability (e.g. a 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 the country-specific regulatory period; iv) consistency with the investment life cycle.

5.2.2 Equity Risk Premium (ERP)

see BoR (17) 169 and BoR (18) 167 for definition and general financial theory

Main output from the survey.

From the replies to the 2018 questionnaire the following statistics emerge. [19]

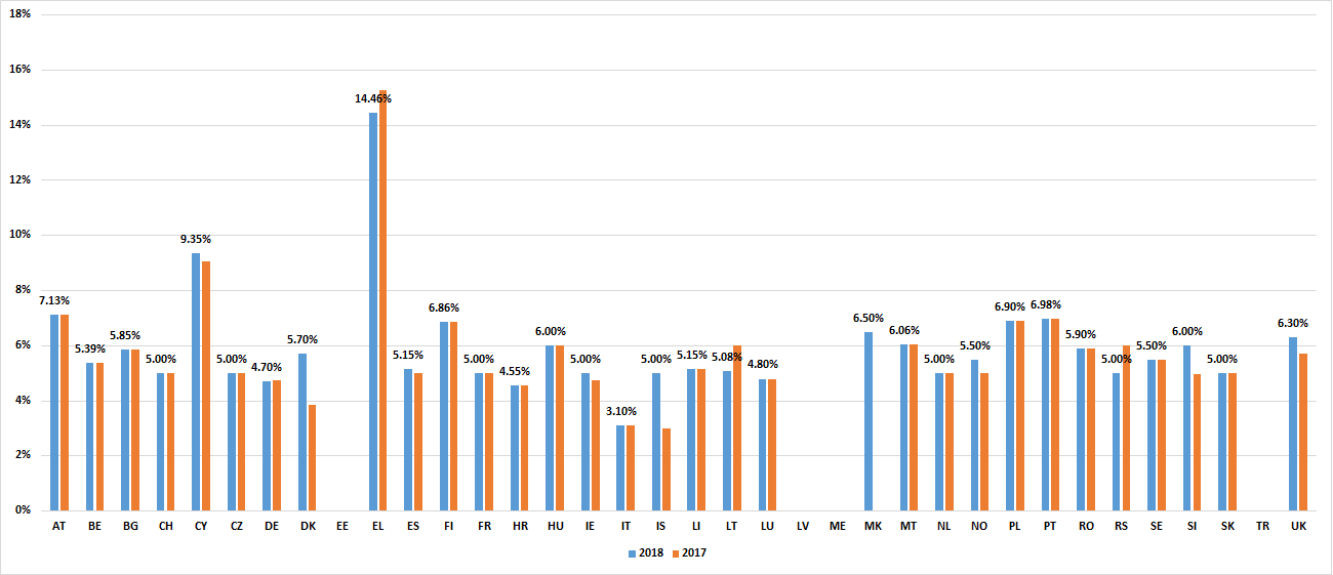
2018 (currently in charge data)	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
Equity risk premium ERP (fixed market) (32 NRAs)	5.90%	5.45%	1.90%	32.13%	14.46%	3.10%
Equity Risk Premium (mobile market) (25 NRAs)	5.66%	5.50%	1.19%	20.96%	9.45%	3.10%

The average value for ERP in the fixed market slightly increased from past year, while the deviation decreased.

procedures for the WACC even in years when the procedure leads to unexpected results. This exponential smoothing consists in weighting the current estimation by 30%, while 70% is the weight attributed to the WACC estimated in the previous period.

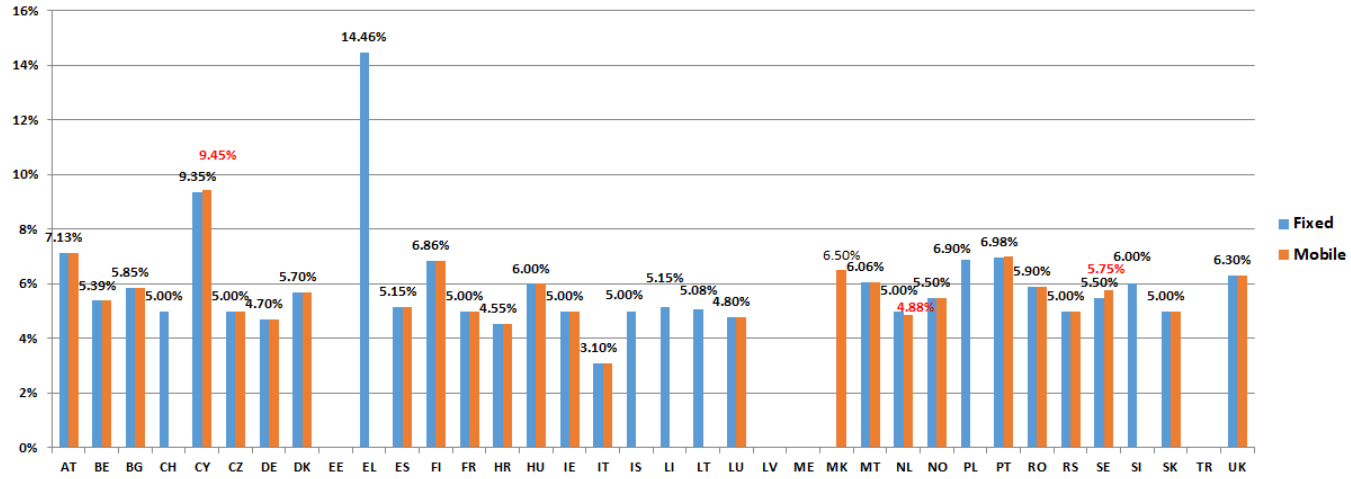
[19] The data represented include a country risk premium in the ERP value provided by NRAs to be consistent with the final WACC estimation (CY, EL). For EL the figure 14.46% comes from adjustment for comparability reasons.

Figure 4 – Equity Risk Premium (fixed market)



Source: BEREC 2018

Figure 5 – Equity Risk Premium currently in charge (fixed and mobile market)



Source: BEREC 2018

From the previous figure it can be observed that when the mobile WACC is estimated separately from the fixed, the ERP is equal for the two markets; only 3 NRAs provided different values.

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). In Table 7 the fixed market survey is reported; 2017 data are reported in brackets. Table 8 shows the survey result for the mobile market.

Table 7 – ERP Methodology Survey for *fixed market* 2018

	Methodology (General)		Specific Methodology		-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 (10)	Historical data	14 (14)	Arithmetic average	12 (11)	Arithmetic average	0
	country specific	11 (8)	Dividend grow model	0	Geometric Average	1 (2)	Geometric Average	0
	other	9 (7)	Historical+DGM	2 (2)	Moving Average	0	Moving Average	0
	benchmarking	1 (1)	Historical+DGM+Suvey	3 (3)	Median	0	Median	0
			Survey	2 (4)	Other	7 (5)	Other	0
			Historical+Survey	6 (4)				

Source: BEREC 2018

Table 8 – ERP Methodology Survey for *mobile market* 2018

	Methodology (General)		Specific Methodology		-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	9	Historical data	11	Arithmetic average	10	Arithmetic average	0
	country specific	7	Dividend grow model	0	Geometric Average	1	Geometric Average	0
	other	7	Historical+DGM	2	Moving Average	0	Moving Average	0
	benchmarking	1	Historical+DGM+Suvey	1	Median	0	Median	0
			Survey	4	Other	5	Other	0
			Historical+Survey	6				

Source: BEREC 2018

In terms of general methodology, no clear-cut preference emerges. Roughly one third of NRAs adopted a notional approach mixing evidence from different countries, one third of NRAs chooses a country-specific ERP (own country ERP), one third opted for a methodological mix – i.e. "other".[20]

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.

[20] 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 historical data, the ERP estimation by NRAs generally derives from a combination of data and judgement.

Most NRAs use historical data alone (14); the second largest group use historical data together with a survey and/or a DGM-Survey approach (11 NRAs); a third group estimates ERP only through a survey approach (2 NRAs).[21]

In the following tables 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 is compared.[22] Countries reported in RED are the ones which declared to have changed methodology. [23]

NRAs that use only historical data generally take into account long-time series.[24]
Where a mixed approach is chosen for the geographical scope ("other"), the estimation generally takes into account many sources, also from different European countries.

[21] In the 2018 questionnaire 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.
[22] Note that not all NRAs have provided specific information on each methodological category.
[23] For PT and CZ there is no change in the methodology between 2017-2018, but for 2018 a different classification of the replies in the questionnaire is provided for some categories.
[24] More than 100 years, taking as source DMS time series, Damoradan, Duff & Phelps, Pictet, as well as national bank sources. In some cases more than one source is used.

Table 9 – ERP Methodology in use

2018

	Historical data	Historical data + (DGM/Survey)	Survey	Total
Notional	3	5	1	9
Country specific	6	3	1	10
Other	4	3	0	7
Total	13	11	2	26

	Historical data	Historical data + (DGM/Survey)	Survey
Notional	FR,HR,RO	DK,LU,MT,NL,PT	RS
Country specific	AT,CH,IE,IT,LI,SK	ES,SE,UK	FI
Other	BE,DE,NO,CZ	CY,HU,SI	

	Historical data	Historical data + (DGM/Survey)	Survey
Notional	5.15%	5.71%	5.00%
Country specific	5.06%	5.65%	6.86%
Other	5.15%	7.12%	

2017

	Historical data	Historical data + (DGM/Survey)	Survey	Total
Notional	5	3	2	10
Country specific	4	2	1	7
Other	2	3	1	6
Total	11	8	4	23

	Historical data	Historical data + (DGM/Survey)	Survey
Notional	BE,FR,HR,LU,RO	DK,MT,NL	RS,PT
Country specific	AT,IT,LI,SK	ES, UK	FI
Other	DE,NO	CY,HU,SI	CZ

	Historical data	Historical data + (DGM/Survey)	Survey
Notional	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 only relatively weak correlations may be observed.

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 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 generally motivated by the desire to combine predictability with a forward-looking perspective in the ERP estimation. The use of a pure forward-looking approach to estimate ERP is generally motivated by trying to include more country specificity in terms of macroeconomic conditions.

In Table 10 we reported and compared for the last two years of data collection the motivations behind the choice of parameters that contribute to the cost of equity (ERP and RFR).

Table 10 – ERP-RFR main methodologies in use (frequency, NRAs, arithmetic average values) for fixed market

2018

		ERP				
		Notional	Country specific	Other	Benchmarking	Total
RFR	Domesic bond	7	8	4	1	20
	Country specific	0	2	2	0	4
	Other	3	1	2	0	6
	Total	10	11	8	1	30

		ERP			
		Notional	country specific	Other	Benchmarking
RFR	Domesic bond	DK,FR,LT,LU, MT,PT,RS	CH,ES,FI,IT,IS,SE,SK,UK	CZ,DE,HU,LU,NO	BG
	Country specific		IE,LI	CY,EL	
	Other	HR,NL,RO	AT	BE,SI	

TMR=ERP+RFR		ERP			
		Notional	country specific	Other	Benchmarking
RFR	Domesic bond	8.27%	7.72%	8.41%	8.39%
	Country specific		7.64%	12.06%	
	Other	9.25%	8.73%	10.62%	

2017

		ERP				
		Notional	Country specific	Other	Benchmarking	Total
RFR	Domesic bond	6	5	4	1	16
	Country specific	0	1	2	0	3
	Other	5	1	1	0	7
	Total	11	7	7	1	26

		ERP			
		Notional	country specific	Other	Benchmarking
RFR	Domesic bond	DK,FR,LT,LU, MT,PT	ES,FI,IT,SK,UK	CZ,DE,HU, NO	BG
	Country specific		LI	CY,EL	
	Other	BE,HR,NL,RO, RS	AT	SI	

TMR=ERP+RFR		ERP			
		Notional	country specific	Other	Benchmarking
RFR	Domesic bond	7.84%	7.94%	8.44%	8.39%
	Country specific		6.54%	12.75%	
	Other	10.59%	8.74%	10.96%	

Source: BEREC 2017

Table 10 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) (8 NRAs). 2018 data show a slightly increasing preference for domestic RFR-ERP estimation in comparison to the previous year. In case of a heavy impact of the financial crisis countries consider to include the country risk premium on ERP (CY and EL). Others consider a notional ERP in conjunction 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 (Table 11). This may be relevant in order to understand if there is a clear picture about the preference of NRAs for a forward-looking approach on RFR estimation (i.e. shorter time windows) rather than on ERP.

Table 11 – ERP-RFR time windows methodology in use (frequency, NRAs, arithmetic average values) for fixed market

2018

		ERP			
		Historical data	Historical data + other	Survey	Total
RFR	<= 1 year	2	3	2	7
	<= 3 year	5	3	0	8
	>= 5 years	5	5	0	10
	Total	11	12	2	25

		ERP		
		Historical data	Historical data + other	Survey
RFR	<= 1 year	CH,SK	ES,HU,SI	FI,RS
	<= 3 year	AT,BE,HR,IE,RO	MT,NL,PT	
	>= 5 years	CZ,DE,FR,IT,LI	CY,DK,LU,SE,UK	

Total market return (TMR=RFR+ERP)		ERP		
		Historical data	Historical data + other	Survey
RFR	<= 1 year	7.09%	9.98%	9.36%
	<= 3 year	9.35%	8.71%	
	>= 5 years	7.32%	8.38%	

2017

		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%

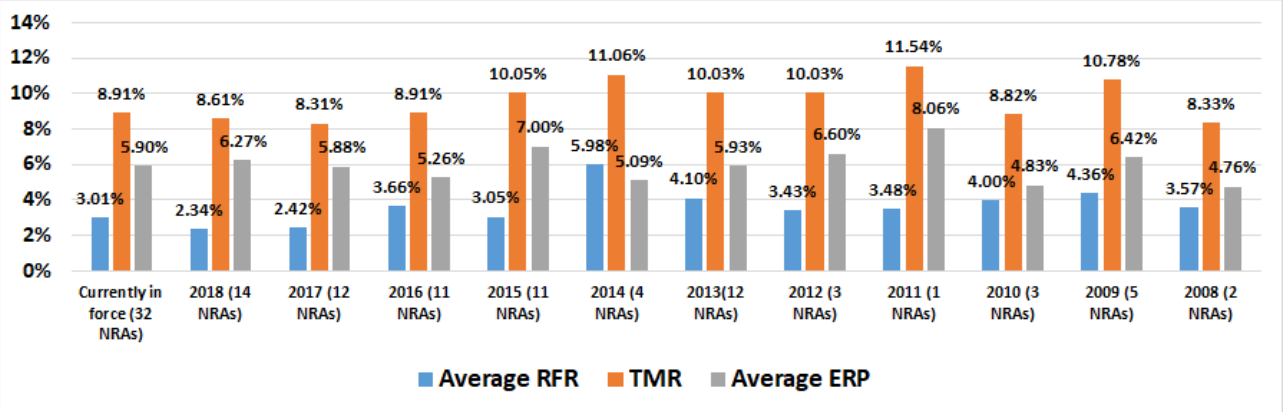
Source: BEREC 2018

From Table 11 we can derive that there is no clear common approach. The most frequent approach, which represents just one-fifth of the sample, is to estimate the RFR on the basis of a 3 year time window and the ERP based on historical time series. NRAs that choose this approach declare their motivation with a wish to be consistent with past WACC decisions. Deviations from pure historical time series are mainly due to the choice of adding more data sources ("sanity check") in order to estimate the parameter. With respect to 2017 we note that more NRAs chose to mix the estimation of ERP based on historical data with other data sources.

Figure 6 considers the average evolution over time of ERP, RFR[25]and TMR (ERP+RFR). TMR has a lower relative standard deviation over time 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.

[25] This analysis is independent with respect to the fact that NRAs takes into account explicitly TMR estimation in ERP/RFR calculation. So the picture provide values of TMR as a matter of fact obtained from RFR+ERP provided by NRAs for WACC calculation. One NRA takes into account explicitly in the RFR and ERP estimation the calculation of TMR = ERP+RTR.

Figure 6 – ERP-RFR-TMR over time fixed market



	Relative standard deviation
RFR	27.10%
ERP	16.80%
TMR	11.85%

Source: BEREC 2018

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

Most NRAs used an arithmetic average (12 NRAs for the fixed market), while a second group of NRAs using a mix of arithmetic and geometric average (7 NRAs for the fixed market). Only one NRA uses a pure geometrical average.

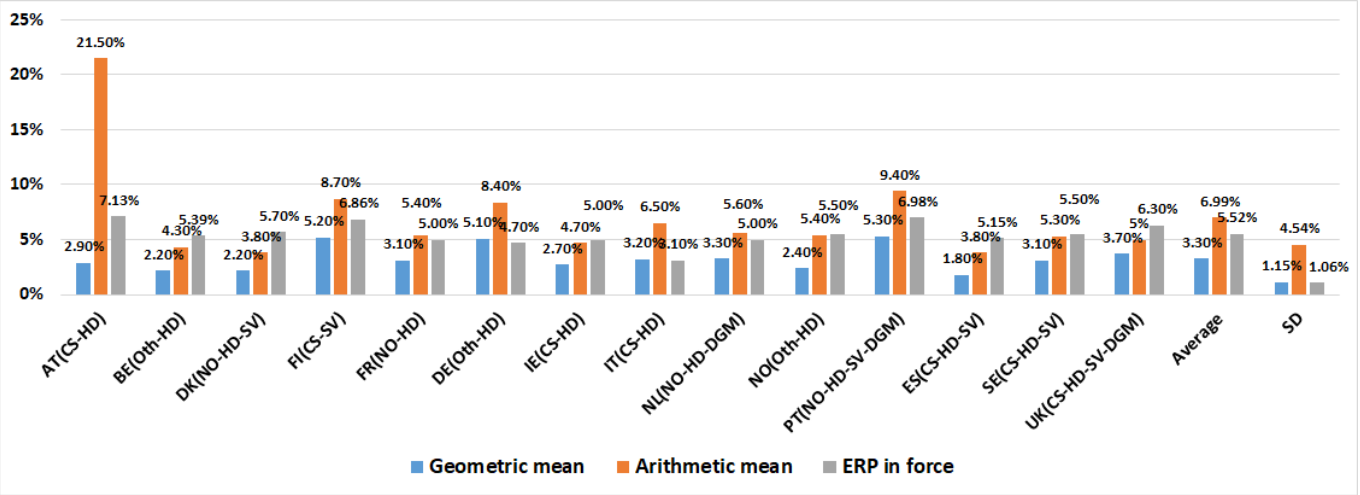
A basic exercise of sensitivity analysis shows that the choice of the "average" significantly affects the ERP value. The figure below shows the comparison of ERP actual values and values obtained "if" other types of averages are applied (e.g. data from the publicly available DMS database 1900-2017[26] were applied to some European countries).[27]

The data in the figure 7 cannot be directly compared with the data provided by NRAs in the questionnaire. When geometric and arithmetic average is presented, data refer to the DMS database updated until 2017, whereas the actual value is the one provided by the NRAs for the RA EWG survey 2018. The figures compare the actual values of ERP with ERP values using pure geometric or arithmetic averages, computed using public reference data.

[26] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3140837.

[27] 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; SV refers to Survey; DGM refers to Dividend Growth Model.

Figure 7 – ERP value from sub set of countries



Source: BEREC 2018 and Dimson, Marsh, Staunton 1900-2017 Source *Damodaran*

We can observe that ERP values are very sensitive to the choice of average type, especially when historical data are considered.

5.2.3 Beta

see BoR (17) 169 and BoR (18) 167 for definition and general financial theory

Main results of the survey.

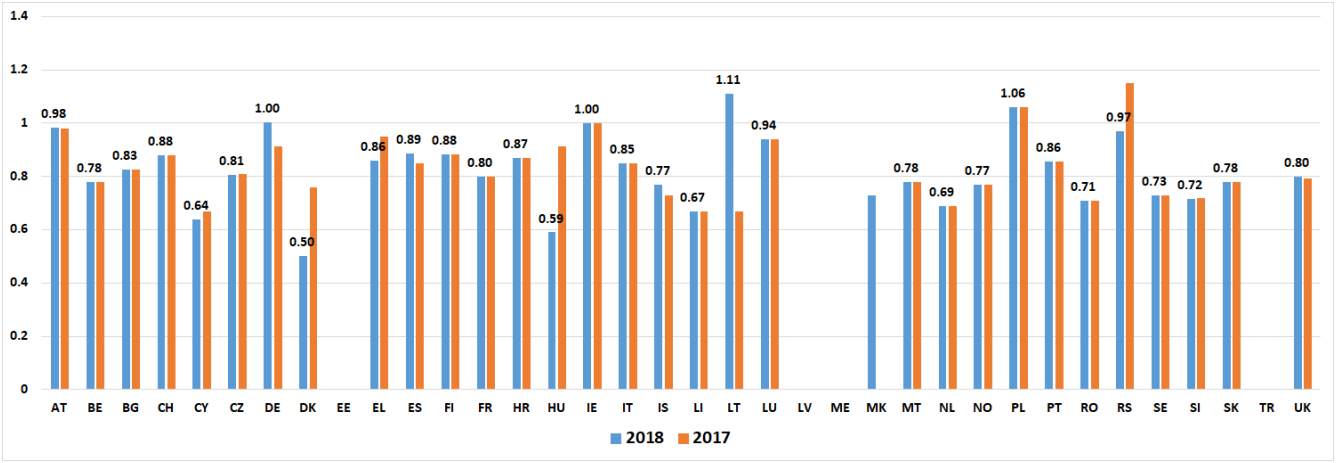
From the replies of to the 2018 questionnaire the following statistics emerge.[28]

2018 Data		Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
Fixed Market	Equity beta (32 Nras)	0.82	0.80	0.14	16.49%	1.11	0.5
	Asset beta (18 NRAs)	0.53	0.53	0.07	13.19%	0.98	0.43
	Beta debt (3 NRAs)	0.14	0.1	0.07	49.49%	0.22	0.1
Mobile market	Equity beta (25 NRAs)	0.84	0.82	0.17	20.02%	1.21	0.35
	Asset beta (14 NRAs)	0.58	0.61	0.09	15.82%	0.686	0.3292
	Beta debt (3 NRAs)	0.16	0.15	0.06	38.47%	0.22	0.1

Average values for 2018 do not differ from 2017.

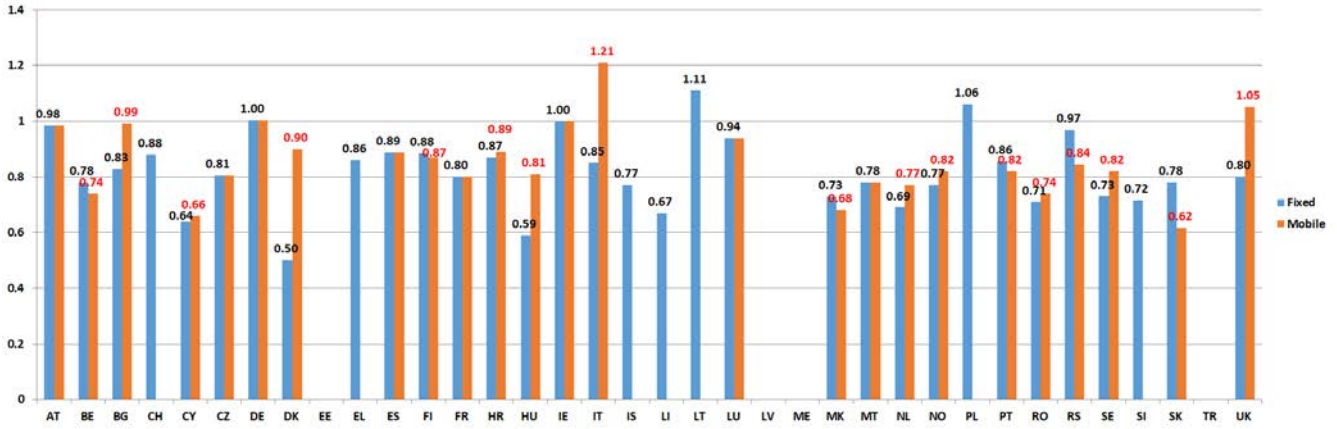
[28] Asset betas/Equity betas are calculated with reference to different market indices, thus comparison should be considered in the light of this fact.

Figure 8 – Equity Beta values Fixed Market



Source: BEREC 2018

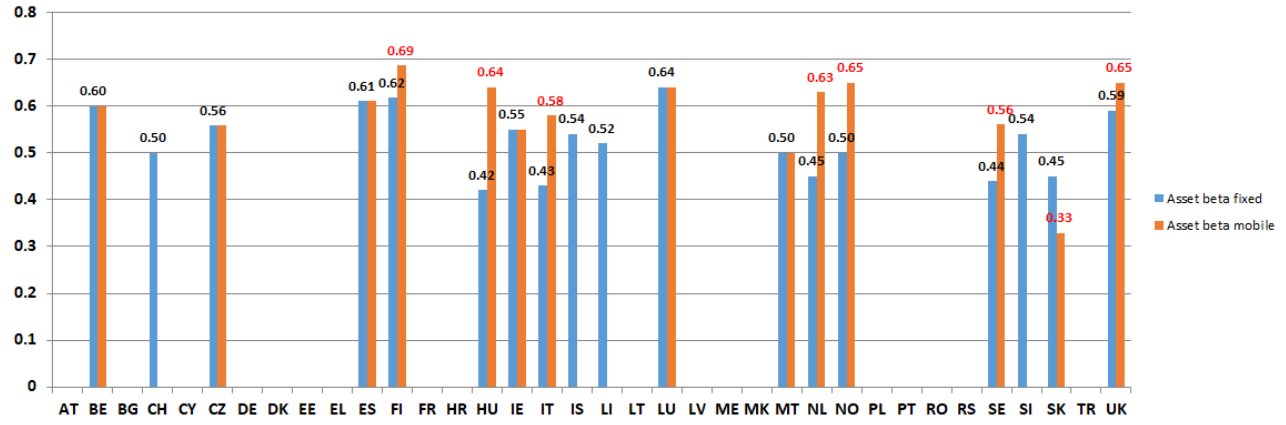
Figure 9 – Equity Beta values Fixed Market and Mobile market



Source: BEREC 2018

Among the 25 NRAs that evaluate WACC also for the mobile market, 8 NRAs estimated the same beta for fixed and mobile market; 11 NRAs estimated a mobile beta higher than the one for the fixed market (on average +0.15); 6 NRAs estimated a lower mobile beta with respect to fixed services (on average -0.14).

Figure 10 – Asset Beta values Fixed Market and Mobile market comparison



Source: BEREC 2018

The following table summarizes the different approaches used by NRAs to estimate beta; the 2017 data are reported in brackets.

Table 12 – Beta Methodology fixed market

	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)	20 (16)	Arithmetic average	6 (3)	daily	8 (9)	1 week	0	Dimson	0	Own Country	3 (2)	yes	20 (21)	Modigliani-Miller	12 (15)	Arithmetic average	0 (1)
	SMP Operator	6 (6)	Geometric Average	0	weekly	8 (7)	1 month	0	Bayesian	5 (4)	European	14 (13)	no	6 (4)	Miles & Ezzell	0	Geometric Average	0
	Other	4 (6)	Moving Average	0	montly	4 (3)	3 month	0	Blume	4 (4)	Word	7 (6)			Hamada	3 (2)	Moving Average	0
	benchmarking	2 (3)	Median	4 (2)	other	1 (2)	6 months	0	Vasicek	1 (2)					Other	4 (4)	Median	2 (1)
			Other	5 (7)			12 months	1 (1)	Others	2 (2)							Other	0
							2 years	5 (6)	No Adjustment	8 (9)								
							3 years	7 (5)										
							5 years	8 (7)										
							10 years	0										
							others	2 (5)										

Source: BEREC 2018

Table 13 – Beta Methodology mobile market

	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)	17	Arithmetic average	5	daily	7	1 week	0	Dimson	0	Own Country	3	yes	16	Modigliani-Miller	11	Arithmetic average	0
	SMP Operator	2	Geometric Average	0	weekly	6	1 month	0	Bayesian	5	European	10	no	4	Miles & Ezzell	0	Geometric Average	0
	Other	5	Moving Average	0	montly	3	3 month	0	Blume	2	Word	5			Hamada	2	Moving Average	0
	benchmarking	1	Median	3	other	1	6 months	0	Vasicek	0					Other	4	Median	2
			Other	5			12 months	1	Others	2							Other	0
							2 years	2	No Adjustment	6								
							3 years	7										
							5 years	6										
							10 years	0										
							others	1										

Source: BEREC 2018

The most frequent methodology used by NRAs is by far to estimate a notional beta based on an analysis of telecom comparators (20 NRAs in case of fixed market). When "Other" is declared (4 NRAs) it generally refers to a hybrid approach that takes into account different sources of estimation; it can be either closer to a notional approach or to an estimation of an SMP beta[29].

Table 14 – Changes in Beta Methodology for fixed access market (2017-2018)

	2018			2017		
	Equity beta	Asset Beta	Countries (2018)	Equity beta	Asset Beta	Countries (2017)
SMP Operator	0.84	0.50	BE,BG,EL,LT,NL,SK	0.78	0.49	BG,DK,EL,LT,NL,SK
notional (generic operator)	0.82	0.54	AT,CH,CY,CZ,DK,ES,FI,FR,HR,HU,IE,IT,IS,LU,MK,PL,PT,RO,RS,SI	0.86	0.59	AT,CH,CY,CZ,ES,FI,HR,HU,IS,IT,LU,PL,PT,RO,RS,SI
Other	0.83	0.51	DE,NO,SE,UK	0.81	0.60	BE,DE,FR,NO,SE,UK
benchmarking	0.73	0.51	LI,MT	0.84	0.56	IE,LT,MT

Source: BEREC 2018

Table 15 only reported NRAs that evaluate a different beta for the fixed and mobile markets. In this case it can be observed that only few NRAs apply different methodologies.

[29] For example, different market indices are considered (BE); in one case a TMI Telecom Stoxx Index is regressed as dependent variable with respect to general TMI Stoxx Index (DE), the comparison between the SMP and own countries operators are benchmarked with other groups of comparable operators (UK, NO).

Table 15 – Beta Methodology for mobile[30] and fixed access markets

	Mobile			Fixed		
	Equity beta	Asset Beta	Countries	Equity beta	Asset Beta	Countries 2018
SMP Operator	0.68	0.46	BE,SK	0.77	0.50	BE,BG,NL, SK
notional (generic operator)	0.77	0.65	BG,CY,DK,FI,HR,HU,MK,PT,NL,RO,RS	0.74	0.49	CY,DK,FI,HR,HU,IT,MK,PT,RO,RS
Other	0.98	0.61	DE,IT,NO,SE,UK	0.83	0.51	DE,NO,SE,UK
benchmarking						

Source: BEREC 2018

Where a notional approach is chosen 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.

One NRA, in order to differentiate the Beta for fixed or mobile apply a regression directly to the equity beta of each comparable of the peer group, considering as weights the percentage of revenues in each sector (fixed and mobile and other revenues) (DK).

Another NRA (LU) applies a regression on asset beta as in the following equation finding no statistical significance between the estimated beta and the weights of revenues, thus failing the corresponding beta decomposition. As a result, no difference between fixed and mobile beta were found.[31]

$$\beta_{asset} = \beta_{fixed} \cdot \omega_{fixed} + \beta_{mobile} \cdot \omega_{mobile} + \beta_{other} \cdot \omega_{other} + \varepsilon$$

The way the average beta is estimated from the peer group may differ accordingly to the different kind of average chosen. The median is more frequent in case of higher number of comparables.

[30] Only NRAs that evaluate a different WACC for the mobile market are considered.

[31] https://assets.ilr.lu/telecom/Documents/ILRLU-1461723625-156.pdf .

Table 16 – Beta notional methodology in fixed markets

	Number of comparable used	Average
CH	12, historical telco companies in UE	Arithmetic average
CZ	34 telecom companies, world spread	Median
DK	14 operators	Arithmetic average
ES	14 comparable operators, with similar business mix and listed in the stock exchange	Arithmetic average
FI	15 telecom companies	Median
HR	20 European Telecom Companies	-
HU	20 European operators listed on the stock exchanges	Median
IT	10 comparable companies (European SMP operator)	Arithmetic average
IS	11 telecom companies in Western-Europe	Other
LU	13 selected comparators are considered	Arithmetic average
MK	13 European comparable fixed line operators in EU	-
PT	16 comparable	
RO	17 countries peer group of operators based in Europe with shares traded on stock exchanges and consistent with previous WACC computation exercises	Other
RS	10 comparable companies and main criteria for selection were: comparable industry, relatively similar products/services and geographical location.	-
SE	European peer group (12 companies)	Arithmetic average

Source: BEREC 2018

In Table 17 it is possible to observe that if a different beta is evaluated between fixed and mobile, when a notional approach is applied, in most cases the number and the kind of comparables chosen reflected a specific mobile target. In other cases the difference in beta values is due just to different timing of the estimation.

Table 17 – Beta notional methodology in mobile markets

	Mobile			Fixed	
		Number of comparables	Average	Number of cmparables	Average
BG	notional (generic operator)	-	-	-	-
CY	notional (generic operator)	-	-	-	-
DK	notional (generic operator)	14 operator	Arithmetic average	14 operators	Arithmetic average
FI	notional (generic operator)	6 telecom companies	Median	15 telecom companies	Median
HR	notional (generic operator)	20 European Telecom Companies	-	20 European Telecom Companies	-
HU	notional (generic operator)	9, European operators listed on the stock exchanges	-	20 European operators listed on the stock exchanges	Median
MK	notional (generic operator)	8 comparable companies mainly involved in mobile services	Median	13 European comparable fixed line operators in EU	-
PT	notional (generic operator)	5 Western European Mobile Operators	Arithmetic average	16 comparables	-
NL	notional (generic operator)	6 mainly mobile operators	Arithmetic average	-	-
RO	notional (generic operator)	23 operators	Other	17 countries peer group of operators based in Europe with shares traded on stock exchanges and consistent with previous WACC computation exercises	Other
RS	notional (generic operator)	10 comparable maily involved in mobile services	-	10 comparable companies and main criteria for selection were: comparable industry, relatively similar products/services and geographical location.	-

Source: BEREC 2018

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 Table 18.

Table 18 – Beta Methodology for sampling period and time windows (fixed market)[32]

		Time windows				
		<=2 Years	<=3 Years	>=5 Years	Others	Total
Sampling period	daily	2 (3)	3 (3)	2 (1)	1 (2)	8 (9)
	weekly	3 (3)	1 (1)	3 (3)	0 (0)	7 (7)
	montly	0 (0)	0 (0)	4 (3)	0 (0)	4 (3)
	Others	0 (0)	1 (1)	0 (0)	0 (1)	1 (2)
	Total	5 (6)	5 (5)	9 (7)	1 (3)	20 (21)

	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
DK	notional (generic operator)	daily	3 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
RS	notional (generic operator)	montly	5 years
SI	notional (generic operator)	weekly	2 years
DE	Other	daily	5 years
SE	Other	weekly	5 years
UK	Other	daily	2 years
BE	SMP Operator	daily	3 years
LT	SMP Operator	montly	5 years
NL	SMP Operator	daily	3 years
SK	SMP Operator	montly	5 years

Source: BEREC 2018

With reference to the time windows chosen for the estimation of the beta, the approach among NRAs is more variable with three main clusters (two, three and five years).

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

[32] 2017 data in brackets.

The RFR time windows and the time windows for the beta estimation are the same in 10 cases out of 22, where information is available for all indicators (Table 19).

Table 19 – Beta fixed market-RFR (time windows)

		Beta (Time windows)			
		<=2 Years	<=3 Years	>=5 Years	Total
RFR (time windows)	<=1 Year	3 (3)	1 (1)	5 (4)	9 (8)
	<=3 Years	0	3 (3)	1 (1)	4 (4)
	>=5 Years	3 (3)	2 (1)	4 (5)	9 (9)
	Total	6 (6)	6 (5)	10 (10)	22 (21)

2018

		Beta (Time windows)			
		<=2 Years	<=3 Years	>=5 Years	Total
RFR (Time windows)	<=1 Year	CH,PL,SI	FI	ES,HU,LT,RS, SK	9
	<=3 Years		BE,HR,NL	PT	4
	>=5 Years	CZ,IT,UK	DK,LU	CY,DE,IS,SE	9
	Total	6	6	10	22

2017

		Beta (Time Windows)			
		<=2 Years	<=3 Years	>=5 Years	Total
RFR (Time windows)	<=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 2018

According to information provided by NRAs, a choice of time window for beta differing from the one for the RFR and where the option chosen is >=5 years, is mainly motivated by predictability, reliability and transparency objectives; also by 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 (Table 20), most NRAs use a Bayesian/Blume adjustment. Some NRAs apply the Blume adjustment explaining their choice (i) to report evidence from an academic study,[33] (ii) remarking that in case of "off the shelf" data provided by Bloomberg, the Blume adjustment is applied, (iii) stating that the Blume adjustment reflects future risks. Other NRAs (8 NRAs), do not make any adjustments 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 available, the estimation of the equity beta can be less reliable.

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

Table 20 – Time windows-Adjustment for Equity beta

	Time Windows			
	<=2 Years	<=3 Years	>=5 Years	Total
No Adjustment	2	1	5	8
Blume	2	1	1	4
Vasiecek	0	1	0	1
Bayesian	0	2	2	4
Others	1	1	0	2
Total	5	6	8	19

Source: BEREC 2018

Most NRAs apply an unlevered beta before estimating the final equity beta (20 NRAs).

Concerning the unlevering formula the most widely used is the Modigliani-Miller formula (Miller being the same formula without tax[34]) 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, rather than a notional one, is estimated.

Concerning the market index, most NRAs (14 NRAs) use a European index (STOXX Europe TMI Telecommunications; STOXX Europe TMI, MSCI Europe Index). Some estimate the equity beta for each comparable 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 (3 NRAs).

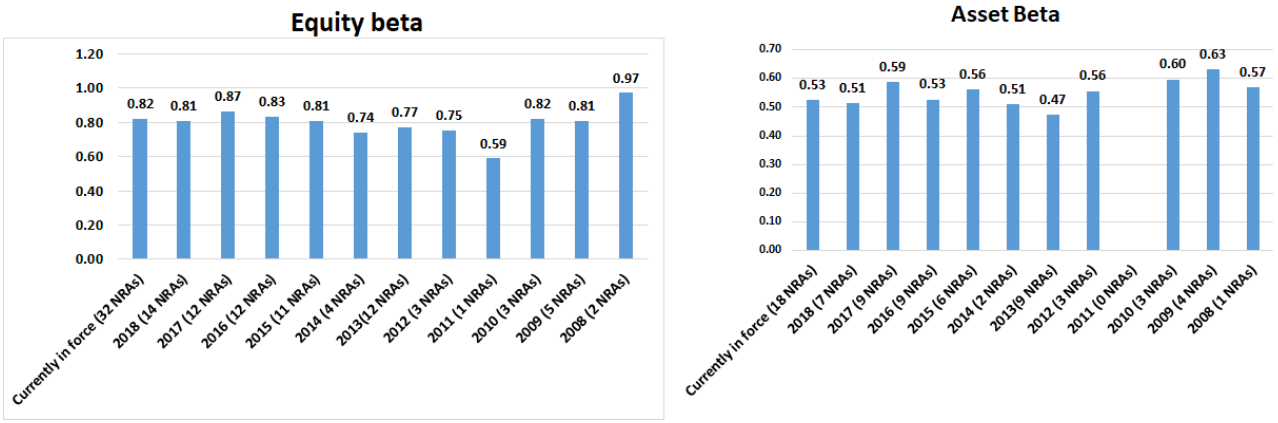
The chosen approach is generally motivated by the fact that the specific index provides a reliable data source and is consistent with earlier decisions.

Sensitivity analysis on the time windows, adjustment and market index shows a relevant variability of the estimation that have been carried out in **annex 1 of** BoR (17) 169; different results can be obtained using different market indexes, time windows and adjustments. A notional approach, in any case, can reduce a certain level of variability.

Overall, in the period covering 2008-2018, estimated beta values have been relatively stable[35].

[34] Sometimes the same formula is referred to as "Hamada formula" or "Fernadez practioners".
[35] The variability may be explained by the number of observations (e.g. one NRA in 2011).

Figure 11 – Evolution over time of the Equity beta and Asset beta estimation



Source: BEREC 2018

Concerning the principle of "internal consistency" a kind of correlation has been found between the choice of the beta and gearing approach with respect to the price control methodology. Generally, in case a Bottom-up approach as allocation method is in use, a "notional beta" is applied. However, this relation is missing for the cost of debt.

5.2.4 The cost of debt

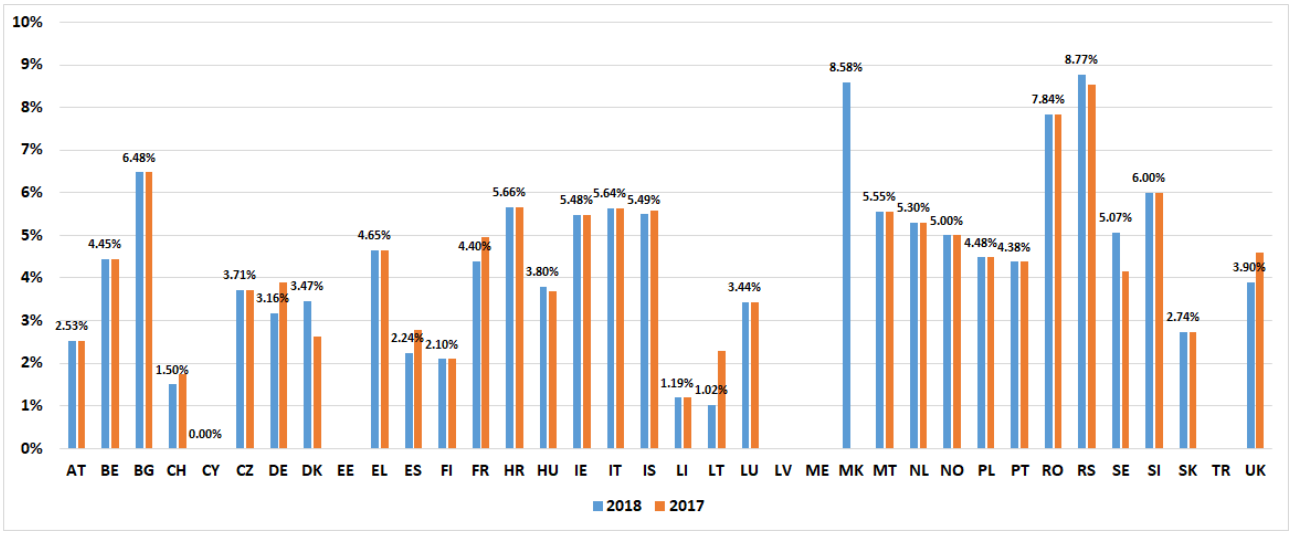
see BoR (17) 169 and BoR (18) 167 for definition and general financial theory

Main output from the survey.

From the replies to the questionnaire 2018 the following statistics come out:

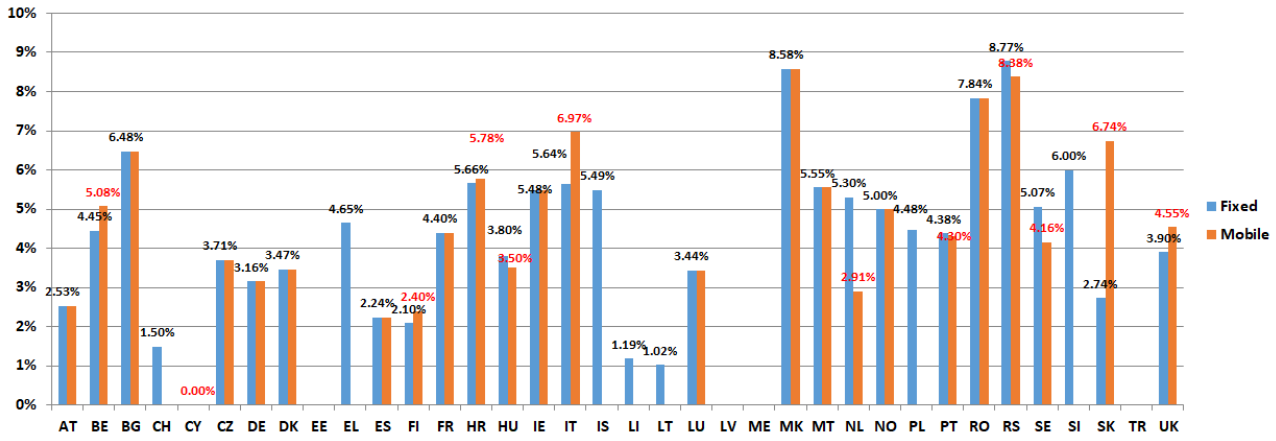
2017	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
Cost of debt (32 NRAs)	4.31%	4.43%	2.08%	48.14%	8.77%	0.00%
Cost of debt (25 NRAs)	4.67%	4.40%	2.08%	44.49%	8.58%	0.00%

Figure 12 – Cost of debt fixed market



Source: BEREC 2018

Figure 13 – Cost of debt fixed and mobile market currently in force



Source: BEREC 2018

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

Table 21 – Cost of debt methodology (fixed market)

	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)	12 (13)	Debt premium	20 (19)	Book value	3 (4)	Secondary traded market	5 (4)	1 year	0 (1)	Spot rate	3 (4)	Arithmetic average	11 (11)	Arithmetic average	0 (1)
	SMP Operator	5 (7)	Cost of Debt	9 (11)	Market Value (Company bond)	17 (10)	Nominal bond yield	9 (10)	3 years	0	3 months	0	Geometric Average	0 (1)	Geometric Average	0
	Other	12 (10)			Other	5 (3)	Other	4 (3)	5 years	2 (0)	6 months	1 (1)	Moving Average	0	Moving Average	0
	benchmarking	1 (1)							10 years	7 (8)	1 Year	3 (4)	Median	0 (1)	Median	0
									20 years	0	2 Years	2 (1)	Other	1 (1)	Other	1 (0)
									Hybrid	1 (3)	3 Years	0 (1)				
									Other	6 (5)	5 Years	1 (1)				
											10 Years	4 (2)				
											Others	1 (2)				

Source: BEREC 2018

Table 22 – Cost of debt methodology (mobile market)

	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)	9	Debt premium	17	Book value	0	Secondary traded market	3	1 year	1	Spot rate	3	Arithmetic average	8	Arithmetic average	0
	SMP Operator	2	Cost of Debt	6	Market Value (Company bond)	16	Nominal bond yield	8	3 years	0	3 months	1	Geometric Average	1	Geometric Average	0
	Other	12			Other	4	Other	4	5 years	1	6 months	1	Moving Average	0	Moving Average	0
	benchmarking	1							10 years	7	1 Year	2	Median	0	Median	0
									20 years	0	2 Years	0	Other	0	Other	1
									Hybrid	0	3 Years	1				
									Other	5	5 Years	1				
											10 Years	3				
											Others	2				

Source: BEREC 2018

The most frequent approach used by NRAs is a notional approach (12 NRAs), the second category chosen by 10 NRAs is "Other" which means a mix of approaches (SMP+ notional). This is followed by the estimation of the SMP cost of debt (5 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 (Table 23). On the other hand, 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-).[36]

[36] 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 23 – Methodology of cost of debt fixed market

	Cost of debt calculated through debt premium	Cost of Debt
Notional (generic operator)	11 (11)	1 (2)
SMP operator	1 (2)	4 (5)
Other	7 (5)	4 (4)
Benchmarking	1 (1)	0 (0)

	Cost of debt calculated through debt premium	Cost of Debt
Notional (generic operator)	CH,DK,FI,FR,HR,HU,IS,LI,PT,RO,RS	SI
SMP operator	AT	BG,IT,LT,NL
Other	BE,DE,IE,*LU*,NO,SE,UK	CZ,ES,PL,SK
Benchmarking	*MT*	

	Cost of debt calculated through debt premium	Cost of Debt
Notional (generic operator)	4.42%	6.00%
SMP operator	2.53%	4.61%
Other	4.40%	3.29%
Benchmarking	5.55%	

Source: BEREC 2018

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 together with a SMP cost of debt.
Concerning the bond windows, the most common approach is to use 10 year bonds in line with the bond windows used to estimate RFR (Table 24).

Table 24 – Bond windows on cost of debt- RFR bond windows

		Bond length						
		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	0	0	2	7	0	1	4
	20 Years	0	0	0	0	0	0	0
	Other	0	0	0	0	0	0	2

Source: BEREC 2018

With respect to time windows, most NRAs choose them in accordance with their choice for the RFR (Table 25).

Table 25 – RFR- Cost of Debt time windows

		Cost of debts			
		<=1 Year	<=3 years	>= 5 Years	Total
RFR	<=1 Year	4 (6)	1 (0)	1 (0)	6
	<=3 Years	1 (2)	1 (1)	2 (2)	4
	>= 5 Years	2 (1)	1 (1)	3 (3)	6
	Total	7	3	6	16

		Cost of debts (time windows)			
		<=1 Year	<=3 years	>= 5 Years	Total
RFR (time windows)	<=1 Year	ES,HU,RS,SK	SI	PL	6
	<=3 Years	RO	PT	BE,HR	4
	>= 5 Years	CZ,IT	LU	FR,SE,UK	6
	Total	7	3	6	16

Source: BEREC 2018

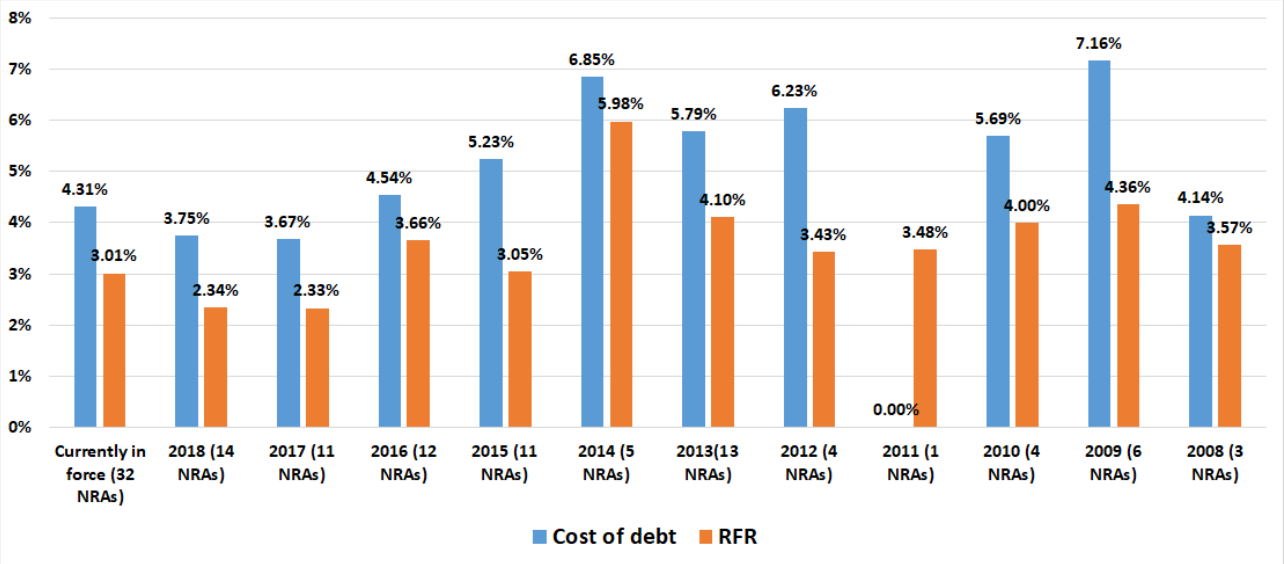
Where differences emerged, they have been motivated by the general availability of data, characteristics of the SMP operator, country specificities as well as consistency with time windows used for beta estimation.

Concerning specific “adjustments” to the Cost of debt, two NRAs apply the following adjustments.

Adjustment	Cost of debt	Cost of debt without adjustment	Adjustment	Motivation
IE (2013)	5.48%	5.18%	0.30%	Aiming up
RS (2018)	8.77%	7.23%	1.54%	Adjustment is made using the inflation rate for Serbia and Eurozone, since the initial value of cost debt is in EUR. Inflation adjustment was made using Fisher equation: “Pretax Cost of debt no adj”*(1+Projected Inflation Rate for RS)/(1+Projected Inflation Rate for Eurozone)

Figure 14 shows the evolution over time of the cost of debt and the RFR.

Figure 14 – RFR- Cost of Debt (fixed market) over time



Source: BEREC 2018

5.2.5 Gearing Ratio

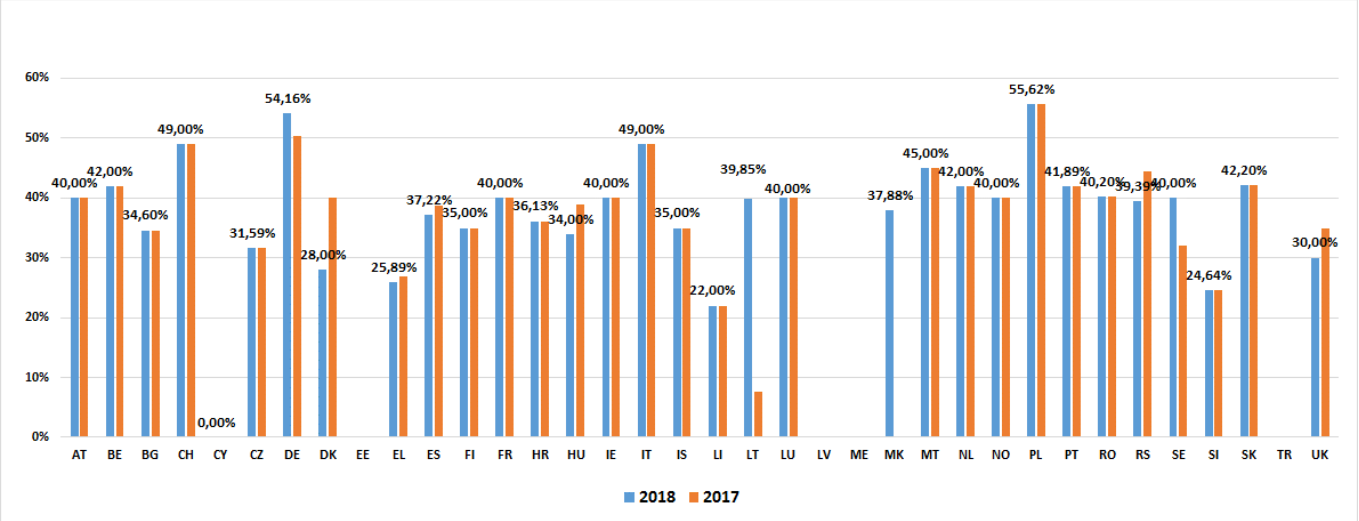
see BoR (17) 169 and BoR (18) 167 for definition and general financial theory

Main results of the survey.

From the replies to the questionnaire 2017 the following statistics emerge:

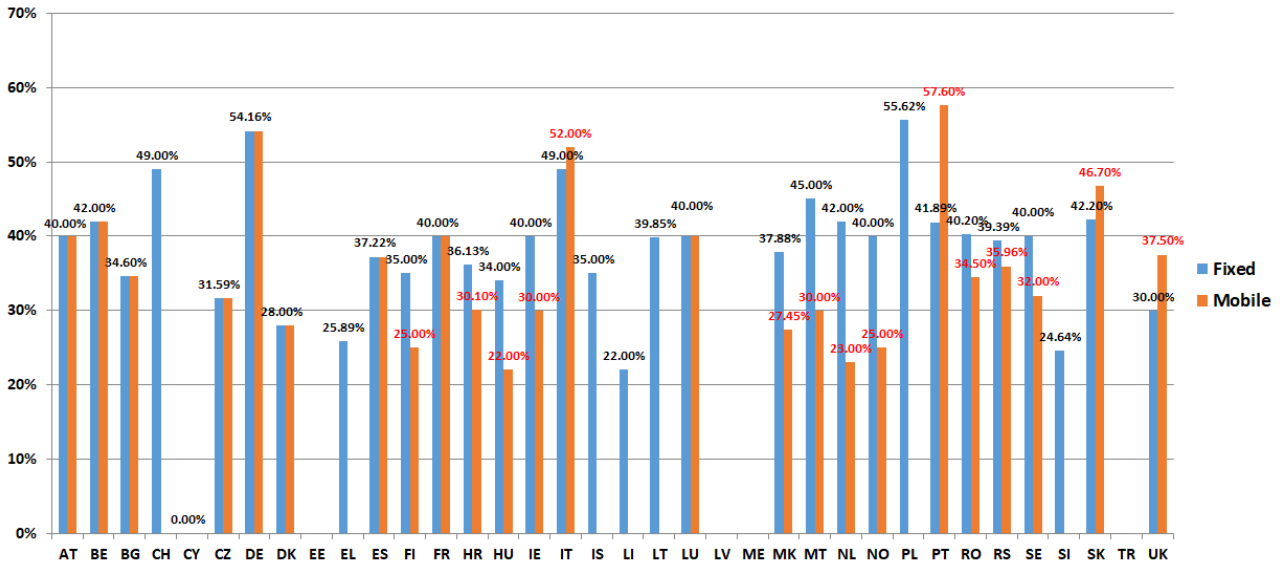
	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
Gearing fixed market (32 NRAs)	37.26%	39.93%	10.20%	27.37%	55.62%	0.00%
Gearing mobile market (25 NRAs)	34.26%	34.50%	11.84%	34.57%	57.60%	0.00%

Figure 15 – Gearing values fixed market



Source: BEREC 2018

Figure 16 – Gearing values fixed and mobile market



Source: BEREC 2018

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

Table 26 – Gearing methodology (fixed market)

	Methodology		Debt component (if applicable)		Equity component (if applicable)		-if notional value "Average methodology"		-if benchmarking is indicated in the methodology section please indicate the average used from other countries	
Gearing	notional (generic operator)	18 (16)	Book value	8 (9)	Book value	1 (3)	Arithmetic average	7 (5)	Arithmetic average	0
	SMP Operator	6 (6)	Market Value	5 (6)	Market Value	12(10)	Geometric Average	0	Geometric Average	0
	Other	5 (5)	Other	2 (1)	Other	2 (2)	Moving Average	0	Moving Average	0
	benchmarking	0					Median	4 (3)	Median	0
							Other	2 (4)	Other	0

Source: BEREC 2018

Table 27 – Gearing methodology (mobile market)

	Methodology		Debt component (if applicable)		Equity component (if applicable)		-if notional value "Average methodology"		-if benchmarking is indicated in the methodology section please indicate the average used from other countries	
Gearing	notional (generic operator)	14	Book value	6	Book value	0	Arithmetic average	7	Arithmetic average	0
	SMP Operator	2	Market Value	4	Market Value	10	Geometric Average	0	Geometric Average	0
	Other	7	Other	1	Other	1	Moving Average	0	Moving Average	0
	benchmarking	0					Median	4	Median	0
							Other	2	Other	0

Source: BEREC 2018

NRAs that have indicated “notional” in general do not adjust the gearing according to 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 2018 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. Where the SMP operator’s gearing is considered, the estimation of the equity component is often computed by using the book value (Table 28).

When the debt component is estimated via the book value, generally long term and short term debt without netting off the cash is considered.[37]

Table 28 – Gearing methodology

2018

	Debt component			Equity component		
	Book value	Market value	Other	Book value	Market value	Other
notional (generic operator)	4	3	2	0	7	2
SMP Operator	2	0	0	1	1	0
Other	2	1	0	0	3	0
benchmarking	0	0	0	0	0	0
Total	8	4	2	1	11	2

	Debt Component			Equity component		
	Book value	Market value	Other	Book value	Market value	Other
notional (generic operator)	DK,HR,LU, SE	ES,HU,IT	CH,IE		DK,ES,HR, HU,IT,LU, SE	CH,IE
SMP Operator	LI,NL			LI	NL	
Other	DE,UK	SK			DE,SK,UK	
benchmarking						
Total	8	4	2	1	11	2

	Debt Component			Equity component		
	Book value	Market value	Other	Book value	Market value	Other
notional (generic operator)	36.03%	40.07%	44.50%		37.76%	44.50%
SMP Operator	32.00%			22.00%	42.00%	
Other	42.08%	42.20%			42.12%	
benchmarking						

2017

	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

	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

	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 2018

Tables 29 and 30 show 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 estimation 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.

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

Table 29 – Gearing and Cost of debt Methodology

		Cost of debt				
		notional (generic operator)	SMP Opearator	Other	Benchmarking	
Gearing	notional (generic operator)	11 (11)	2 (3)	5 (2)	0 (0)	18
	SMP Operator	1 (1)	3 (3)	2 (1)	0 (1)	6
	Other	0	0	3 (5)	1 (0)	4
	Benchmarking	0	0	0	0	0
	Total	12 (12)	5 (6)	10 (7)	1 (1)	28

		Cost of debt				
		notional (generic operator)	SMP Opearator	Other	Benchmarking	
Gearing	notional (generic operator)	CH,FI,FR,HR,HU,IS,PT,RO,RS,SI	AT,IT	CZ,ES,IE,LU,SE		18
	SMP Operator	LI	BG,LT,NL	BE,PL		6
	Other			DE,SK,UK	MT	4
	Benchmarking					0
	Total	12	5	10	1	28

		Cost of debt			
		notional (generic operator)	SMP Opearator	Other	Benchmarking
Gearing	notional (generic operator)	36.66%	44.50%	37.76%	
	SMP Operator	22.00%	38.82%	48.81%	
	Other			42.12%	45.00%
	Benchmarking				

Source: BEREC 2018

Table 30 – Gearing and Beta estimation Methodology

		Beta				
		notional (generic operator)	SMP Opearator	Other	Benchmarking	Total
Gearing	notional (generic operator)	17 (13)	0	1 (2)	0 (1)	18 (16)
	SMP Operator	1 (1)	4 (4)	0	1 (1)	6 (6)
	Other	0	1 (1)	2 (3)	1 (1)	4 (5)
	Benchmarking	0	0	0	0	0
	Total	18 (14)	5 (5)	3 (5)	2 (3)	28

		Beta				
		notional (generic operator)	SMP Opearator	Other	Benchmarking	Total
Gearing	notional (generic operator)	AT,CH,CZ,DK,ES,FI,FR,HR,HU,IE,IT,IS,LU,PT,RO,RS,SI				18
	SMP Operator	PL	BE,BG,LT,NL		LI	6
	Other		SK	DE,UK	MT	4
	Benchmarking					0

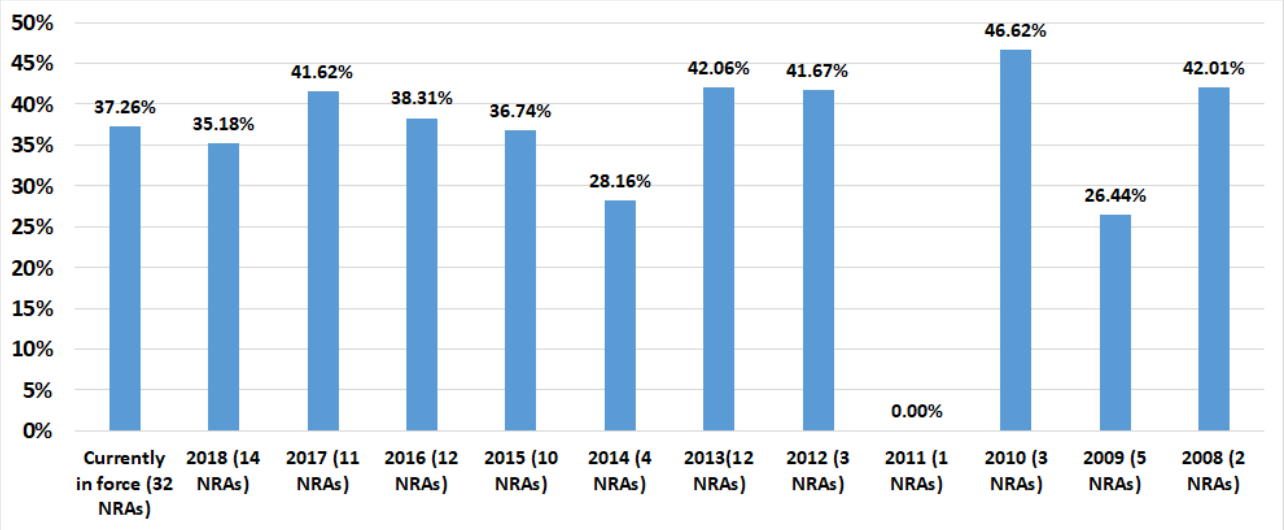
		Beta			
		notional (generic operator)	SMP Opearator	Other	Benchmarking
Gearing	notional (generic operator)	37.71%		40.00%	
	SMP Operator	55.62%	39.61%		22.00%
	Other		42.20%	42.08%	45.00%
	Benchmarking				

Source: BEREC 2018

The evolution over time of the gearing estimation is reported in figure 17[38].

[38] The evolution is depending on the NRAs that calculated the WACC in the respective year.

Figure 17 – Gearing over time



Source: BEREC 2018

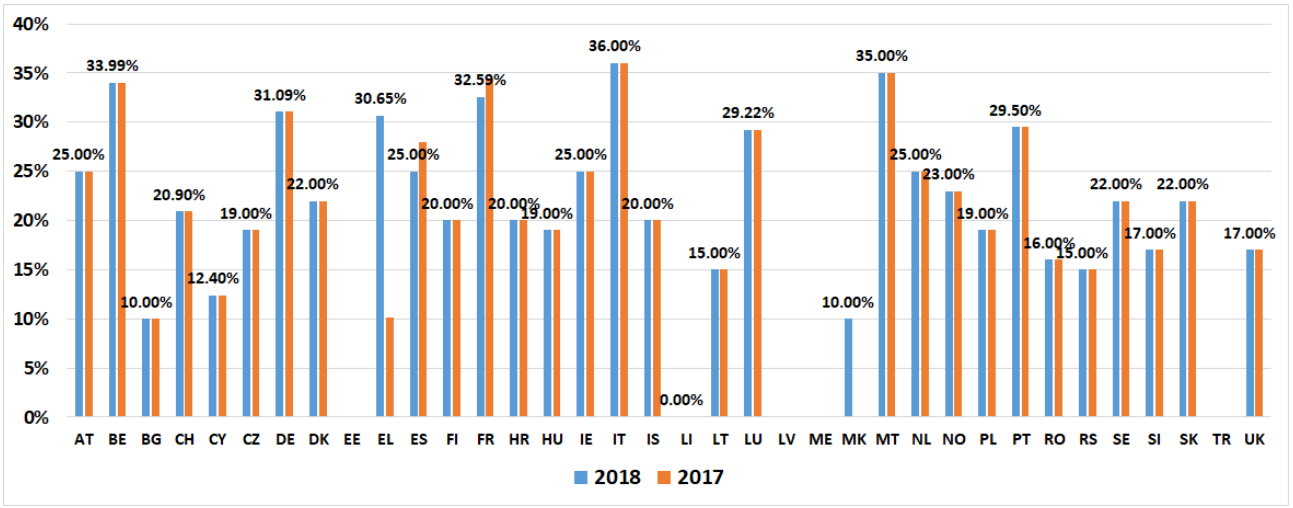
5.2.6 Tax rate

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

	Average	Median	Standard Deviation	Relative Standard Deviation	Maximum	Minimum
Tax rate fixed market (32 NRAs)	21.79%	21.45%	8.05%	36.96%	36.00%	0.00%
Tax rate mobile market (25 NRAs)	22.51%	22.00%	7.95%	35.33%	36.00%	9.00%

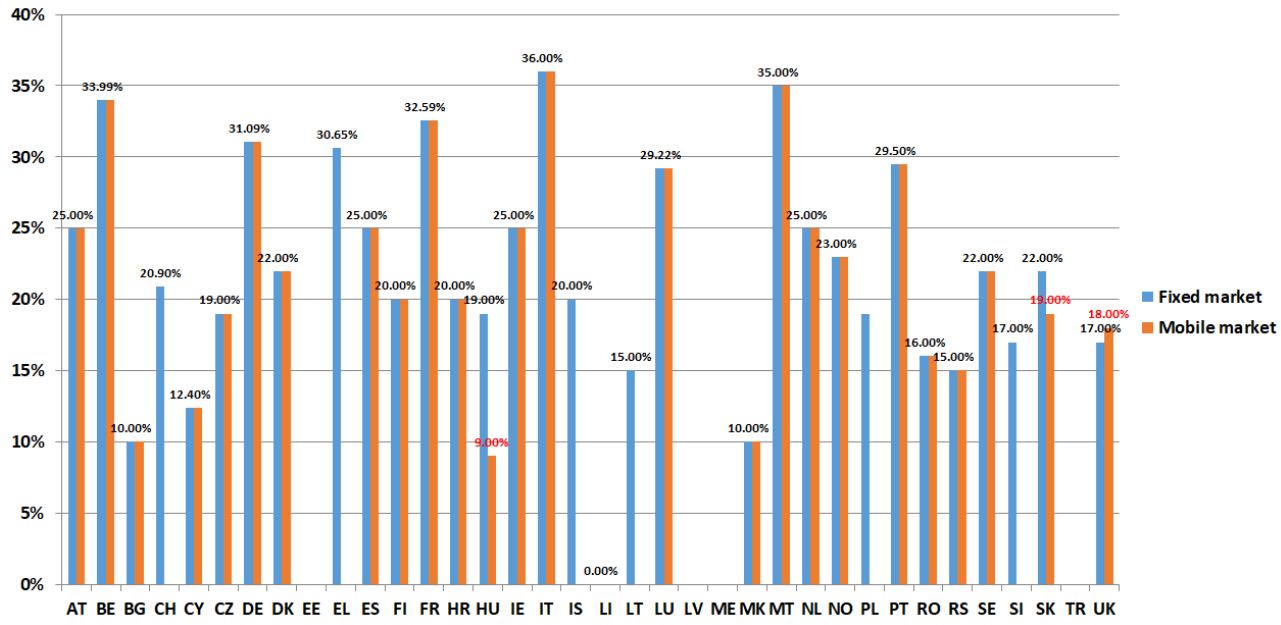
As already mentioned, taxation is also an important parameter to explain WACC variation between NRAs and it represents a typical country-specific parameter.

Figure 19 – Tax rate current in use (fixed 2017-2018)



Source: BEREC 2018

Figure 20 – Tax rate current in use (2018 fixed and mobile)



Source: BEREC 2018

5.2.7 Other Adjustments

Since the last year's report BoR (17) 169, three phase II cases have been carried out by the Commission and, consequently by BEREC for the required opinion, on WACC calculation by NRAs.

In all four cases BEREC agreed with the serious doubts of the Commission in relation to the adjustment included in the WACC calculation (BoR (17) 251 BoR (18) 55, BoR (18) 67 and BoR (18) 205. Specifically, the serious doubts of the Commission concerned in all cases a "size premium" included in the cost of equity. The Commission considered that the inclusion of a size premium in the WACC calculations was not compliant with Art(2)a and 8(5) of the Framework Directive in conjunction with Articles 13(1) and (2) of the Access Directive. The main motivations were that a size premium is not commonly applied by other NRAs in the EU and that the WACC formula with CAPM should be able to fully account for non-diversifiable risk of a company that invests in the country in which the calculation is done. In its opinions, BEREC

agreed with the Commission that the conventional application of the CAPM should be able to appropriately capture the non-diversifiable risk associated with country specific companies. Specifically, the size premium could not imply a higher non diversifiable risk, because it should not be accounted for by the conventional application of the CAPM.

Apart from a size premium, specific questions have been addressed in the 2018 questionnaire on technical adjustments on single parameters estimation and, in general, on the cost of equity.

In table 31, NRAs that apply an adjustment to the cost of equity are listed. Technical adjustments to the cost of equity are evaluated as: Post tax cost of equity (RFR+ Equity Beta*ERP) + "Adjustment". The following adjustments do not include other adjustments reported in previous sections.

Table 31 – Adjustment to cost of equity

	Adjustmet for cost of equity not included in the other parameters	Motivation
BE (2015)	0.51%	Obtained to take into account additional country risk premium CPR*lambda (the Risk Free Rate in this case is obtained as the weighted average of the German and Euro bond)
CZ (2016)	0.42%	The country risk premium captures risks connected with investments in the local market that are directly included neither into the risk free rate nor into the equity risk premium derived from the developed stock markets.The specific calculation method for estimating the country risk premium was based on a widely accepted approach developed by prof. Damodaran and represents the difference between the product of a country default risk and ratio of stock and bond markets volatility and a country default risk. The formula for that calculation is as follows: CRP=RS*(σ_c/σ_b)-RS Where: CRP country risk premium RS country default risk σ_c standard deviation of stock market revenues σ_b standard deviation of bond market revenues
DE (2018)	-0.92%	The adjustment is obtained considering a different equity ratio for the estimation of the weight of cost of Equity, including in the debt also the non-interest bearing debt
HU (2018)	0.80%	risk size premium=modification of beta: the size of the hungarian operators (capitalisation) differ from the average of the peer group. The Hungarian equity market does not have appropriate liquidity and there is a limited number of traded entities, so the market specific parameters of WACC cannot be directly observed on the Hungarian market. For 3 SMP operators could not be derived a beta, because they are not listed on the stock exchanges, besides this they can be characterised with a significantly different size in market activity.
NO (2018)	0.35%	
RS (2018)	1.38%	As for the cost of debt Adjustment is made using the inflation rate for Serbia and Eurozone, since the initial values of cost of equity are in EUR. Infation adjustment was made using Fisher equation.
SI (2014)	-1.96%	
SK (2016)	1.74%	Size premium

Source: BEREC 2018

In the table 32 the adjustments applied by NRAs to each parameter in the WACC formula and/or cost of equity are shown in comparison to the main methodology in use for the main parameters. Technical adjustments are more frequent when "RFR" and/or "ERP" are estimated using a not pure country-specific approach.

Table 32 – Combination Adjustment/ main methodologies

	RFR	ERP	Beta	Cost of debt	Cost of equity
BE (2015)					X
CY (2018)		X (contry risk premium)			
CZ (2016)					X (CRP Damoradan)
DE (2018)					X
DK (2018)	X (consistency ERP+QE)				
EL (2018)		X (contry risk premium)			
ES (2018)	X (QE)				
HU (2018)					X (Size Premium)
IE (2013)	X		X	X	
RO (2013)	X (CRP Damoradan)				
RS (2018)				X (takes into account inflation of own country with respect to EURO zone inflation)	X (takes into account inflation of own country with respect to EURO zone inflation)
SI (2014)	X (CRP+Size premium)				X
SK (2016)					X (Size premium)

	RFR	ERP	Beta	Cost of debt
BE	other	other	SMP Operator	Other
CY	country specific bond	Notional value	notional (generic operator)	Other
CZ	domestic bond	other	notional (generic operator)	Other
DE	domestic bond	other	Other	Other
DK	domestic bond	Notional value	notional (generic operator)	notional (generic operator)
EL	country specific bond	other	SMP Operator	0
ES	domestic bond	country specific	notional (generic operator)	Other
HU	domestic bond	other	notional (generic operator)	notional (generic operator)
IE	country specific bond	country specific	notional (generic operator)	Other
RO	other	Notional value	notional (generic operator)	notional (generic operator)
RS	domestic bond	Notional value	notional (generic operator)	notional (generic operator)
SI	other	other	notional (generic operator)	notional (generic operator)
SK	domestic bond	country specific	SMP Operator	Other

Source: BEREC 2018

With reference to the principle of "internal consistency" there is a relation between the choice of the beta and gearing approach with respect to the price control methodology. Generally, in case a Bottom-up approach is in use as allocation method a "notional beta" is applied. This kind of relation is missing for the cost of debt.

Table 33 – Combination Adjustment/ main methodologies

		Price control and modeling	
		BU LRIC/BU LRAIC	TD/FDC
Beta and gearing	Notianal	**14**	3
	SMP/Other	1	**10**

		Price control and modeling	
		BU LRIC	TD/FDC
Cost of debt	Notional	6	4
	SMP/Other	10	7

Source: BEREC 2018

Annex 2

WACC parameter quantitative analysis

As done in last year's report BoR(17)169, as new observation on WACC estimation are available, it is possible to analyze the time series on WACC estimation for causal inference analysis. In this 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.

As done in the report BoR(17)169, as new observation on WACC estimation are available, in order to identify parameters that may better explain the WACC variations on a historical basis. We use the following regression model, which links the WACC values to six main parameters:[39]

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

Regression analysis can provide a deep understanding and numerical information on the causality between the dependent variable and each independent variable, taking into account information provided by other independent variables. This cannot be addressed by a simple correlation analysis between each independent and the dependent variable as this only considers a measure of the extent the two variables move together, independently with respect to the information on variation provided by all other independent variables (thus not being able to prove real causality).
Several checks are needed to validate the use of a linearized model in order to infer or predict[40]. In case of a panel data analysis using a linear regression model, it is necessary, *inter alia*, to address the following main elements: i) linearity 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" of 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 (fig- ure 1)[41]. 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.

[39] The parameter have been analyzed not icluding adjstment not attributed to single parameter.
[40] "Statistics for business and economics" Heinz Kohler 1994.
[41] The residual of an observed value is the difference between the observed value and the estimated value of the quanti- ty of interest.

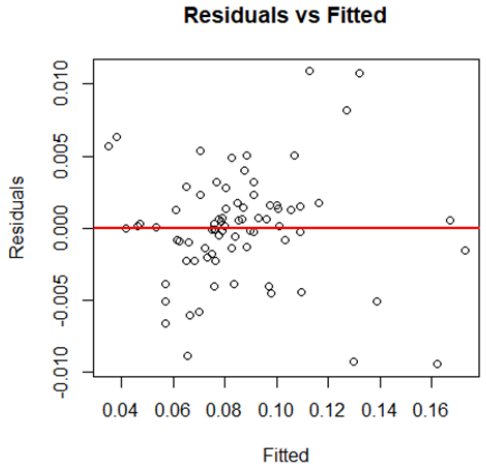


Figure 1

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 the "random" shape (visible in the residual plots).

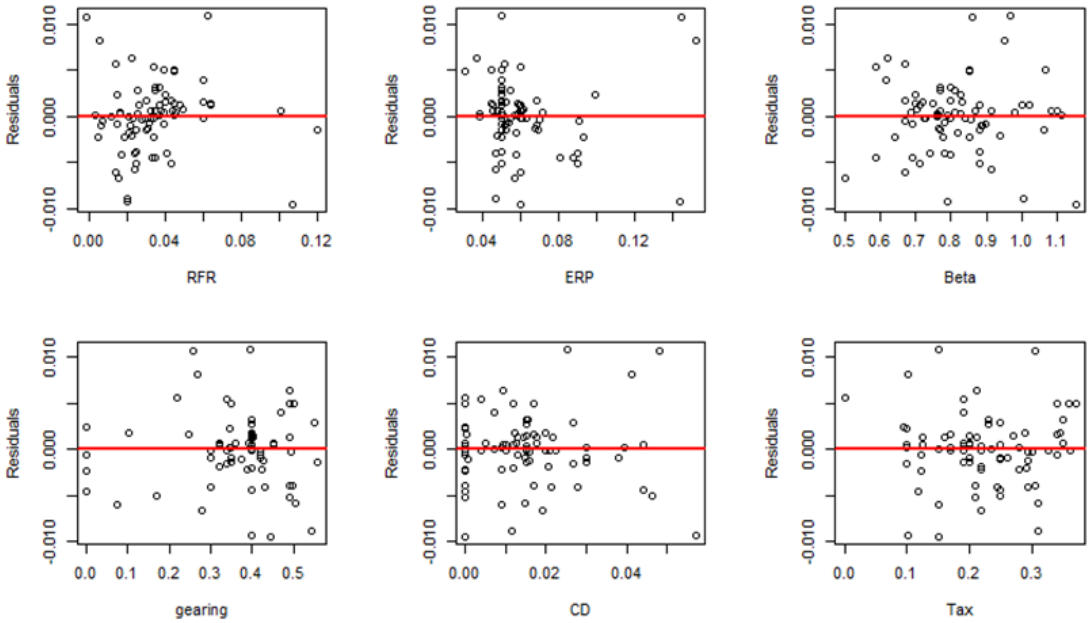


Figure 2

Another relevant measure to detect non-linearity in the model is provided through the use of the partial residual plot[42] (figure 3), which, in case of multiple regression, shows 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 the dependent variable depends on six main parameters, the use of a partial residual plot is therefore more correct than simple single-variables scatter plots[43] (correlation measure). In Figure 3 a nonparametric fitting (green line) helps to 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.

[42] 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.

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

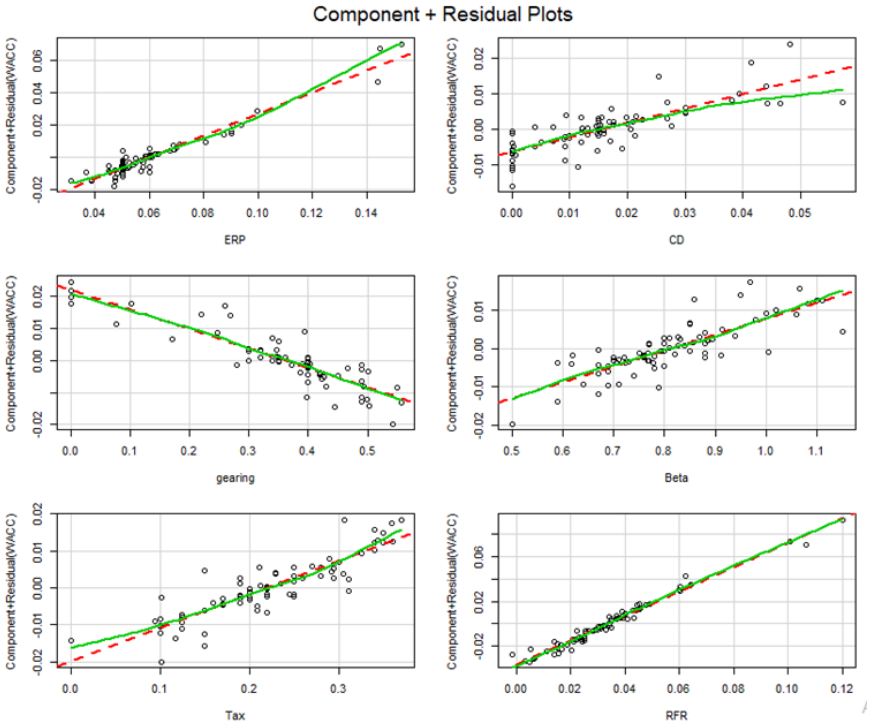


Figure 3

Normality, multicollinearity, homoscedasticity

In Figure 4, summarised statistics are provided showing that all regressors are statistically sig- nificant with an adjusted R squared of 0.98. Moreover, the standard variance inflation factor (VIF) shows 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 in figure 1); (ii) the normal Q-Q plot of the standardised 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 finding similar results, as shown in Figure 5.[44]

[44] Global test and Breush-Pagan test have been carry on with a result to discard the null Hypotesis of Non linearity, Skewness, Kurtosis, Kind of Model (categorical/continuos), Heteroscedaticity.

Figure 3 – WACC - Nominal panel data statistics

```
Call:
lm(formula = WACC ~ ERP + CD + gearing + Beta + Tax + RFR, data = mydatasell)

Residuals:
       Min         1Q     Median         3Q        Max
-0.0094894 -0.0014935  0.0001169  0.0015488  0.0108937

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.029317   0.003803  -7.709 5.80e-11 ***
ERP          0.668261   0.028376  23.550  < 2e-16 ***
CD           0.403733   0.041654   9.693 1.25e-14 ***
gearing     -0.060957   0.005296 -11.510  < 2e-16 ***
Beta         0.041399   0.004045  10.234 1.29e-15 ***
Tax          0.089950   0.006533  13.769  < 2e-16 ***
RFR          1.100303   0.023344  47.134  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.003982 on 71 degrees of freedom
Multiple R-squared:  0.9797,    Adjusted R-squared:  0.978
F-statistic: 570.4 on 6 and 71 DF,  p-value: < 2.2e-16
```

VIF

```
     ERP       CD  gearing     Beta      Tax      RFR
1.879388 1.443651 2.021375 1.340471 1.327068 1.178228
```

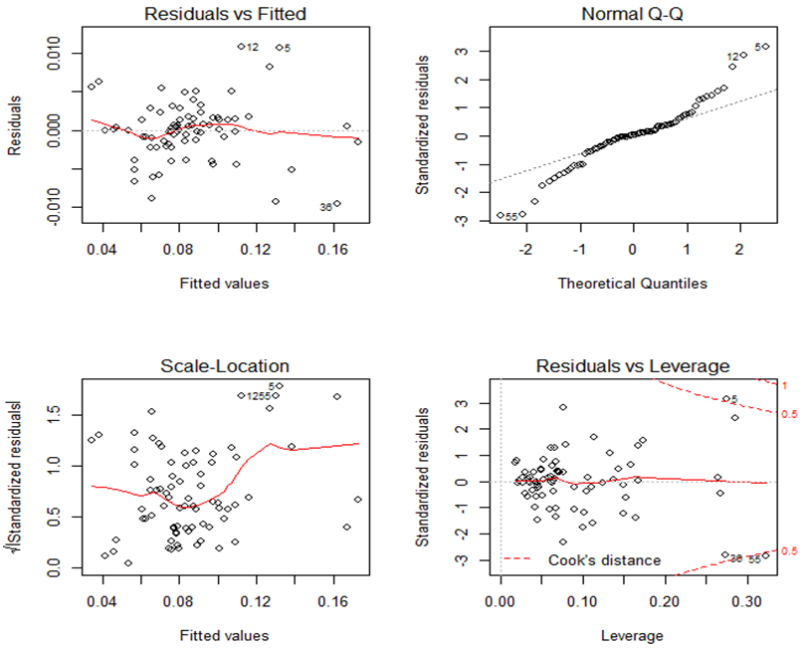
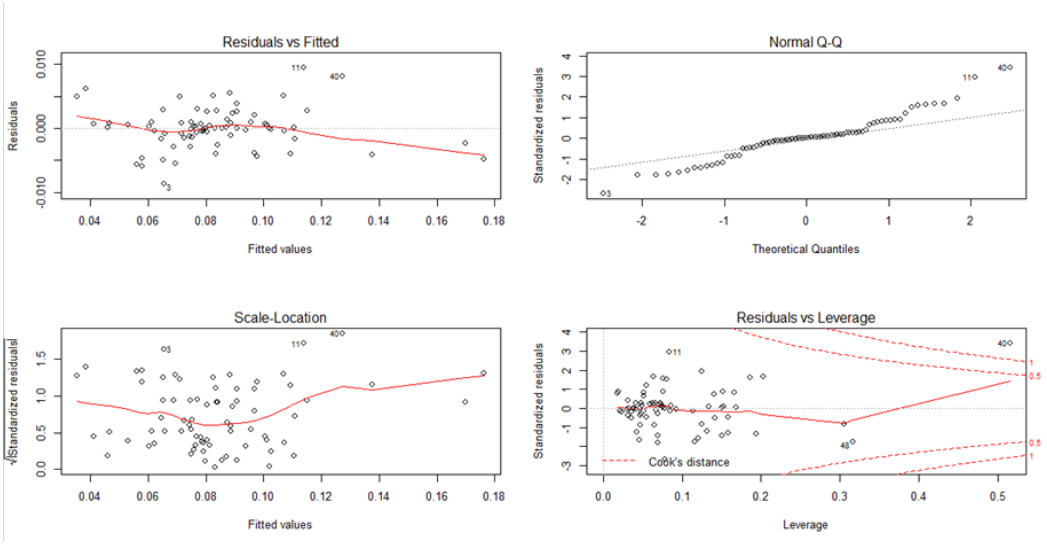


Figure 4

```
Call:
lm(formula = WACC ~ ERP + CD + gearing + Beta + Tax + RFR, data = mydatasel1)

Residuals:
       Min         1Q     Median         3Q        Max
-0.0087106 -0.0014252  0.0000029  0.0009550  0.0095205

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.030778   0.003584  -8.587 1.89e-12 ***
ERP          0.679993   0.028915  23.517  < 2e-16 ***
CD           0.378648   0.036957  10.246 2.01e-15 ***
gearing     -0.056708   0.004711 -12.038  < 2e-16 ***
Beta         0.041692   0.003571  11.675  < 2e-16 ***
Tax          0.082740   0.005765  14.351  < 2e-16 ***
RFR          1.132494   0.021597  52.438  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.003369 on 68 degrees of freedom
Multiple R-squared:  0.9832,    Adjusted R-squared:  0.9818
F-statistic: 664.6 on 6 and 68 DF,  p-value: < 2.2e-16
```

VIF

```
     ERP       CD  gearing     Beta      Tax      RFR
1.652929 1.216682 2.197829 1.327290 1.365769 1.131105
```



Source: BEREC 2018

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,[45] comparing the value obtained with a model with N independent variables and the values obtained with models com- posed 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=78) and when the possible 3 "outliers" have been deleted (n=75).

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

N=78	Total	RFR	ERP	Tax	gearing	beta	DP
R^2	97.8%	70.18%	19.15%	7.98%	6.23%	5.38%	5.05%
AIC	-855	-269	-168	-99.05	-80	-69	-64
N=75	Total	RFR	ERP	Tax	gearing	beta	DP
R^2	98.18%	72.69%	14.60%	5.42%	3.81%	3.58%	2.75%
AIC	-847.32	-277.32	-164.32	-102.51	-83.61	-80.51	-68.03

Source: BEREC 2018

The conclusion that most of the variability is explained by the RFR estimation and, to a far less extent, by the ERP estimation is statistically significant (with respect to last year's analysis the relevance of the RFR and ERP is increased, as can be shown for the percentage of R^2). All other parameters provide a much lower explanation to the variation of the final WACC value.

[45] 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.