Setting the Telecom WACC: Procedures and Estimates of the German Network Regulator Bundesnetzagentur

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Abstract

In many countries national regulators set prices or price caps for wholesale products offered by operators of telecommunication networks. The price caps are set in a way that allows the operators to earn a reasonable rate of return on their investment. Regulators estimate this rate by using the weighted average cost of capital (WACC) formula. A crucial input into this formula is the cost of equity capital. In Europe, the capital asset pricing model (CAPM) is typically used to estimate this cost.

The WACC formula and the CAPM give a solid framework to quantify the reasonable return on investment. But a large number of details have to be specified which may influence the result considerably. This paper describes and explains how the German network regulator Bundesnetzagentur (BNetzA) currently estimates the weighted average cost of capital (WACC) which is used when regulating telecommunications markets. The paper also contains comments on the reasons for following its own approach rather than adopting procedures used in other countries and other contexts.

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I Introduction and summary

In the Member States of the European Union and in many other countries, under certain conditions, wholesale prices of operators of telecommunication and other networks are regulated. National and/or regional regulators set prices or price caps which allow the operators to earn a reasonable rate of return on their efficient investments. Regulators typically estimate this rate by using the weighted average cost of capital (WACC) formula.[1] A crucial input into this formula is the cost of equity capital. In Europe, the capital asset pricing model (CAPM) is typically used to estimate this cost.[2]

The CAPM provides a solid theoretical foundation for the estimation of the future cost of equity capital. Because of its abstract nature, a lot of details have to be filled in before it can be applied to real world problems. For many of these details, no universally accepted solution exists. In the regulatory context, every little detail may matter, because large sums of money are involved. So while the fundamental principles are shared, the ways in which CAPM is implemented may for a number of reasons differ considerably between countries. The situation is similar for the other WACC components.

The EU Directory-General for Communications Networks, Content and Technology (DG Connect) currently makes an effort to harmonize the CAPM based calculation of the WACC within the Member States.[3] To contribute to this effort, the German network regulator Bundesnetzagentur (BNetzA) has asked me to describe and explain the calculation of the weighted average cost of capital (WACC) which is currently used in the regulation of the German telecommunications sector.[4] Since 2010 a single WACC is estimated for both, traditional fixed and mobile wholesale markets, on which I will primarily focus. In 2010 it became an issue, whether and to what extent a fibre-to-the-home (FttH) WACC would differ from the traditional WACC for copper based access to the unbundled local loops (ULL). Up to now there were no next-generation access (NGA) activities in Germany which are regulated. In section IV I will make a few comments on the WACC for NGA investments, such as FttH.

In the telecommunications area BNetzA has used a CAPM based WACC since 2010. From 2005 to 2010 a simplified CAPM/WACC procedure was used (Bilanzwertmethode). At the time the German regulator looked for a suitable way to set the WACC for the telecom markets, regulators in other countries had already used the relevant concepts for a number of years.[5] Their experience was a solid basis for finding a solution for Germany. In discussions with stakeholders adjustments to the procedures used in other countries were made to fit the German situation. In addition to describing and explaining the German procedures I will also comment on the reasons for following its own approach rather than adopting procedures used in other countries and other contexts.

The German regulator has to apply the European Directives as transposed into German laws. These require, inter alia:[6]

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[1] Australian Competition and Consumer Commission (ACCC) (2013) describes how regulation is organized in Germany and 16 other major industrial countries.

[2] BEREC (2013, 2015, 2016) give an overview of the CAPM/WACC procedures used by 27 European telecom regulators.

[3] See DG Connect (2015). A major contribution to this effort is made by Brattle (2016).

[4] Several employees in Division 3 and Division 1 of BNetzA and in the responsible Ruling Chambers contributed by providing useful comments. This document is only intended for use in international discussions with the objective of harmonizing the WACC calculation in EU member states.

[5] The pathbreaking academic discussions already took place in the 1960s, see Modigliani/Miller (1966 and 1967). Using the CAPM to estimate the equity cost of capital in regulatory contexts was suggested first, to my knowledge, by Robichek (1978) and Litzenberger/Ramaswamy/Sosin (1980).

[6] The relevant German laws are discussed in more detail in Stehle (2016, Section III.1).

- an international perspective,
- transparent, stable and well-documented processes and calculation procedures,
- results that are predictable by stakeholders, and
- results that provide a stable operating environment for the regulated operators, facilitating their planning and budgeting process.

Data availability and data quality requirements restrict the set of feasible estimation procedures for several WACC components. Traditionally, in the German capital market, new types of financial instruments are introduced considerably later than in the U.S. and the U.K., e.g. index linked bonds and bonds with a very long time to maturity.[7] Therefore, these instruments cannot be used in Germany.

Within these limits, BNetzA determines an appropriate procedure to estimate and implement the WACC. Typically the decisions are based on reports and studies, taking into account the relevant academic research.[8] Because of the mentioned legal requirements, only well-accepted research results may be used as a basis for regulation.[9] The whole process is subject to review by the German administrative court system (Verwaltungsgerichte). In case of further appeals, the highest German court may become involved.

Theoretically, the WACC estimate should be the best prediction of the WACC of efficient firms for the upcoming price control period, which in Germany is typically a time period of two years. Typically the WACC is determined two or three months before the price control period starts on the basis of the data that was available on the reference date. As a consequence, all input factors used in the WACC calculation are estimates for the price control period. If historical data is used in the calculations, it is assumed, often without special notice, that the historical data provides the best estimator for the control period.

WACC estimation is simplified by the fact, that the regulated firms (currently Deutsche Telekom, Vodafone, Telefonica, before 2013 also KPN) are all major enterprises, that have international stockholders and operations in many countries. As a consequence, their stocks and bonds are traded in well-functioning and highly liquid markets.

Table 1 contains the most important input factors used to estimate the German telecom WACC, focusing on the years 2010 and 2016. The following Section II covers the calculation of the cost of equity capital in detail; Section III covers the other aspects. A short summary of the calculation procedure is as follows:

- The cost of equity capital is based on an international interpretation of the Sharpe-Lintner CAPM. In a first step all calculations are made in nominal terms which results in a point estimate of the nominal WACC in line 14. (See Section II.1.)
- Instead of using firm specific values for the WACC weights (lines 11-13) and the bond yield spreads (implicit in line 8), value-weighted averages based on a peer group consisting of the ten largest European telecom companies are used. (See Section II.2.)

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[7] The first German government bond with an initial maturity of 30 years was issued in 1986. In the U.S. such bonds have existed since WWII. In the U.K., the first index-linked government bond was issued in 1981, in Australia in 1985, in the U.S. in 1997, in Germany in 2006.

[8] I have provided several studies in order to fine-tune the calculation procedures in recent years (Stehle 2007, 2010, 2016). Important prior expert opinions in the telecommunications area were given by Kempf (2002 and 2005), Ballwieser (2001 and 2006), von Colbe (2001) and Schneider (2001). Prior expert opinions are also discussed in the BNetzA decisions BK4-07-001 and BK3-09-005.

[9] My expert opinions were based as far as possible on the major finance textbooks, recently especially on Brealey/-Myers/Allen (2014), Welch (2014) and Koller/Goedhart/Wessels (2015). In Stehle (2016) the British, the Australian and the U.S. procedures to estimate the WACC in the telecom and other regulatory areas are also used as important inputs.

- From 2010 to 2014 a value-weighted average was also used in the beta estimation process. That is, stock betas for the ten largest firms were calculated on the basis of daily data for the last five years, using simple (OLS, ordinary least squares) regressions in which the STOXX Europe Total Market Index (TMI, STOXX symbol: BKXR) is the independent variable. No adjustments were made to these betas. The averaging process involved unlevering to obtain asset betas and subsequent relevering. Starting in 2015, the beta calculation was simplified by using the telecom sub-index of the STOXX Europe TMI (STOXX symbol: BTER) as the dependent variable in the beta calculation, which gives nearly identical results but is considerably less complex and much more transparent. Weights and yield spreads continue to be value-weighted averages over the ten largest European telecom companies. (See Section II.3.)
- The risk-free rate of interest (line 3) is calculated as an average over the last ten years of the yield to maturity of German government bonds with a time-to-maturity of ten years. No 'uplifts' of any type of the risk-free rate, the cost of equity capital or the WACC because of e.g. 'country' risk are made.(See Section II.4.)
- The 'international' market risk premium[10] (line 4) is based on annual time series data on the rates of return of stocks and bonds for the U.S., the U.K. and Germany. For these three countries time series on the rates of return of 'all' stocks are available that are based on today's index technology and on archival data for individual stocks that has been checked carefully. The historical risk premium approach is used to forecast the future risk premium. The equity risk premium is estimated as a simple average of the arithmetic and the geometric mean. (See Section II.5.)

The details of estimating the cost of debt, of making a WACC point estimate and of the smoothing procedure for the WACC are discussed in section III:

- The cost of debt estimate is based on the same risk-free rate as the cost of equity capital. The average yield spread of the ten firms in the peer group is added to the risk-free rate (line 8). No other adjustments are made. (See Section III.1.)
- A small part of total debt (see line 13) is classified as non-interest-bearing. This classification is used to avoid double counting of explicit or implicit interest expenses. (See Section III.2.)
- The weights used in the WACC calculation (lines 11 to 13) are based on the total market value of the equity and the book values of all non-equity balance sheet items. There is no netting of assets and liabilities. (See Section III.3.)
- Using the current GDP deflator (line 15), a point estimate of the real WACC is calculated (line 16). The real WACC point estimate in line 16 is a common estimate for both, the traditional fixed and mobile markets. (See Section III.4.)
- The high fluctuation of the point estimate for the WACC over time is not in line with the requirements of the German law. Therefore an exponential smoothing procedure is used since 2009 which leads to the WACC that is used in setting the prices/price caps. The procedure's objective is to achieve fairness in the long run without having instability and unpredictability in the short run. It allows the regulator to stick to the chosen estimation procedures for the WACC even in years when these produce unexpected results. The smoothing procedure distinguishes between

[10] I use the terms 'market risk premium' and 'equity risk premium' as synonyms. This is discussed briefly in Stehle (2016), at the end of Section I.

the two traditional networks. Line 17 in Table 1 contains the smoothed WACC for the fixed network, line 18 that for the mobile network. Over time, both will become nearly identical. (See Section III.5.)

Table 2 contains the time series of the point estimates for the fixed and the mobile network and the corresponding WACCs after smoothing for the years 2007 to 2016. It illustrates the effect of the smoothing procedure. In the time series of the point estimates for the fixed real WACC the largest 'jump' is in 2009. In this year the estimate is 2.56 percentage points lower than the preceding one. The smoothed WACC, that is the WACC used in price setting, is only reduced by 0.72 percentage points.

The summary as well as Tables 1 and 2 show, that the German way of estimating the CAPM based WACC in the telecommunications market is very similar to the procedures used in other countries and typically is in line with the recommendations made in Brattle (2016). However, a number of important differences exist:

- A precise CAPM/WACC calculation procedure has been adopted in 2010. Its input data is well defined. Judgements of any type and 'uplifts' or downward corrections which are debatable are avoided as much as possible. Rather than changing the procedure when the results are not in line with the law or expectations, a well-defined smoothing procedure is used that provides the stability required by the law.
- Most regulators estimate the future risk-free rate as an average of historic interest rates. Brattle (2016) recommends that the averaging period should not exceed 12 months. The BNetzA, for various reasons, uses an averaging period of ten years in all regulatory areas. However, since the risk-free rate is not uplifted in any way, the resulting risk-free rate currently is comparable to that used in other countries.
- The risk premium estimate is based only on data for U.S., the U.K. and Germany. For these three countries time series for the returns on stocks are available which are based on modern index calculation procedures and on high quality historical data on the individual firms that existed in the historic time periods. For other countries often only data based on historic indices is available for the years prior to the 1980s, which, for various reasons, may lead to a downward biased estimate of the market risk premium. Such data, especially the data on additional countries provided by Dimson/Marsh/Staunton, is not used, neither is their European or World Index.
- Across firms, weighted averages are used, since firm sizes differ considerably.
- Beta calculation is based on the telecom sub-index of the STOXX Europe TMI (STOXX symbol: BTER) as the dependent variable in the OLS regression. This is less complex and more transparent than the commonly used procedure in which unlevering and relevering calculations obscure the basic economic argument.

In the following sections those aspects of the German calculation procedures that are different from those used in other countries and/or from Brattle (2016) are covered in more detail than those that are similar to the other European countries. Only briefly discussed, for example, are the total returns methodology for estimating the cost of equity suggested by Wright et al. (2003), alternatives for the CAPM and alternative methods for estimating the risk premium, e.g. the dividend discount model, the implicit risk premium and consensus forcasts. These are discussed more extensively in Stehle (2016, 2010 and 2004) and in Brattle (2016).

Table 1: WACC calculation 2010 and 2016, for both, fixed and mobile

	Year	**2010**	**2016**	Comments	Details
	Reference Date:	June 30	June 30	Data available on this date is used	Section
[2]	Beta	0.78	.91	Beta is calculated by a single OLS regression.The STOXX Europe TMI is the independent, the STOXX Europe TMI Telecommunications Index the dependent variable	II.3
[3]	Risk-free rate of interest (in %)	4.07	2.41	Average over the last ten years of the yield-to-maturity of German government bonds with a current time to maturity of ten years	II.4
[4]	Market Risk Premium (in %)	4.73	4.73	The market or equity risk premium is based on data for the U.S., the U.K. and Germany, 1XXX-2015	II.5
[5]	Cost of equity capital (in %) after taxes	7.76	6.72	Based on the CAPM formula 7,76 = 4,07 + 0,78 * 4,73	
[6]	Tax factor	1.44	1.45		
[7]	Cost of equity capital (in %) before taxes	11.16	9.75	Line 5 multiplied by line 6 11.16 = 7.76 * 1.44	
[8]	Cost of interest-bearing debt capital, before tax	5.77	3.88	Sum of the risk-free rate (line 3) plus the yield spread on 10-year bonds, a market-value weighted average of the yield spreads of the bonds of the 10 largest European telecom companies	III.1
[9]	Tax factor for debt	1.04	1.04		
[10]	Cost of interest-bearing debt capital, after tax	5.98	4.03	Line 8 multiplied by line 9	III.2
[11]	Equity in % of total assets	44.38	44.86	Market-value weighted average of the 10 largest European telecom companies	III.3
[12]	Interest-bearing debt in % of total assets	49.85	50.28	Market-value weighted average of the 10 largest European telecom companies	III.3
[13]	Non-interest-bearing debt in % of total assets	5.77	4.86	Same	III.3
[14]	WACC nominal (in %) (before taxes)	7.94	6.40	7.94 = 11.16 * 0.4438+5.98 * 0.4985	
[15]	Inflation rate (in %)	1.02	1.38	Average GDP inflation rate over the last ten years	III.4
[16]	WACC real point estimate (in %)	6.92	5.02	6.92 = 7.94 - 1.02	
[17]	WACC real (in %) after smoothing for fixed market	7.11	5.63	5.63 = 0.3 * 5.02 + 0.7 * 5.90 0.3 and 0.7 are the parameters used in the exponential smoothing	III.5
[18]	WACC real (in %) after smoothing for mobile market	7.88	5.72	5.72 = 0.3 * 5.02 + 0.7 * 6.02 6.02 is the WACC real after smoothing for 2015 for the mobile market, see Table 2	III.5

Note: Columns 2 and 3 are from BK3-10-098 (mobile 2010-2012), page 48, column 4 from BK3c-16-017 (ULL, one-off charges, 2016-2018).

Table 2: Fixed and mobile market real WACCs 2007 - 2016

Ref. date	Point estimates	Smoothed WACCs fixed /mobile	Used in decision[11]	Decision date	Regul. period start	Regul. period end
19.01.07	8.07		BK4-07-001 ULL-monthly charges	30.03.2007	01.04.2007	31.03.2009
21.09.07	9.32%		BK3-07-024 Termination mobile	30.11.2007	01.02.2007	31.03.2009
2008[12]	8.07/9.32	7.91/9.32%				
20.01.09	5.51/5.87	**7.19**/8.29%	BK3-09-005[13] ULL-monthly charges	31.03.2009	01.04.2009	31.03.2011
30.06.10	6.92 %	7.11/**7.88**%	BK3-10-098[14] Termination mobile	24.02.2011	01.12.2010	30.11.2012
30.06.10	6.92 %	**7.11**/7.88%	BK3-11-003 ULL-monthly charges	17.06.2011	01.04.2011	30.06.2013
2011	6.92 %	7.05/7.59%				
30.09.12	6.12 %	**6.77**/7.15%	BK3-13-002 ULL-monthly charges	26.06.2013	01.07.2013	30.06.2016
30.09.12	6.12 %	6.77/**7.15**%	BK3-12-085[15] Termination mobile	19.07.2013	01.12.2012	30.11.2014
30.09.13	6.13 %	**6.58**/6.84%	BK2a-13-002[16] Carrier lines	08.07.2014	01.11.2013	30.06.2015
30.06.14	5.30 %	**6.20**/6.38%	BK3c-14-015[17] Interconnection	01.04.2015	01.12.2014	31.12.2016
30.06.14	5.30 %	6.20/**6.38**%	BK3a-14-011....14 Termination mobile	24.04.2015	01.12.2014	30.11.2016
30.06.15	5.20 %	**5.90**/6.02%	BK2-15-001[18] Carrier lines, SDH	05.02.2016	01.07.2015	31.12.2016
30.06.15	5.20 %	**5.90**/6.02%	BK3-16-0005 ULL-monthly charges	05.02.2016	01.07.2016	30.06.2019
30.06.16	5.02 %	**5.63/**5.72%	BK3c-16-0017[19] ULL-one-off charges	27.09.2016	01.10.2016	30.09.2018
30.06.16	5.02 %	5.63**/5.72**%	BK3-16-0103.....05 Termination mobile	07.12.2016	01.12.2016	30.11.2018

Source: Various decisions by the Ruling Chambers from 2007 to 2016. All decisions relating to the unbundled local loop, monthly rates, and all decisions on mobile termination charges are included. In addition, several other decisions are included which cover WACC problems extensively.

Comments: Column 2 contains point estimates as of the reference date (Ref. Date, column 1). Before 2007 only estimates for the fixed WACC were made. For 2008 and 2009 separate estimates were made for fixed and mobile. Since 2010 only a single WACC is estimated that is used for fixed and mobile. Column 3 contains smoothed WACCs to be used in the next regulatory period. The first of the two WACCs refers to the fixed, the second to the mobile market. The bold smoothed WACC is the one that underlies the decision that is referenced in column 4.

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[11] In this table I use a reference number that facilitates locating the original decision on the website www.bundesnetzagentur.de. For the official reference number see the document. When a decision is revised, e.g. because of a court decision, the revised decision may possibly be found by using the official reference number. A final decision (Beschluss) is often marked by 'Endgueltig' or 'final' in the results of the search engine and has an exact date at the end. Drafts are often marked 'Vorlaeufig' or by 'Konsultationsentwurf' by the search engine.

[12] In 2008 and in 2011 no new point estimate was made.

[13] This reference number leads to the press release, at its end is a link to the decision. The WACC is covered on pages 39-47.

[14] Reference number ..098 was the decision for Dt. Telekom, ..099 for Vodafone, ..100 for Telefonica and ..101 for KPN. The WACC was identical for all four mobile network operators.

[15] Again, there were four separate decisions (084-087), one for each operator. The decision for Vodafone (..085) is easy to find. Again the WACCs were identical for all four.

[16] While this reference number may be used on www.bundesnetzagentur.de, I recommend to google with the search commands "BK2-13-002" and "Beschluss".

[17] Here a draft can be found by using "BK3c-14-015" and "Konsultationsentwurf". The final decision is planned for September.

[18] Use the given reference number for searching on www.bundesnetzagentur.de and look for "Tenor des Beschlusses". A parallel decision, BK2-15-002, was made for Carrier lines, Ethernet.

[19] This is a draft. It does not describe the WACC calculation in detail, but only mentions the smoothed WACC on p. 49.

II Estimating the cost of equity capital

II.1 The capital asset pricing model (CAPM)

II.1.a CAPM aspects which are relevant in the regulatory context

The CAPM is a very abstract single-period model of the price formation in a well-functioning capital market. Neither the length of the analyzed time period nor the geographical boundaries of the market are specified.

The CAPM is well described and discussed in most modern finance textbooks.[20] I only want to add three observations: the implicit assumption with regard to international capital market integration, the fact that the risk-free rate is included twice in the CAPM equation and the fact, that the CAPM models real rates of return.[21]

An important aspect of the CAPM is that it models a financial market in which no impediments to security transactions exist, e.g. no transaction costs, taxes or information asymmetries. This assumption is unrealistic even for the U.S. stock market which Sharpe and Lintner had in mind when they developed their models. But assumptions like these are needed if economic results are to be derived in a transparent way. In the CAPM context two national stock markets can either form a (fully) integrated 'international' capital market or they can constitute two (fully) segmented national markets. The view that the existing national markets are segmented is still the prevalent view in academic research today, which focuses on the U.S. stock market. For this market high quality data on individual stocks has been available for the years since 1926 during the last 50 years.[22] Data sets for other countries that match the U.S. data with respect to quality, years of coverage and accessibility are not available.

Until a few years ago, regulators in most countries also assumed - typically implicitely - that their home country's financial markets are fully separated from foreign financial markets. That is, that its investors cannot invest in foreign markets, neither can foreign investors invest abroad. In this case, all CAPM input parameters must reflect the conditions in the home market. This view was prevalent in Germany until 2010. It is still the prevalent view in the U.S.[23] and in Australia. A notable exception is the U.K., where an international view has been taken at least since 2005. As a consequence only limited experience exists with respect to the international view.

It is safe to assume that today the financial markets of the EU member states or the OECD are fully integrated in the CAPM sense.[24] Whether today countries like Russia, Chi-

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[20] See, e.g. Brealey et al. (2014), pp. 197-2004. Note that in their equations, e.g. on page 200, they omit the expected value operator. It seems that they do not want to scare MBA students. Stehle (2010) discusses the major aspects of the model in Section IV.2, pages 56 – 67. Its extension to a multi-period context is discussed in Stehle (2004).

[21] Sharpe (1964) and Lintner (1965) do not distinguish between real and nominal rates of return. At the time when these papers were written, the authors had the U.S. capital market in mind, in which, in the preceding years, inflation rates were low. Neither do most textbook discussions of the model distinguish between real and nominal. Since the model is based on the assumption that investors are rational, and rational investors do not have a money illusion, the model can only be interpreted as a model of real rates of return. A similar argument would be that the arguments of the underlying utility functions are consumption goods and not nominal amounts of money. When international CAPMs were introduced in the middle of the 1970s, the difference between nominal and real rates of return was explicitely acknowledged, see, e.g. Grauer/Litzenberger/Stehle (1975) and Stehle (1977). A recent contribution in this context is Koedijk et al. (2016).

[22] Provided by the Center for Research in Security Prices (CRSP) of the Booth School of Business at the University of Chicago. Wharton Research Data Services facilitates the use of academic data bases. The website of Kenneth French contains many standard calculations.

[23] See Federal Communications Commission (2016), p. 236.

[24] Presently the EU has 28 member states, the OECD 35. Not all EU members are OECD members. Bulgaria, e.g. is an EU but not an OECD member. Economically, the most important difference is that the U.S. and Japan are OECD but not EU members.

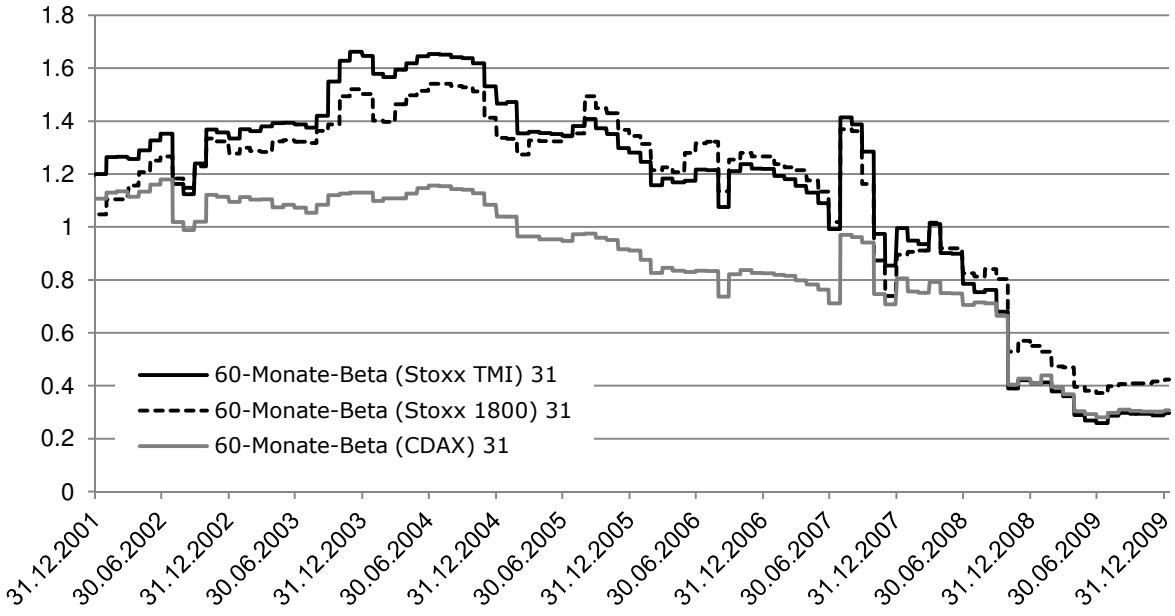
na, India, Indonesia or Iran should be added to these sets of markets is an open question. In any case, this would not be a problem when estimating betas.

Defining the set of countries whose capital markets are fully integrated in the CAPM sense is more problematic when the risk premium is estimated. This estimation process typically uses data for the past 50 to 150 years. Major problems in this context are that

- integration probably did not occur at a well-specified point in time but was a slow process;
- empirical research exists but does not point to a well-specified assumption about international capital market integration.

Stehle (2010) analyses the implications of three alternative assumptions when estimating betas: (1) the German capital market is fully segmented, in this case the CDAX stock index would be the proper index, (2) the set of countries included in the STOXX Europe TMI index are fully integrated (3) all countries included in the Dow Jones STOXX Global 1800 are fully integrated.

The analysis shows,[25] that for the Deutsche Telekom AG, Vodafone and KPN the two international indices have produced nearly identical betas, at least since 2002. They seem to be equally well suited for beta estimation. Because the ten firms chosen to form the peer group are all European, the STOXX Europe Total Market Index (TMI) is selected for the final beta estimation. This implies the assumption that today the financial markets of the 18 countries[26] which are included in this index are fully integrated in the way that is assumed by the CAPM. Figure 1 is one graph used in this discussion. It illustrates the dif-



Betas for the three alternative indices are based on monthly data based on end-of-the-month rate of return data. Source: Stehle (2010, p. 157).

Figure 1: Beta estimates for Deutsche Telekom AG, 2002 to 2009, for three alternative indices

[25] See Stehle (2010), pages 153-161.

[26] Austria, Belgium, Danmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxemburg, the Netherlands. Norway, Portugal, Spain, Sweden, Switzerland and the UK.

ference between the alternative assumptions 'full segmentation' and 'full integration' for the beta of Deutsche Telekom AG. The main reason for the lower beta between 2002 and 2007 when the purely German CDAX index is used for estimation could be that in the German market portfolio telecommunications is less important than in the two international settings. As a consequence, the risks associated with telecommunications can be diversified to a greater extent.

A second important aspect of the CAPM is that the risk-free rate appears twice in the CAPM equation: once independently and once as part of the risk-premium. The estimates used in both cases should be consistent. Identical or at least similar securities with similar times to maturity should be used in the two estimation processes. This is a point that is also stressed in Brattle (2016).

A third aspect is that even though the CAPM basically models real rates of return and a real WACC is needed for price control purposes in Germany, all WACC input factors and the WACC are first estimated in nominal terms. This is the standard procedure in most countries.

There are two important arguments for making a nominal WACC estimate as a first step:

- Interest rate, stock price and balance sheet data as well as tax rates are typically quoted in nominal terms.
- To estimate the risk premium directly in real terms, the "true" historic inflation rates would be required.[27] Experts agree that historic time series of inflation rates have an upward bias: the true historic inflation rates are most likely lower than the inflation rates implied by historic price indices.[28]

II.1.b The simplified CAPM/WACC method used before 2010

The strengths and weaknesses of the CAPM have been discussed extensively in all parts of the German regulatory process, at least since the end of the 1990s.[29] It was not used as the main model before 2010. But in many decisions the actual estimate was compared to a CAPM estimate. Until 2001, e.g., the cost of equity capital was based on a decision by the Managing Board of the Deutsche Telekom on the required return on equity after taxes, which was 20 % in 2001. This estimate was verified in the BNetzA decision by a nearly identical CAPM estimate.

From 2003 to 2009 a simplified CAPM/WACC method was used ('Bilanzwertmethode', balance sheet method), in which (1) a beta of 1 is assumed implicitely, (2) the expected rate of return on the market portfolio of all stocks is assumed to be constant over time,[30] (3) the WACC weights are based on balance sheet values not market values, and (4) a

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[27] This statement implicitely assumes that the historic risk premium approach is used. Estimating the real risk premium directly would require that in a first step, the time series of nominal rates of return on stocks and bonds are transformed to real rates with the formula $(1+R_t^{real}) = (1+R_t^{nom})/(1+I_t)$, the well-known Fisher equation (see Brealey et al. (2014, p.63)). In a second step, average real rates of return on stocks and bonds would be calculated and subtracted from each other. Dimson/Marsh/Staunton avoid this two-step procedure by defining the risk premium not as the 'arithmetic' difference between the average rates of return on stocks and bonds but by the 'geometric' difference. In their own words (2002, p.164): "The formula is 1 + equity rate of return divided by 1 + riskless return, minus 1". This formula has the advantage that the nominal and the real risk premium are identical. It is not the standard procedure, however.

[28] In Stehle (2016, Section IV.5.e) this is discussed in greater detail, based on the results of a workshop organized by the Deutsche Bundesbank in 1999, see Herrmann (1999).

[29] See BK4-01-001, pp. 41-47, BK4-03-010, BK4-05-004 and Kempf (2002).

[30] Siegel (2002) argues that this a a better assumption than the assumption that the risk premium is constant over time which is traditionally used in CAPM applications. Wright/Mason/Miles (2003) propose to estimate the risk premium on the basis of of the assumption of a constant rate of return on the market portfolio of all stocks. Their proposal is discussed in Section II.5.c.

purely national view is taken with respect to the boundaries of the assumed market, i.e. the risk premium is based on German data only. There were several reasons for not using the standard CAPM/WACC procedure, which, at the time, was already used in several European countries, notably the U.K. The two most important reasons were:

Up until 2008, the beta of Deutsche Telekom AG was higher than 1, before 2005 considerably higher (up to 1.6 in 2004).[31] At that time only the traditional fixed products offered by Deutsche Telekom were subject to regulation. The BNetzA argued, e.g. in its 2001 decision (BK4-01-001, p. 45), that the high beta reflected the high uncertainty associated with the mobile business and that the systematic risk of the fixed business was considerably lower. As a consequence it would be improper to use a firm-wide beta. Estimating a pure fixed beta was considered infeasible at the time, due to the unavailability of the required input data.[32]

Between 1996, the time of Deutsche Telekom's Initial Public Offering , and 2004 the ratio of the market value and the book value of its equity fluctuated considerably: between 0.8 (August 2002) and 7.0 (April 2000).[33] The BNetzA feared that with market value weights the stability of the WACC, which is required by the German law, could not be achieved and therefore decided to use pure book-value weights. As I have already mentioned, not even book-value weights could produce the required stability, so a smoothing procedure had to be introduced in 2009. This introduction facilitated the switch to the CAPM in 2010.

Because of these and other reasons[34] Stehle (2007, p. 5) recommended that the BNetzA ought to continue using the Bilanzwertmethode (balance sheet method) at least until 2010 but should prepare a switch to the CAPM in the years thereafter. The prediction, that most European countries will use the CAPM in the long run and the pursuit of applying identical or at least similar regulatory regimes in all countries were important reasons for this recommendation. The Bilanzwertmethode (in the way it was used from 2005 to 2009) is still considered to be a good method for estimating the WACC and it is therefore discussed extensively and compared with the CAPM/WACC procedure in current regulatory decisions.

Before and during the time the Bilanzwertmethode was used, the BNetzA analyzed in depth which components of the total debt should be included in the WACC calculation and which costs of debt should be used for different types of debt. I will come back to these issues in Section III.1 and III.2.

II.1.c Alternative capital asset pricing models

Using other models than the standard CAPM as the 'foundation model' has been discussed but rejected. In Germany, because of the high personal income tax rates and the differential taxation of dividends and capital gains, the 'After (Personal) Tax CAPM' suggested by Brennan (1970) has been used extensively in the context of valuation of firms, based on Stehle (2004). But Kempf (2005), in an expert report for Deutsche Telekom AG, noted that in the context of regulation, both models would produce very similar es-

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[31] See Stehle (2010), pages 156-158.

[32] This argument and the use of the Bilanzwertmethode were accepted in the Higher Administrative Court (OVG-Nordrhein-Westfalen) procedure 13 A 1521/03 in 2005, which was confirmed by Germany's highest administrative court in its decision BVerwG 6 B 70.05. These court decisions also confirmed that, at the time, the CAPM would not be a proper model for regulatory purposes in Germany.

[33] See Stehle (2010), page 73.

[34] Inter alia Koller/Goedhart/Wessels (2005, pp. 310-311) discuss the problems of using the CAPM in financially turbulent times.

timates for the cost of equity capital. When the tax advantage of capital gains over dividends was (nearly) eliminated in 2008, the need to use this somewhat more complex model was further reduced.

Other theoretical or purely empirically based capital asset pricing models, potentially applicable to the German market, were discussed in Stehle (2010) but rejected for a variety of reasons, including:

- The Zero-Beta CAPM
- The Arbitrage Pricing Theory
- The Intertemporal CAPM
- The International CAPM
- The Skewness CAPM
- The Consumption Based CAPM
- The Fama-French Three Factor Model

Most of these models have also been discussed extensively and subsequently rejected by other regulators. With respect to the Fama-French three factor model I would like to add that the size effect has not been constant over time in Germany and therefore is difficult to predict for the future. From 1954 to 1990 it had the usual form in Germany, after 1990 a strong 'reverse' size effect existed.[35]

II.2 The peer group choice: The value-weighted average of the 10 largest European telecom companies

Until 2007 only the fixed network of the Deutsche Telecom AG was regulated, as the incumbent had significant market power in the relevant markets. All input parameters used in implementing the Bilanzwertmethode were based on data on this firm and/or the German capital market. Since then, prices have also been set for certain mobile termination services of Deutsche Telecom, Vodafone and Telefonica. Before 2014 a fourth mobile network operator, E-Plus, existed which was owned by the Dutch firm KPN. It was taken over by Telefonica. Actually, all regulated mobile operators are the German subsidiaries of larger parent companies, but BNetzA has decided not to take the intransparent and complicated legal structures of these firms into account and to treat a parent company and its subsidiaries as an economic unit.[36]

All three parent companies are very large and exchange-listed. Their stocks and bonds are held by investors from all major countries, not just their home country.[37] All three practically offer or are capable to offer telecommunication products and services 'around the world'. An international perspective in the WACC calculation would be proper even if it were not required by law.

When the regulation was extended to four companies in 2007, it was observed, that they had different product portfolios and capital structures. Using the respective parent company's beta and capital structure would possibly have produced very different WACCs for

[35] See Brückner/Lehmann/Stehle (2012) and Brückner/Lehmann/Schmidt/Stehle (2015).

[36] The complicated legal structures of the four mentioned mobile operators are discussed in Stehle (2007, pp. 4-16) and in the BNetzA decision BK3-07-024.

[37] According to Ernst & Young (2015) 37 % of the shares of Deutsche Telekom AG were owned by foreigners in 2005, 47 % in 2014.

the four companies, which is undesirable. In the process of beta estimation it is a common procedure to use a number of firms as a peer group. For these and other reasons [see Stehle (2010) pp. 91-95] the betas, the WACC weights and the bond yield spreads are calculated as value-weighted averages based on a peer group of the ten largest European telecom companies since 2010.

The decision to only include European firms was made because they are regulated in similar ways and most will be subjected to EU harmonization efforts. Table 3 shows total assets, total market values and total sales for the 15 largest European telecoms in 2010. The table shows that rankings based on any one of these three size characteristics are nearly identical for the top nine companies. As the 10th firm, Portugal Telecom was selected because of its EU membership.

The table also shows that the 10 firms included in the averages differ considerably with respect to size. As a consequence, value-weighted not equal-weighted averages are used in the calculation of beta, the capital structure measures and the cost of debt capital. This also has the advantage, that is doesn't matter much, whether 10, 12 or 15 firms are included in the peer group.

Table 3: The 15 largest European exchange listed telecom firms according to total assets, the total market value and total sales (all in Mio. €), in 2010

Country	Firm	Book value of the equity	Market value of the equity	Book value of total debt	Total market value	Rank	Market value of the firm	Rank	Total sales	Rank
UK	Vodafone Group	102,057	89,903	74,371	176,427	1	164,274	2	49,980	3
German	Deutsche Telekom	41,937	44,900	85,837	127,774	2	130,737	3	64,602	1
Spain	Telefonica	24,274	89,089	83,867	108,141	3	172,956	1	56,731	2
France	France Telecom/O	28,748	46,165	63,296	92,044	4	109,461	4	45,944	4
Italy	Telecom Italia	27,120	19,049	59,061	86,181	5	78,110	5	27,120	5
UK	British Telecom	-2,951	10,795	35,183	32,232	6	45,979	6	23,442	6
Sweden	Telia Sonera	13,900	22,727	12,405	26,304	7	35,132	8	10,648	9
Netherl.	Royal KPN N.V.	3,841	19,093	21,010	24,851	8	40,103	7	13,509	7
Norway	Telenor	10,249	16,189	9,755	20,004	9	25,944	9	11,765	8
Portugal	Portugal Telecom	2,385	7,638	12,446	14,831	10	20,084	11	6,785	11
Switzerl	Swisscom	4,535	13,812	10,267	14,802	11	24,079	10	8,089	10
Danmk	TDC	3,639	6,509	7,975	11,613	12	14,483	12	4,829	14
UK	Virgin Media Inc.	1,679	3,864	8,666	10,345	13	12,530	15	4,284	16
Greece	OTE	1,980	5,117	8,314	10,294	14	13,432	13	5,984	13
Austria	Telekom Austria	1,614	4,404	6,885	8,499	15	11,288	16	4,802	15

As a consequence of their size, it can safely be assumed that the relevant capital markets for the ten included firms function well. Problems like market illiquidity are therefore unlikely for the stocks of these firms.

Until 2010, separate WACCs were used for fixed and mobile products. Since 2010 only one WACC which applies to both, the traditional fixed and the mobile market, is calculated. In the decision it was acknowledged that fixed and mobile activities and the relevant product markets differ economically in many respects. But it was argued that it is difficult to distinguish between them for the purpose of a CAPM based WACC estimation. Most of the large companies offer both fixed and and mobile products. It was also argued that in

Germany, in recent years, these markets had become more (not less) similar to each other.[38]

II.3 Beta estimation

II.3.a Calculation of the betas of individual stocks

In Stehle (2010, pp. 153-161) various ways to estimate the equity betas of the parent companies of the four regulated telecom operators in Germany are graphically explored using data for the years 1997 to 2009:

- Daily data versus monthly data.
- Monthly data based on monthly returns for time periods ending on the last day of a month vs. monthly data based on time periods ending on the 15th day of a month.
- Daily data based on the last 250 trading days vs. daily data for the past five years.
- Data based on the German CDAX index, the STOXX Europe TMI and the STOXX Global 1800.

All rates of return were taken from the home markets and adjusted for exchange rate changes.

With the graphical analyses two undesirable properties of betas based on monthly data were identified: (1) occasional large changes from one month to the next as a consequence of using an additional monthly rate of return and omitting one rate of return, and (2) differences that resulted from the calculation of the monthly rates of return (month-end rates vs. mid-month rates of return). Betas based on daily data seem to exhibit less fluctuation on a month-to-month basis. In addition, the confidence intervals for the estimates are smaller.

A close inspection of Figures 1 and 2 shows that in 2009 and 2010 the daily betas are considerably higher than the monthly betas. In both graphs, the betas are based on the past 60 months. Cooper (1996, p. 4) and CEG (2013) notice a similar effect. This is not necessarily an empirical regularity. But it certainly demonstrates that beta estimates may contain a large error.

Whether betas based on the last 250 trading days or betas based on daily data for the last five years are better predictors for the beta in the price control period is debatable. Since betas based only on data for the last year are more volatile, they are less in line with the stability requirement of the German law.

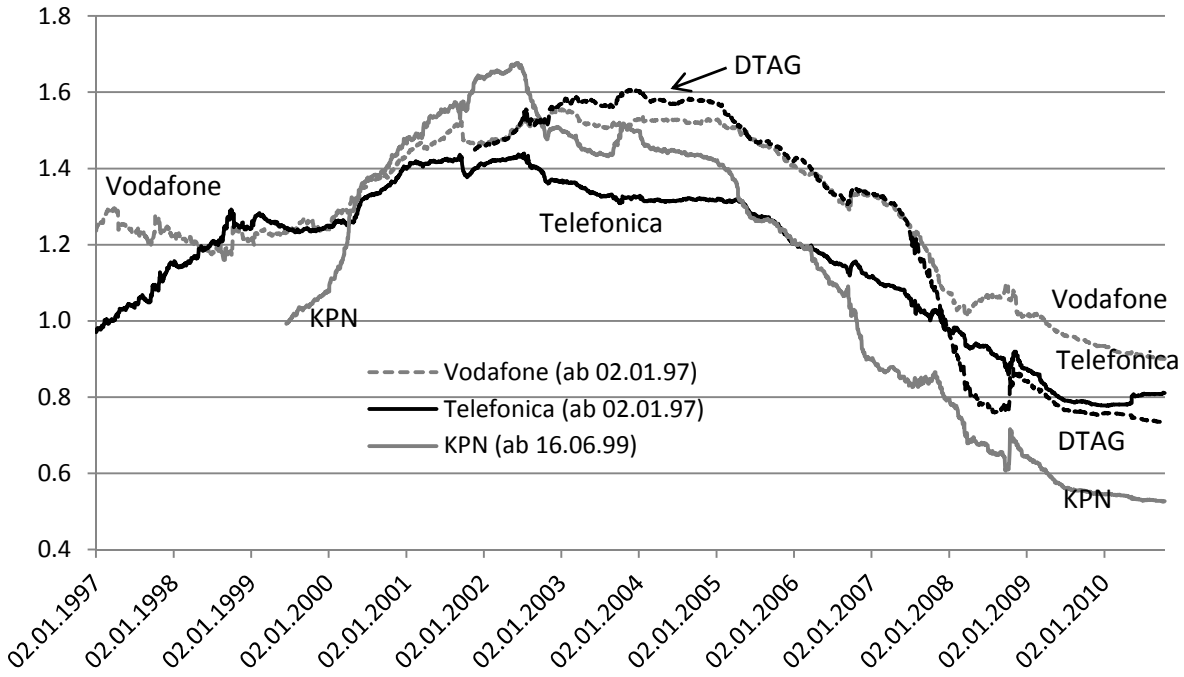
As a consequence of these and other reasons Stehle (2010) recommends that individual betas should be calculated based on daily data for the last five years. Simple (OLS, ordinary least squares) regression estimates are appropriate. Given that the firms are traded in very liquid markets the regression procedures recommended by Dimson/Marsh (1983) are not needed and beta adjustments of the type suggested by Blume (1975) and Vasicek (1973) are not appropriate. The Blume adjustment is not appropriate when the beta is consistently below 1 and is expected to remain constant or fall. In the latter case, the Vasicek adjustment is also not appropriate.

Figure 1 shows the betas of the parent companies of the four regulated operators in Germany: Deutsche Telekom, Vodafone, Telefonica and KPN for the years 1997 to 2010,

[38] Stehle (2010), pp. 85-90, discusses the desirability and the possibility to estimate separate WACCs for fixed and mobile products. In three expert opinions this issue is discussed in even greater detail. See Friedl/Küpper (Feb.2, 2011), Stehle (March 17, 2011) and Friedl/Küpper (April 2011). In view of this exchange the regulator upheld its decision in 2011.

based on daily data for the last 60 months.[39] The graph shows that the equity betas of all four firms decline after 2004. The financial crisis that started in 2007 did not stop the downward trend. The betas of the four firms behave in the expected way: They change in approximately the same way in the long run. In the short run considerable differences exist in their time series behavior.

In Stehle (2010, pp. 99-101) the behavior of the four time series in October 2008 is analyzed in detail. Between October 9 and October 14, in the middle of the financial crisis, the beta of Deutsche Telekom increased considerably, much more than the beta of Telefonica and KPN. The beta of Vodafone decreased. During these days all stock prices went down considerably because of the crisis. The stocks of Deutsche Telekom declined most, probably because of press reports about a huge data scandal. As a consequence, its beta increased by an unusually large amount. The example illustrates that the use of a peer group beta is superior to using the beta of a single company.



The betas on a given date are based on daily rate of return data for the past five years. The beta calculation is based on the STOXX Europe TMI. The rate of return data is taken from the home market and adjusted for exchange rate changes. Source: Stehle (2010, p.101).

Figure 2: Equity betas of Deutsche Telekom AG (DTAG), Vodafone, Telefonica and KPN, January 2, 1997 to June 30, 2010

II.3.b Unlevering and relevering beta

From 2010 to 2014 equity betas (often used synonyms are raw beta and regression beta) were estimated for all ten firms of the peer group. Using their individual debt-equity ratios asset betas (often called unlevered beta or operating beta) were calculated. A value-weighted 'industry' asset beta was calculated which was relevered to an 'industry' equity beta (relevered beta) by the value-weighted average of the debt-equity ratios.

The process is described and discussed in Stehle (2010, pp. 102-105 and 164-168). Different formulas for unlevering and relevering are discussed and different assumptions

[39] Only data from official trading days are used. It is assumed that the four companies are traded on every official trading day.

about the debt beta are analyzed, since the literature is not in agreement with respect to these details. Using the data for the reference date June 30, 2010 all four alternatives (Modigliani-Miller formula with and without a debt beta of 0.2, Miller formula with and without a debt beta of 0.2) resulted in very similar industry equity betas, all were between 0.781 and 0.798. The industry asset betas varied between 0.354 and 0.514.

The analysis also shows that the effect of using value-weighted averages when calculating the industry beta is also minor. Unweighted averages based on the four methods were in the range 0.763 to 0.787 for the equity beta, between 0.349 and .505 for the asset beta.

Stehle (2010) recommends using value-weighted averages, the Modigliani-Miller formula and a debt beta of 0 because the BNetzA also uses this formula and a debt beta of zero in the regulatory areas electricity and gas. This results in a beta of 0.781 which is rounded to 0.78 and used in Table 1.

II.3.c The switch to the STOXX Europe TMI Telecommunications Index

A nearly identical beta is obtained by performing only one simple linear regression in which the STOXX Europe TMI Telecommunications is used as the dependent variable. This index, like the STOXX Europe TMI is a value weighted index containing the 10 firms that were initially used as a peer group plus a number of smaller firms. Table 3 shows that the next five largest firms, that is, number 11 to 15, taken together, are only half as large as the largest firm at the time, Vodafone. So this result is not surprising.

In the following years the same result was obtained. So in 2014, in order to simplify the calculation and to make it more transparent, BNetzA started to calculate the beta only with the telecommunication subindex (see BK3c-14-015, page 76), a practice it still follows and plans to continue.

Using two indices from the same index family has the added advantage that identical stock prices and exchange rates are used on each trading day. This further reduces the need for a beta adjustment of the type proposed by Dimson and Marsh (1983). No such adjustment is made.

II.4 The risk-free rate of interest

The risk-free rate of interest is based on the time series WU8612 published by the Deutsche Bundesbank, the German central bank, on its website. This time series reflects the interest rate of German public debt securities with a current time to maturity between 9 and 10 years.[40] An average for the last ten years is calculated and used in the CAPM equation and in the calculation of the cost of interest-bearing debt capital. No uplifts of this average rate are made. Various types of uplifts have been recommended by experts and/or made by regulatory agencies because of

- Country risk
- Quantitative easing by the central banks
- 'Regulatory risk' and/or
- The use of unequal times to maturities in the CAPM equation.

[40] Using government bonds with a maturity longer than 10 years may be desirable for economic reason, but data for longer maturities is not available in Germany for the years before 1986, see footnote 9. To my knowledge such data is not available for most countries before the 1980s. The U.S. and possibly the U.K. are notable exceptions.

Uplifts of these types are discussed in Brattle (2016), in Section VI.A. They are common in many countries; sometimes other parts of the CAPM formula are adjusted. This is not the case in Germany.

Taking the average over the last ten years is in line with the German telecommunication law, however the law would also allow using a shorter or no averaging period.[41] The ten year average and the smoothing procedure discussed in Section III.5 cushion regulated firms, their customers as well as current and/or possible future competitors from unexpected changes of the interest rate, e.g. those associated with the current 'quantitative easing' (QE) programs of several major central banks. These programs are possibly responsible for the currently low interest rates in many countries. The German WU8612 interest rate in Juli and August 2016 has been negative on most days, this has never happened in prior years. In addition to the effect of quantitative easing programs, which seem to affect most countries, 'safe haven' or 'flight to quality' effects may contribute to the currently exceptionally low interest rates in Germany and some other countries.

Using a ten year average of the risk-free rate of interest and the smoothing procedure discussed in Section III.5 has several advantages compared to making adjustments or uplifts to the risk-free rate on a period by period basis:

- Elements that are debatable are avoided in the estimation process. Typically experts have very different opinions about the types of adjustments that are needed and about their proper level. There is no general agreement on the theories underlying the commonly used adjustments and the available data is very limited.
- The averaging and the smoothing procedure add stability and make it easier for the involved stakeholders to forecast the WACCs to be used in future regulatory periods. This reduces the regulatory risk.
- Both, the averaging and the smoothing procedure, only reduce the trend of the WACC temporarily. If the German interest rate remains at the level of 0 % during the next ten years, the average will be 0 % in ten years.
- Both procedures work symmetrically. When interest rates will eventually go up again, the average will be below the current rate for several years. Thus fairness is achieved in the long run without having instability and unpredictability in the short run.

II.5 The market risk premium

Estimates of the U.S. equity risk premium have been presented and discussed since the 1960s.[42] A voluminous literature exists on this topic. Efforts to estimate an international risk premium started considerably later, at the end of the 20th century.

II.5.a The international risk premium: Estimation problems

Jorion/Goetzmann (1999) discuss the hypothesis that the high magnitude of the U.S. risk premium may be caused by a 'survivorship bias': the U.S. economically was by far the most successful economy in the 20th century. In an effort to verify their hypothesis empirically they look at a large number of countries. An important weakness of their study is that they could identify only five other countries for which a rate of return time series for stocks of the desirable length (more than 50-70 years) exists that includes dividends. In

[41] Before 2010 the WU8612 interest rate on the reference date was used.

[42] An important monograph, e.g., is Cornell (1999).

these five countries and in the U.S. dividends added between 3.45 and 5.17 % to the rate of return on stocks between the 1920s and 1995 (see their table III), therefore the inclusion of dividends is an important requirement in estimating the equity risk premium. Dimson/Marsh/Staunton, in a series of publications that started in 2002, make a huge effort to include dividends in their rate of return time series for a number of industrialized countries that start in the year 1900 and to estimate a 'World risk premium'.

The various discussions of the U.S. equity risk premium are mostly based on the S&P 500 index for which at least since 1926 calculation procedures are being used that are practically identical to those implied by the CAPM and to those used in modern indices (e. g. the DAX index family which exists since 1988). Unfortunately, the other five time series that include dividends used by Jorion/Goetzmann (1999) are based on historic stock market indices. These were calculated based on the knowledge about stock markets and their indices which existed during the time of their calculation in the various countries, which is not necessarily according to today's index technology and is not necessarily the same in all countries.

Dimson/Marsh/Staunton, when possible, use "high-quality contemporary return indexes with broad coverage". But often they also have to link together a sequence of historical indices. Actually this is the case for extended time periods for most of the 16 countries for which they presented data in 2002 (the number of countries has expanded to 23 in their recent publications).

Calculating a stock market index that can be used to get an unbiased estimate of the long-run rate of return on stocks is not a trivial task. Not only cash dividends but also other important types of corporate actions must be included accurately and in the proper way:

- Stock dividends
- Stock splits
- Rights issues

The earliest 'indices', e. g. the Dow Jones Industrial Average, which is calculated since 1896, were just averages of a small number of stock prices. In 'indices' calculated at the beginning of the 20th century, the stock prices were often divided by the nominal values of the stocks before a weighted or unweighted average was taken, e.g. in Switzerland after 1910.[43] Dimson/Marsh/Staunton use such a time series, which gives a downward biased rate of return estimate, for Switzerland from 1911-1925.[44] A huge step toward modern indices was taken when price indices according to the formula of Laspeyres were calculated and rights issues were taken into account correctly; this happened in Switzerland in 1958. It took 30 more years until a modern performance index was calculated in Switzerland.

The ways in which the three mentioned types of corporate actions are used and handled in different countries differ. Historically, this probably impeded that countries learn from each other in the area of index calculation. Today this still complicates a comparison of the various stock market indices.

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[43] See Bundesamt für Statistik (1927) p. 219.

[44] See Dimson/Marsh/Staunton, Sourcebook (2016), p. 173.

As a consequence, only limited evidence exists on the question whether historic stock market indices, calculated on the basis of the local stock market knowledge existing at the time of their calculation, provide an unbiased estimate of the historic rate of return on stocks. Dimson/Marsh (2000) provide evidence on the U.K. experience in this respect. They present a new stock market time series for the U.K. that is based on today's index technology and high quality archival data on rates of return on individual stocks. They state (on page 7):"As compared with other U.K. data sources, our new indices are more comprehensive and accurate, and they follow a consistent definition throughout the sample period". They also discuss the weaknesses of several prior U.K. indices. The discussion in Dimson et al. (2002) includes even more details, especially in their Section 3.1 ("Good indices and bad") and 3.2 ("Index design: a case study"). Here they state (p. 35): "For the United Kingdom, no satisfactory series existed for 1900-54, so we painstakingly constructed an index for the top one hundred companies from original archive data.." On p. 36 they add: "..we discovered that the de Zoete index used an inappropriate rights issue adjustment". This is one of the indices used by Jorion/Goetzmann. Other weaknesses which the new time series of Dimson/Marsh (2002) avoided were the bias introduced by choosing companies with hindsight, the bias introduced by including only very large stocks and the bias introduced by starting right after the First World War.

Unfortunately, a 'painstaking' effort to calculate a stock market time series that covers a long time period before 1980 and is based on today's index technology as well as high quality archival data on individual stocks has so far been made only for a few countries in addition to the U.S. and the U.K.: One such country is Germany.[45] Stehle (2016, pp. 34-35) discusses two cases in which the historic German indices underestimate the rate of return on stocks considerably: (1) Stehle/Huber/Maier (1996) have replicated the DAX, the German blue-chip index, for the years before its existence, 1960-1987. Their estimate for the average rate of return in these years is 9.79 %. Mella, using historic blue-chip indices, estimates that the average return in these years is only 5.58 %. (2) The average rate of return on German stocks in the years 1938-1954 has been estimated by Gielen (1964) using Germany's most important historic index. His estimate of the arithmetic mean is 15.75 %. Ronge (2002) and Stehle et al. estimate this return by using today's index technology. Their estimates are 20.78 % and 21.15 %.

Even though the evidence about the quality of historic indices is limited, the available evidence suggests avoiding them if possible. This is done in the current German procedure.

II.5.b The current BNetzA procedure

In the estimation of the equity risk premium for regulatory purposes a single percentage point matters a lot. For this reason Stehle (2010 and 2016) recommends not to use the stock market time series presented by Dimson/Marsh/Staunton except those for the U.S., the U.K. and Germany. These three time series are based on today's index technology and on high quality archival data that has been used in many academic studies. For the same reason Stehle (2010 and 2016) does not recommend the use of the estimate of Dimson et al. for the rate of return on the World Market Portfolio.[46]

Stehle (2010) recommends that the estimate of the 'international' market risk premium is based on the risk premiums of the three countries. Since the U.S. stock market is

[45] Other countries are Belgium (Annaert et al. (2015)) and France (LeBris/Hautcoeur (2010).

[46] The discussion of the quality of stock market data has intensified recently. Wheatley/Quach (2013), in their NERA report, discuss the quality of the Australian data intensively, on pp. 9-28.

much larger and the data quality for this market is the highest, he recommends adding a second time series for the U.S. which is based on the data on Robert Shiller's website for the years 1871 to 1925 and also on the S&P 500 for the years since then.[47] The inclusion of this time series not only increases the implicit weight of the U.S. market but also extends the historic time period on which the international premium is based by adding data on the performance of stocks during the 'Longest Depression' in modern U.S. history.

For each of the four time series the arithmetic mean risk premium is calculated by subtracting the average rates of return on stocks from the average rate of return on bonds. Modern bond indices are chosen that reflect the rates of return on bonds with a remaining time to maturity of approximately ten years. For Germany the REXP performance index is used. Similarly, the geometric mean risk premium is calculated. By averaging arithmetically across the means and across the four time series the estimate for the international risk premium is derived: 4.73 % which is the risk premium used as the relevant input in the CAPM equation. Implicitely, the weight of the U.S. is 50 %, the weights of the U.K. and Germany are 25 %.

In Table 4, the column 'Average' shows the unweighted mean of the arithmetic and the geometric mean for each of the four time series used, which is taken as an estimate of the national risk premiums for the three countries in the specified time periods. The estimates of these four risk premiums are very similar: they differ by less than one percentage point. As a consequence it seems safe to assume that changing the weights or using different weights for each time period would not have changed the result in a significant way.

The major advantage of this procedure is that today's index technology is combined with high quality data for the included countries. The risk of including downward biased rate of return data on stocks is practically eliminated. A side benefit of this estimation procedure is that no assumption about the development of the international capital market integration over time is necessary. It is also not necessary to assume that all investors in the three countries already held internationally well-diversified stock portfolios at the begin-

Table 4: The 'international' risk premium and its calculation (in %)

Country	Time Period	Arithm. Mean	Geom. Mean	Average
U.S.	1871–2009	5,35	3,94	4,64
U.S.	1926–2009	6,01	4,38	5,19
U.K.	1900–2009	5,40	4,10	4,75
Germany	1955–2009	5,98	2,72	4,35
	Average	5,69	3,79	4,73

Source: Table V.10 in Stehle (2010, p. 109)

ning and during the 20th century.[48] The only assumptions are (1) that the national risk premiums have been stable during the time periods used for estimation and (2) the appropriate weights of the four time series are constant during these periods.

[47] Robert Shiller's time series has been used in many studies, e.g. Fama/French (2002). In the preparation of Stehle (2010) Shiller's time series for stocks was compared to Siegel's time series, both are nearly identical.

[48] Brealey/Myers (1991, pp. 873-875), in the 4th edition of their textbook, discuss the international integration of capital markets extensively. They conclude: "The truth seems to lie closer to the [segmented markets] scenario." And: " Nobody knows quite why investors are so reluctant to buy foreign shares".

The means of the four time series and the over-all mean have fluctuated from year to year since the introduction of the procedure in 2010. Accidentally, the over-all mean in 2016 is the same as in 2010. Thus the procedure is well in line with the stability requirement of the German Telecommunications Act.

II.5.c The historical risk premium approach vs. the total returns methodology

The historical risk premium approach is used to forecast the future risk premium. This is the standard textbook approach. It is based on the assumption, that the risk premium is constant over time. Darmodaran (2016, Appendix 1, pp. 123-125) provides an illustrative example that covers the U.S. 1928-2015.

An alternative estimation procedure was suggested in a prominent U.K. report by Smithers & Co. in 2003 which was commissioned by a group consisting of nearly all U.K. regulators. It was authored by Wright/Mason/Miles and is also referred to as the total returns methodology or the Wright method. It is based on the assumption that the average real return on stocks is constant over time. This assumption is more in line with the historical data for the U.S. and the U.K. than the assumption of a constant risk premium. But the traditional assumption of a constant risk premium is more in line with German and Australian data, so there is no reason for Germany to depart from it. This is discussed extensively in Stehle (2016). Brattle (2016) also does not recommend the calculation procedure suggested by Wright et al. (2003). Both, the historical method and the method suggested by Wright et al., have been discussed extensively in Australia in recent years. In June 2015 the Australian Energy Regulator rejected the Wright method (Jemena Gas (NSW) – Access Arrangement 2015-2020). The Australian Competition Tribunal upheld this decision in a merits review in February 2016.

II.5.d Other models/methods to estimate the risk premium

Other models/methods to estimate the equity risk premium are not used. In Stehle (2016, Section VI)

- dividend discount models based on the historic growth of earnings or dividends
- dividend discount models based on estimates by financial analysts (implicit risk premiums)
- forecasting procedures based on the sequence of historical premiums and possibly on additional or other data
- consensus forecasts
- combinations of estimates

are discussed but not recommended. For some of these methods the data required for estimation is not available in Germany. For some, the empirical evidence for the out-of-sample performance is not convincing. For some, such evidence does not exist at all.[49]

[49] Welch/Goyal (2008) discuss the importance of the out-of-sample performance when comparing forecasting methods.

III The cost of debt and the WACC calculation

III.1 The cost of interest-bearing debt

The future cost of interest-bearing debt is estimated as the sum of the risk-free rate used in the CAPM model and the average yield spread of the ten firms in the peer group. For each firm in the peer group the bond with a current time to maturity closest to ten years is identified. For each of the selected bonds the government bond of the home country is identified that matches the firm's bond best. Care is taken, that both bonds are sufficiently liquid. The yield spreads for the ten firms are calculated. Their value-weighted mean is taken as the estimate for their future yield spread. Table V shows the calculation details for the reference date June 30, 2010.

Table 5: Calculation of the average yield spreads on June 30, 2010.

Firm	Maturity date	Yield spread (in %)	Total market value of the firm	Company Weight in %
Telefonica	11.11.2019	2.07	172,832.66	21.02
Vodafone	04.06.2018	1.37	164,332.41	19.99
Telekom	29.03.2018	1.53	130,500.11	15.87
France Telecom	09.04.2020	1.08	109,460.91	13.31
Telekom Italia	29.01.2019	2.43	78,101.13	9.50
British Telecom	07.07.2015	2.54	45,974.98	5.59
KPN	04.02.2019	1.41	39,975.88	4.86
Telia Sonera	07.03.2017	1.15	35,115.22	4.27
Telenor	29.05.2017	1.07	25,926.16	3.15
Portugal Telecom	04.11.2019	3.13	19,908.83	2.42
Sum			822,128.29	100.00
Unweighted mean		1.778		
Total-market-value weighted mean		1.696		

III.2 Non-interest-bearing debt

Economically, for all debt, interest has to be paid, implicitely or explicitely. The question, for which types of debt an interest rate of zero percent is appropriate when calculating the WACC has been discussed extensively in Germany.[50] Having a component of the WACC for which the interest rate is assumed to be zero has a long tradition in the telecommunications regulation. In the areas of electricity and gas regulation such a component is mandatory by law.

An example is the treatment of accounts payable. Typically in Germany, equipment vendors and suppliers of materials offer an early payment discount to their customers. These discounts are traditionally large, so the buyers typically will make an effort to pay early. In the 'old days' Deutsche Telekom AG, when buying a cell tower, put the full purchasing price in its balance sheet and used the balance sheet figure to calculate depreciation, even when it made a prepayment and the actual payment was lower than the gross purchasing price. Depreciation is deducted when calculating taxable income. If the trade

[50] Stehle (2010) summarizes this discussion, which took place between 2000 and 2002, on pp. 205-209.

credit would be considered interest-bearing in the calculation of the WACC, there would be a double counting of the implicit interest that is paid on the trade credit. As a consequence, in the calculation of the WACC for regulatory purposes, the interest rate on accounts payable was set to zero until 2010. In 2010 Deutsche Telekom AG informed the BNetzA, that the current practice is to put the net purchasing price in the balance sheet, that is, the gross purchasing price minus the prepayment discount.

Another item that was considered non-interest-bearing in the 'old days' was pension provisions. These traditionally play an important role in the financing of German firms. Many employers promise their employees to pay a pension after their retirement, typically a defined benefit pension. A balance sheet item, pension provisions (Pensionsrückstellungen) exists, which is equal to the estimated present value of the pension promises made by the firm. Traditionally interest on this item was viewed as a cost of labor and deducted in the calculation of gross income. If the pension provision would also have been classified as intest bearing debt, the interest on it would have been double-counted. Today, interest on pension provisions is typically not included in labor cost any longer. As a consequence, pension provisions, since 2010, are viewed as interest-bearing debt.

As a consequence of these and other reclassifications, the amount (and as a consequence the weight) of the non-interest-bearing debt has decreased significantly during recent years. But it still is one of the areas in which the different stakeholders have different views.

One of the balance sheet items that is still considered a non-interest-bearing part of debt is deferred tax liabilities. This is supported by Brealey/Myers (2014, page 488, footnote 7).

III.3 WACC estimation

The WACC concept and the WACC formula are well described and discussed in most modern finance textbooks.[51] As a consequence of the existence of non-interest-bearing debt, the right-hand side of the WACC equation contains three products. In practice, since the cost of the non-interest-bearing debt is zero, only the first two products matter.

The WACC weights are calculated as value-weighted averages over the 10 largest European telecom companies. In a first step of the calculation equity, as a fraction of the total market value, is determined for each firm. Firm specific fractions are also calculated for interest-bearing and non-interest-bearing debt. The company specific fractions are weighted by the company weights, these are given in the last column of Table V. In Table 1 the resulting WACC weights are in lines 11-13.

All types of debt are included in the calculation; there is no netting between assets and liabilities.

Many companies consider only long term financing when calculating the WACC. They leave out the cost of short-term debt. Brealey/Myers, in all editions, have stated that this is incorrect. In (2014, p.489) they state: "The lenders who hold short-term debt are investors who can claim their share of operating earnings. A company that ignores this

[51] In Brealey et al. (2014), e.g. on p. 221 and pp. 437-441. The 'textbook formula' (p. 221) is built on the Modigliani/Miller models. This is covered in detail in Copeland/Weston/Shastri (2005, pp. 559-569). In Stehle (2010) it is discussed on pp. 52-56.

claim will misstate the required return on capital investments". Not including short-term debt would also give an undesirable incentive to the regulated firms: By substituting long-term debt with short-term debt they could increase the WACC.

A few lines later, Brealey/Myers state that current liabilities are usually "netted out" by subtracting them from current assets, which may be an acceptable approximation. But they add: "But when short-term debt is an important, permanent source of financing – as is common for small firms and firms outside the United States – it should be shown explicitly on the right-hand side of the balance sheet [used in the calculation], not netted out against current assets. The interest cost of short-term debt is then one element of the weighted-average cost of capital."

Table 6: The WACC weights used in 2010

Country	Firm	Equity	Interest-bearing debt	Non-interest-bearing debt
Germany	Deutsche Telekom	34,22%	53,03%	12,75%
Spain	Telefonica	51,48%	45,14%	3,38%
France	France Telecom/Orange	42,17%	53,65%	4,18%
U.K.	Vodafone Group PLC	54,74%	38,25%	7,01%
U.K.	British Telecom	23,47%	72,19%	4,34%
Italy	Telecom Italia	24,38%	73,82%	1,81%
Netherlands	Royal KPN N.V.	47,44%	49,03%	3,52%
Sweden	Telia Sonera	64,67%	31,26%	4,07%
Norway	Telenor	62,37%	33,23%	4,40%
Portugal	Portugal Telecom	37,48%	55,12%	7,39%
Unweighted Mean		44,24%	50,47%	5,29%
Total-market-value weighted mean		44,38%	49,85%	5,77%

The WACC weights (bottom line) are calculated as weighted averages of the firm-specific fractions in column (3)–(5). The total market values of the firms are used in the weighting process (market value of the equity plus the book value of the debt, based on the most recent annual balance sheet).

Source: Stehle (2010), Table V.4 on page 97.

III.4 Transforming the nominal into a real WACC

The estimated nominal WACC is translated to a real WACC by using the Fisher equation (see footnote 28) and the German GDP deflator (the implicit GDP price deflator). More specifically, annual inflation rates are taken from time series ZR037 on the website of the Economic Council of Economic Experts, an academic body advising the German government (Sachverständigenrat). The average of the rates for the last ten years is used.[52] This average is used in order to be in line with the calculation of the risk-free rate of interest.

III.5 The combination of a point estimate and exponential smoothing

From early on, BNetzA chose to achieve transparency by using a relatively simple, well-defined procedure that delivers a stable point estimate for the WACC. The intention was that a procedure, once accepted, would be used for at least several years. However, in financially turbulent times it is next to impossible to use a point estimate for the WACC based on a well-defined procedure and, at the same time, to provide the stable economic

[52] To find this time series, I recommend to google with the search commands 'Deflatoren', 'Sachverstaendigenrat', 'ZR037'.

environment required by law. In 2009 the WACC estimate was 2.56 percentage points or 32 % below the prior estimate made in 2007 (see Table 2). The WACC estimate could have been "manipulated" by adjusting the calculation procedure and/or the input data. The problem with such a procedure is that in a future period the WACC estimate may increase by 2.5 percentage points. What options would the regulator then have? To go back to the original procedure and/or the original data?

The regulator decided in 2009 (see BK3-09-005) to continue using the current procedure and to adjust from then on the WACC point estimate by a well-defined smoothing procedure. The smoothing procedure is supposed to reduce the financial risks that result from unexpected WACC changes for the regulated firms, for their (wholesale) customers and for firms that consider entering these markets. It reduces the necessity of using "fudge factors" in the setting of the WACC.[53]

A major characteristic of the smoothing procedure is that in a first step, point estimates for each input factors are made and combined to a point estimate for the future nominal and the real WACC in the traditional way. The real WACC estimate for the future is used in the second step as an input for the exponential smoothing procedure. The smoothed (real) WACC currently used is the second input. The smoothed WACC to be used in setting the prices in the next regulatory is calculated by the formula:

Real WACC to be used in the next regulatory period = 0.3* real WACC point estimate for the next period

+0.7*real WACC currently used

In 2016 (see Table 1, line 17 and Table 2, next to last line) the following calculation was made for the fixed WACC on which the draft decision for 2016-2018 is based: 5.63 = .3*5.02+.7*5.90

The parameter value 0.3 has often been recommended for similar situations in the German academic literature.

The 2009 decrease of the estimated WACC by 2.56 percentage points had to do with the financial crisis that started in 2007. In 2008, stock prices in Germany decreased by about 40 %, the yield-to-maturity on 10 year government bonds went down by nearly 1.5 percentage points. An alternative for the smoothing procedure would have been an adjustment of the WACC estimating procedure that takes the effects of the financial crisis into account. Unfortunately, well-accepted theoretical or empirical guidance on this topic was not available at the time and is still not available now.

The smoothing procedure has a welcome side effect when the historical method is used to estimate the risk premium:[54] Using this method, the 40 % decrease of stock prices leads to a lower estimate of the equity risk premium and, as a consequence, to the cost of equity capital and the WACC. Most experts agree that in a financial crisis the premium stays put or goes up a bit. The smoothing effect alleviates this undesirable property of the historical method.

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[53] A fudge factor is a modification of a calculation, formula or model in order to make it fit expectations or data. Brealey/Myers/Allen, in their textbook, have always argued strongly against using fudge factors in setting discount rates (in the 11th ed., 2014, e.g., on pages 231 and 247), in the 4th ed. (1991) on pp. 197-199 and 875-876.

[54] The historical method is discussed in Sections II.5.b and II.5.c.

IV Estimating the WACC for NGA networks

At present, there are no NGA activities in Germany which are price regulated ex-ante. The BNetzA regularly monitors the relevant markets and firms. So far, activities that should be regulated according to the European directives or the German law could not be identified. Like in several other European countries, it seems unlikely that this will change in the near future (see Brattle (2016), p. 11).

To inform the involved parties about the probable magnitude of a WACC estimate for their future NGA activities, in case these would be regulated, the BNetzA commissioned an expert report for this topic, Stehle (2010). Its major results were:

- A special WACC is only needed for FttH (or FttB) networks, not for xDSL products.
- While the traditional method to estimate the German telecom WACC, the Bilanzwertmethode, could, in principle, also be modified in a way that would allow the estimation of an FttH WACC, enormous data problems would exist.
- Creating FttH networks that run parallel to or replace the traditional networks is associated with non-diversifiable risks which are higher than the risks associated with traditional fixed and mobile networks, especially in the starting years.
- Once these networks are well established, the risks of running such networks will probably decrease.
- An estimation of the FttH CAPM beta with the standard methods (pure play, full-information) is not possible in 2010, because there are no listed firms that have a significant part of their operations in this area, neither in Germany nor in other countries.[55]
- A rough estimate of the real WACC for FttH networks is 2.78 percentage points higher than the WACC-estimate for the traditional fixed and the mobile network. It is based on a higher equity beta (1.3 vs. 0.78), the use of the arithmetic mean in the estimation of the risk premium and a higher yield spread (2.5 vs 1.70 %).
- Even if the estimation method cannot be improved in the near future, the assumed beta should be decreased by 0.03 per year, so that in ten years the beta estimate is 1.0.

[55] These difficulties still exist, see Harris/Fischietti/Chou for the Brattle Group (2015).

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