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The Cost of Equity of Network Operators - Empirical Evidence and Regulatory Practice

by

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Abstract

Since the events of liberalization of energy markets leading to the introduction of unbundling and incentive regulation for electricity and gas network operators in many countries, the long-lasting discussion between regulation authorities and regulated firms about adequate equity costs has gained in intensity. Heavy criticism has been formulated by the affected network operators, suggesting that the methodology is not adequate, that data sets of companies used for computation of equity returns are not comparable or that other parameters of the formula, such as the market risk premium and the risk-free interest rate, are not appropriate.
One aim of this paper consequently is to give an overview of results obtained in the field of empirical research, the focus lying on utilities, network operators and specific industry betas. As such, this paper may serve as a hub to research papers and give numerous sources for practitioners and researchers. Secondly, this paper presents and discusses the most important drivers of systematic risk which is an indispensable groundwork for determining adequate betas. Thirdly, an overview of the handling of equity return by regulation authorities will be provided. Fourthly, a recent data set with more than 20 network operators will be used to compute the required equity return with different methodologies (CAPM, Fama-French-TFM, Ross-APT). This provides evidence that regulatory practice ignores the Fama-French-TFM or the APT, even though these approaches prove to be valid to improve estimation quality. Consequently, this paper supports regulators and practitioners in search for the right approach to use concerning investment decisions and regulatory rule setting.

Keywords: Network operator, cost of capital, asset pricing models, regulation, cost of equity
JEL-Classification: G31, G38, L9

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1 Introduction

Since the events of liberalization of energy markets leading to the introduction of unbundling and incentive regulation for electricity and gas network operators in many countries, the long-lasting discussion between regulation authorities and regulated firms about adequate equity costs has gained in intensity. Regulators typically use the Capital Asset Pricing Model developed by Sharpe (1964), Lindtner (1965) and Mossin (1966), including as major parameters the beta, representing the systematic risk of a share or a portfolio that cannot be hedged away, the risk-free interest rate and the market risk premium. Heavy criticism has been formulated by the affected network operators, suggesting that the methodology is not adequate, that data sets of companies used for the computation of the beta are not comparable or that other parameters of the formula, especially the market risk premium and the risk-free interest rate are not chosen appropriately.

At the centre of this discussion, the question is raised if the CAPM is the right concept to compute equity costs and how the CAPM should be applied in the specific context. With regard to network operators, two major applications of the CAPM are observable: required equity returns are included into the weighted average cost of capital used to discount capital streams in investment decisions and regulators fix equity cost for regulatory purposes notably revenue regulation. The first application is required by investors and has found its way into textbooks long ago. The investment decision of a firm should, according to standard textbooks such as Brealey et al. (2007), depend on the net present value (NPV) of a project and is thus related to two major components: the value of the future cash-flows and the discount factor, which is governed by the cost of capital. An investment following Dixit and Pindyck (1994, pp. 3ss) can be considered as "the act of incurring an immediate cost in the expectation of future rewards". Cash-flows related to the investment will be discounted with the weighted average cost of capital, which is computed based on the leverage, the interest rate on debt and the required return on equity. Three major approaches are commonly used to calculate the cost of equity: The Dividend Growth Model, the Capital Asset Pricing Model (CAPM) (and different more advanced methodologies built on the CAPM) and the Arbitrage Pricing Theory (APT). The dividend growth model (DGM) was introduced by Gordon (1959) and is basically a cash-flow evaluation model. The CAPM generalizes the assumption that investors choose efficient portfolios along the capital market line, the result being a market equilibrium theory of asset prices under risk. The CAPM is a very popular approach in theory and practice, even if major reservations to its application exist due to the restrictiveness of its assumptions. Many extensions and modifications have been discussed, one of the most important ones being the three-factor-model (TFM) presented in Fama and French (1992) which improves quality by additionally incorporating size and valuation effects. An alternative to the CAPM based on a fundamentally different approach is the Arbitrage Pricing Theory (APT) by Ross (1976). The expected return for a stock depends linearly on a set of factors that may for instance be macroeconomic such as interest yield, GDP growth or default risk premium.

From a regulator's point of view, equity costs represent a major cost factor that is considered in the context of regulation. Classically, the regulator provides a calculation scheme for regulatory equity which is multiplied with a predetermined equity cost rate usually calculated by external advisors using the CAPM. The CAPM-approach in regulation of rates of return was first discussed by Breen and Lerner (1972) who suggest that regulators should use the CAPM carefully especially if individual betas are attributed to each firm. In this context, a fierce discussion has taken place in countries such as Australia, Germany or UK about the adequate cost of equity, especially with regard to assumptions about beta and the market risk premium.[1] The major problem with cost of equity is that different approaches based on different data sets lead to significantly different results. Fama and French (1997) conclude that the market risk premium and the betas are the major sources of uncertainty:

Estimates of the cost of equity for industries are imprecise. Standard errors of more than 3.0% per year are typical for both the CAPM and the three-factor model of Fama and French (1992). These large standard errors are the result of (i) uncertainty about true factor risk

[1] This paper will focus on the discussion of risk measured primarily through beta. A discussion about the use of market risk premiums can be found in Brigham et al. (1985).

premiums and (ii) imprecise estimates of the loadings of industries on the risk factors. Estimates of the cost of equity for firms and projects are surely even less precise.'

One aim of this paper is to summarize major empirical results obtained by researchers with regard to the discussed uncertainty. Literature on utilities' cost of equity is vast: A branch of research is dedicated to computing utilities' equity returns based on different methodological approaches. A first model (before the CAPM was established) was developed by Miller and Modigliani (1966) using a Dividend Growth Model. McDonald (1971) and Litzenberger and Rao (1971) present a similar model to estimate the required return on public utility equities. Higgins (1974) uses an infinite growth model to compute the cost of equity. Hagerman and Ratchford (1978) examine the economic and political variables that affect the rate of return on equity allowed by the regulator. Thompson (1979) estimates the cost of equity capital for electric utilities based on an infinite growth model. Bower et al. (1984) present evidence that the APT may lead to better results than the CAPM. Brigham et al. (1985) find that risk premiums should be based on expectations, not historical data. Conine and Tamarkin (1985) discuss the implications of skewness in utilities' return distributions. Norton (1985) presents an empirical study on the impact of regulation on beta. Shome and Smith (1988) publish the most recent work based on a DGM to compute utilities equity cost of capital. Ahn and Thompson (1989) use a modified continuous time asset pricing model to analyze the effect of regulatory risk on the cost of capital. Elton et al. (1994) compute the equity cost for nine New York Utilities with the Arbitrage Theory Model based on Ross (1976). Fama and French (1997) analyze the magnitude of a CAPM vs. their three-factor-model approach incorporating firm size and the ratio of book-to-market-value. Cooper and Currie (1999) analyze the equity cost of the UK water sector. Buckland and Fraiser (2001) investigate whether beta of UK water utilities is constant and whether variation is explainable. Craig et al. (2001) assess the cost of capital for a standalone transmission company. Gerke (2003) uses data from German and European Utilities companies to calculate required equity return. Miller and Zhang (2003) compute equity costs for the Chinese power and water sector. Wright et al. (2003) conduct a study of the cost of capital for regulated utilities in the UK. Gray and Officer (2004) present a report about equity beta for the discussion between Austrian utility companies and the regulator. Lally (2005) presents equity beta data contesting their results. Rocha et al. (2007) present evidence about capital costs of South-American electricity distributors. Frontier Economics (2008) compute the required return on equity for the German regulator. Kema Consulting (2008) estimate equity returns. Kobialka and Rammerstorfer (2009) measure the effects of different events on the risk of some German energy companies. PwC (2009) present betas and equity return for the UK regulation authority OFGEM.

Some authors have been focusing on the question, how finance theory may be applied to regulation with regards to the problem of beta instability. Breen and Lerner (1972) discuss that a regulatory body might be misled if it attempts to use estimated beta coefficients in an uncritical way. Myers (1972) summarizes how rate of return regulation can be reasonably based on finance theory. Brigham and Crum (1977) argue that the use of historical betas is problematic, and the CAPM should only be applied in rate cases with a great deal of caution. Pettway (1978) analyzes the stability of betas and finds that during some periods of the early 1970s, stable betas could be computed. Chen (1982) finds that about half of the companies considered in his sample have beta instability problems. Hill and Schneeweis (1983) and Bowen et al. (1983) find that the incident at Three Mile Island led to a significant change in the industry beta. Uselton et al. (1986) show that major incidents such as the Three Mile Island incident or the OPEC crisis have not changed industry risk permanently. Fraser et al. (1988) however find that these events have altered the structure of risk with risk shifting from systematic to individual risk. In this context, Gombola and Kahl (1990) discuss approaches how to forecast systematic risk. Kihm (2007) suggests that regulators should use an equity cost approach only to determine the minimum equity return and focus on the real issue to find the fair equity return. Malko et al. (2007) recommend regulation authorities to use different mathematical models to obtain the cost of equity and apply a sound judgment when considering these results.

A third branch of research has focused on the question, if and how regulation influences systematic risk. This research is based on a hypothesis by Peltzman (1976) who assumes that regulators buffer shocks and thus decrease systematic risk. Clarke (1980) finds that the introduction of fuel adjustment clauses in the early part of the 1970's reduced beta. Golec

(1990) analyzes the financial effects of fuel adjustment clauses on beta and states that the clauses only have minor effects. Riddick (1992) finds that regulation lowers systematic risk, using a stochastic model for beta. Lewellen and Maurer (1993) discuss the impact of deregulation based on an analytical valuation model. Alexander et al. (1996) present evidence about how regulation affects beta based on a comparison of several countries. Sawkins (1996) analyzes the key regulatory initiatives in the English and Welsh Water industry and finds that these events have affected investors' expectations. Kolbe and Burucki (1998) state that deregulation leads to an important increase of required equity return. Binder and Norton (1999) find that betas decrease as regulation becomes more severe. Robinson and Taylor (1998) research the effect of regulation on beta with an event-study methodology. Morana and Sawkins (2000) present evidence about the impact of regulatory uncertainty on share price volatility of the English and Welsh water industry. Nwaeze (2000) finds that deregulation significantly increases risk.
One aim of this paper consequently is to give a more detailed overview of results obtained in the field of empirical research, the focus being utilities in general and network operators in particular. As such, this paper shall serve as a hub to research papers and give numerous sources for practitioners and researchers. Secondly, this paper will present and discuss the most important drivers of equity returns. Thirdly, as data sources with regard to network operators are limited, this paper will show how regulators handle the equity cost and evaluate these approaches. Fourthly, this paper will present an application of different valuation models to a set of 20 network operators. As such it is the first paper comparing the effectiveness of different equity cost valuation models to a relatively large set of network operators. This work may help regulation authorities and companies setting equity costs in the future.
The structure of this paper is as follows. The second section will give an overview over existing research with regard to the valuation models, empirical evidence and discuss the range of results obtained and the major explanatory factors. Section three presents an overview of the approach regulation authorities have taken in more than 20 countries. In section four, recent results of an own analysis based on the CAPM, Fama-French-Three-Factor-Model and the APT will be presented. In section 5, an approach of how regulators may use a simplified TFM model with regard to non-listed network operators will be discussed. The last section concludes.

2 Theoretical Background and Empirical Evidence about Utilities' Cost of Capital

This section is threefold: First, cost of capital concepts and their regulatory application will be presented. Second, an overview over existing empirical evidence is given. Third, the main drivers of systematic risk will be discussed in order to gain insights about the practical application of the cost of capital models.

2.1 Cost of Capital Concepts

The dividend growth model (DGM) was introduced by Gordon (1959) and is basically a cash-flow evaluation model. In this model, the stock price is determined by the dividend , the dividend growth rate g and the discount rate, which represents the cost of equity r_e. If the dividend growth rate is assumed to be zero, the share price corresponds to the infinite payment stream computed with the actual dividend and the cost of capital:

$$P = \sum_{t=1}^{\infty} D \cdot (1+g)^t / (1+r_e)^t$$

The CAPM developed by Sharpe (1964), Lindtner (1965) and Mossin (1966) starts from the hypothesis that investors choose efficient portfolios, which can be found along the capital market line in the presence of a risk-free asset. The result is then a market equilibrium theory of asset prices under risk which notably leads to the conclusion that solely systematic risk matters in the evaluation of equity costs. The systematic risk is thereby measured through β_e corresponding to the correlation between the asset return and the market return. Further the market return r_m and the risk-free interest rate r_f are relevant in the evaluation of equity cost:

$$r_e = r_f + \beta_e (r_m - r_f)$$

One has however to bear in mind that the measured sensitivity captures market risk as well as financial risk due to leverage. Therefore several techniques have been developed for delevering equity betas[2], resulting in so-called asset betas. The formula used along this paper is the Hamada formula, which is used by Morningstar to unlever in the Beta Book. The asset beta β_a depends on the observable equity beta β_e, the corporate tax rate τ and the debt-to-equity ratio *D/E*.

$$\beta_a = \frac{\beta_e}{1 + (1 + \tau) D / E}$$

The CAPM is a powerful and popular approach in theory and practice, even if major reservations to its application exist. Many extensions and modifications have been discussed, one of the most importing being the three-factor-model (TFM) presented in Fama and French (1992) which improves quality by additionally incorporating size and valuation effects. They consider two effects that have been identified empirically: First, smaller firms tend to have higher equity returns than big firms because they are more risky (bankruptcy is more costly for small firms than for big firms). Secondly value stocks require higher returns than growth stocks due to relatively weak prospects. Fama and French (1992) use return differences generated from portfolios of small and big companies (SMB, small minus big) and portfolios of value and growth stocks (HML, high minus low book-to-market-value) to derive time-series for SMB and HML values.

$$r_e - r_f = a + \beta_e (r_m - r_f) + s_e SMB + h_e HML + \varepsilon$$

An alternative to the CAPM based on fundamentally different approach is the Arbitrage Pricing Theory (APT) by Ross (1976). The return for a stock depends linearly on a set of *n* factors *I* via *n* individual sensitivities $\beta_{e,i}$. These factors may for instance correspond to macroeconomic variables (i.e. inflation, yield spread). The return generating process is then written as follows:

$$\tilde{r}_e = a + \beta_{e,1} I_1 + \ldots + \beta_{e,n} I_n + \varepsilon$$

The expected return thus depends on the risk-free rate, the sensitivities $\beta_{e,i}$ and the loadings λ_i of factor *I*:

$$r_e - r_f = a + \beta_{e,1} \lambda_1 + \ldots + \beta_{e,n} \lambda_n$$

The factor loadings λ_i can be interpreted as average price for each risk factor *I*. From an application point of view, the aforementioned models are the relevant ones that have been applied during the last 50 years to evaluate the cost of capital. Further valuation models are for instance found in Elton at al. (2009).

Regulators and regulated companies typically use the CAPM to compute equity return as a component of the weighted average cost of capital (WACC). An important aspect that has to be considered in setting regulatory returns is taxes. An assumption of the classic CAPM is that all incomes are tax-free. Transferred to an environment with corporate taxes on benefits, CAPM-based required equity returns have to be considered post-tax. The cost of debt is normally given pre-tax; the tax shield has to be accounted for separately. From a regulator's point of view, there are three basic options to set a WACC, pre-tax, Vanilla and post-tax. The pre-tax-WACC is given by:

$$r_{WACC} = \frac{1}{1 + \tau} \cdot \frac{E}{D + E} r_e + \frac{D}{D + E} r_d$$

This concept is applied if the regulatory regime does not consider taxes as regulated expenses that the customer has to pay via regulated network tariffs. As they consequently reduce the network operator profit, these taxes have to be earned in advance. The post-tax-WACC is computed as follows:

[2] Cf. Pratt and Grabowski (2007, pp.143-150).

$$r_{WACC} = \frac{E}{D+E} r_e + (1-\tau)\frac{D}{D+E} r_d$$

The use of post-tax-approach is adequate when taxes are included in the regulatory cost base as if the firm was solely equity financed. Therefore, the tax shield has to be removed. The Vanilla-WACC is used, if actual tax charges are included in the regulatory cost base.

$$r_{WACC} = \frac{E}{D+E} r_e + \frac{D}{D+E} r_d$$

From an investor's point of view, all that matters is the post-tax WACC.

2.2 Overview over Empirical Evidence

Empirical work on equity cost of utilities companies is vast, with the first results already published in the 1960s. Table 1 presents important empirical results obtained by various authors. Unfortunately, these results were mostly obtained for integrated utilities as unbundling has gained major importance only during the last decade, e. g. with the unbundling standards set in the European Union in the year 2005. Standard results presented in include the valuation model used, asset-beta, equity-beta, market risk premium r_m-r_f, utility/network operator risk premium r_m-r_f, risk-free interest rate r_f and the total cost of equity r_e. To make the results more comparable and to account for large differences in inflation over time, the results were adjusted for inflation and thus represent real interest rates.

Table 1: Comparison of empirical studies' results (interest rates computed to real values)

Authors	**Data**	**Years**	**Model**	β_a	β_e	r_m-r_f	r_e-r_f	r_f	r_e
Miller and Modigliani (1966)	63 US electric utilities	1954-1957	DGM	-	-	-	3.7%	0.8%	4.5%
Litzenberger and Rao (1971)	78 US electric utilities	1960-1966	DGM	-	-	-	2.2%	0.0%	2.2%
McDonald (1971)	102 US electric and gas utilities	1958-1969	DGM	-	-	-	2.5%	1.5%	3.9%
Higgins (1974)	81 US electric utilities	1960-1968	DGM	-	-	-	2.9%	0.0%	2.9%
Pettway (1978)	36 US electric utilities	1971-1976	CAPM	-	0.50	-	-	-	-
Hagerman and Ratchford (1978)	Value Line Investment Survey, 89 utilities companies, questionnaires	1975	CAPM	0.32	0.69	-	5.4%	-0.4%	5.0%
Thompson (1979)	76 US electric utilities	1958-1976	DGM	-	-	-	7.6%	0.7%	8.2%
Clarke (1980)	50 US electric utilities	1965-1974	CAPM	-	0.62	-	-	-	-
Bower et al. (1984)	77 US electric and 25 US gas utilities	1971-1979	CAPM	-	0.68	10.9%	7.4%	-1,7%	5.7%
			APT	-	-	-	5.4%	-1.0%	4.4%
Brigham et al. (1985)	Dow Jones Utilities	1966-1984	DGM	-	-	5.6%	5.1%	2.1%	7.1%
Conine and Tamarkin (1985)	60 US electric utilities	1971-1980	CAPM	-	0.77	7.5%	5.8%	2.1%	7.9%
			TFM	-		7.5%	7.2%	2.1%	9.3%
Norton (1985)	CRSP, 21 regulated companies	1975	CAPM	-	0.63	-	-	-	-
Fraser et al. (1986)	86 US electric utilities	1974-1983	CAPM	-	0.35	-	-	-	-
Shome and Smith (1988)	96 US electric utilities	1971-1985	DGM	-	-	-	3.6%	2.1%	5.7%
Golec (1990)	79 US electric utilities	1969-1983	CAPM	-	0.36	-	-	-	-
Gombola and Kahl (1990)	61 US electric and 48 US gas utilities	1967-1981	CAPM	-	0.52	-	-	-	-
Riddick (1993)	Electric and gas distribution utilities on CRSP tapes	1965-1986	CAPM	-	0.53	-	-	-	-
Elton et al. (1994)	NYSE, sample of 122 utilities	1978-1990	APT	-	-	-	6.0%	2.6%	8.6%
Alexander et al. (1996)	Utilities from more than 15 countries	1990-1995	CAPM	0.50	-	-	-	-	-
Fama and French (1997)	NYSE, AMEX, NASDAQ	1963-1994	CAPM	-	0.66	5.2%	3.4%	1.4%	4.8%
			TFM	-	-		5.4%	1.4%	6.8%
Cooper and Currie (1999)	LBSRMS, seven water companies	1994-1999	CAPM	0.57	0.72	9.2%	6.6%	2.8%	9.4%
Buckland and Fraser (2001)	LSE, 10 UK water companies	1989-1999	CAPM	0.60	0.76	-	-	-	-
Cragg et al. (2001)	US and UK electric, gas and pipeline companies	1990-1999	CAPM	-	0.55	-	4.6%	2.7%	7.3%
			APT	-	-	-	9.8%	2.7%	12.5%

Miller and Zhang (2003)	S&P IFCG China Index, 12 electric and 3 water utilities	1993-2002	CAPM	-	0.97	7.9%	7.7%	2.0%	9.7%
Gerke (2003)	14 German utilities in CDAX utilities	1992-2001	CAPM	0.48	-	3.6%	1.7%	4.7%	6.4%
	17 European utilities	1992-2001	CAPM	0.65	-	7.9%	5.1%	4.7%	9.8%
Gray and Officer (2004)	Energy Distribution and Retailing GICS	1994-2004	CAPM	-	1.02	-	-	-	-
Lally (2005)	64 US electric and 29 US gas utilities	1999-2003	CAPM	0.30	0.75	-	-	-	-
Rocha et al. (2007)	Value Line Investment Survey	1998-2005	CAPM	0.41	-	6.9%	5.2%	2.8%	8.0%
Frontier Economics (2007)	23 utilities companies	2006-2007	CAPM	0.39	0.79	3.0%	6.6%	3.0%	6.6%
Kema Consulting (2008)	6 European electricity network operator	2000-2008	CAPM	0.37	1.00	6.3%	6.3%	2.7%	9.1%
	4 European gas network operators	2000-2008	CAPM	0.41	1.10	6.3%	6.9%	2.7%	9.7%
PwC (2009)	7 UK, 14 international utilities	2004-2009	CAPM	-	0.90	5.0%	4.5%	2.5%	7.0%

Some adaptations were required to enhance comparability. All nominal values were adjusted for inflation using data from the US Federal Reserve. If the risk-free rate was not published in the paper, T-Bill 3 months average for the analyzed period was taken as proxy. For the later publications regarding Europe and South America, such modifications were not necessary as real values were published. A table with all modifications is available upon request.

Average cost of equity for utilities amounts to roughly 8% in real terms and the risk premium for utilities to 5.3%, with a standard deviation of 2.0%. The equity beta is regularly found to be below 1 (with a mean value of 0.71), the asset beta below 0.7 (with a mean value of 0.46). In earlier studies, authors have often referred to the equity beta while the more recent research focuses on asset betas in order to differentiate between business risks and risks due to the financing structure. The major reasons that may explain the different results are: the valuation methodology, the time series used for the computation and the companies selected. Authors using similar methodologies, data sets and time series mostly obtain comparable results.[3]

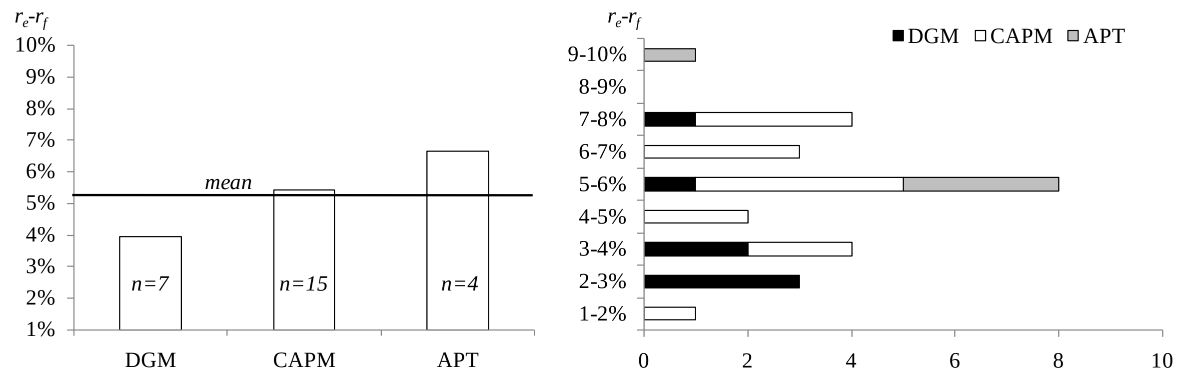

Figure 1: Risk premium (average per valuation model, number of studies)

2.3 Drivers of Estimated Equity Returns

In this section, reasons for the obtained differences will be discussed. The aim of this work is to provide guidelines for application of cost of capital concepts for regulators and network operators.

Valuation Models

The choice of the cost of equity model has considerable impact. Thompson (1979) discusses the important differences obtained with dividend growth models. He suggests that the main differences between his results and the results obtained by Miller and Modigliani (1966), McDonald (1971), Litzenberger and Rao (1972) and Higgins (1974) are mainly due to the use of different models (finite vs. infinite growth) and the inclusion of deferred taxes with much uncertainty about the true impact of each factor left. A more recent discussion concerns differences obtained with CAPM and APT on identical data sets. Bower et al. (1984) claim that regulatory authorities should not use the single-factor CAPM-approach but refer to the APT-approach. Conine and Tamarkin (1985) find that using a three-moment CAPM leads to

[3] For instance Miller and Modigliani (1966) vs. Litzenberger and Rao (1971), Cooper and Currie (1999) vs. Buckland and Fraser (2001) or Frontier Economics (2008) vs. Kema Consulting (2008).

significantly higher capital cost estimates than using the standard CAPM. Elton et al. (1994) find that the difference between valuations based on either CAPM or APT is significant. In another empirical research, Fama and French (1997) calculate the cost of capital for several US industries using CAPM and TFM. They find that a difference of about 2% between both approaches is common and that the standard error in the estimate of the rate of return frequently exceeds 3%. Table 2 indicates that equity costs are often higher with multi-factor-models and that these models obviously also lead to a substantial increase in R^2. We will discuss in section 5 whether these conclusions hold also for network operators.

Table 2: Studies using different valuation approaches

Cost of equity	**Factors**	R^2_{MFM}	R^2_{CAPM}	COE_{MFM}-COE_{CAPM}
Bower et al. (1984)	Market risk, unexpected inflation, yield spread (Δ long term government bonds - T-Bills one-month), risk premium (Δ long term government bonds - BAA corporate bonds)	0.43	0.27	-2.3% electricity +1.9% gas
Conine and Tamarkin (1985)	Market risk, skewness	-	-	1.4%
Fama and French (1997)	Market risk, Firm size, Book/market ratio	0.62	0.55	2.0%
Cragg et al. (2001)	Market risk, Exchange rate index, Oil price, 3 month U.S. treasury bill yields, Expected GNP deflator, Expected growth in GNP , 30-year U.S.T-bill yields[4]	-	-	5.2%

The common use of CAPM is nevertheless comprehensible due to the ease of application and the coherent theoretical background. Today, researchers and regulation authorities seem to have mostly abandoned the search for alternatives to the CAPM as no evidence of more recent use can be found. That issue will be discussed more thoroughly in section 5.. For companies and regulation authorities, this implies that different valuation methodologies should be used in order to validate results obtained with the CAPM. A further analysis of risk drivers is important to explain in more depth the different results obtained in empirical studies and to deduce implications for the practical use of valuation models. Leverage plays a specific role in this context as it can be interpreted as a multiplier of market risk. From empirical research, one can distinguish four additional determinants of risk: activities in the value chain (generation, distribution, sales), branch (electricity, gas, and water), regulation scheme (rate of return, incentive) and regulatory events (i.e. announcements, hearings) as well as firm size.

Leverage

Leverage is an important driver of risk at a firm and industry-specific level. As the systematic risk beta can only be measured in its leveraged form ('equity beta'), several techniques exist to unlever it obtaining an 'asset beta'.[5] After unlevering, which results in excluding the capital structure risk, only the business risk is reflected in the asset beta. Therefore, in the following sections the influences on systematic risk will be measured using asset betas.

Activities in the value chain: Network operator vs. integrated utility company

Betas reflect systematic risk. Consequently, integrated utilities should be characterized by different betas than pure distribution or transmission network operators. Unfortunately, most empirical evidence has been founded on data of integrated US electric companies. One interesting first step is consequently to compare pure (either transmission or distribution, or mixed) network companies with integrated companies. We identified only three studies that permitted to separate results with regard to the value chain.

Table 3: Summary of results

[4] Elton et al. (1994) use the same selection of factors to compute equity returns, but unfortunately do not present standard-CAPM results that can be compared with the APT results.

[5] Cf. Pratt and Grabowski (2008, pp. 143-150).

Beta values	Equity beta			Asset beta		
	Integrated	*Network*	**Δ**	*Integrated*	*Network*	**Δ**
Gray and Officer (2004)	0.87	0.65	0.22	0.45	0.36	0.09
Frontier Economics (2008)	-	-	-	0.50	0.39	0.11
Kema Consulting (2008)	0.68	0.61	0.07	0.43	0.37	0.06
Mean values	0.74	0.63	0.15	0.46	0.37	0.09

Frontier Economics (2008) conclude that risks are significantly different for network operators as compared to integrated utilities firms. Table 3 supports this assumption, one can see that betas of integrated utilities are higher than network operator betas. In the available studies, no significant evidence can be found for a difference between pure distribution network operators, pure transmission network operators and mixed forms. One may thus conclude that often liberalized generation and retail activities are characterized by higher systematic risks than the regulated network business. Given the ongoing unbundling activities for instance in Europe, more data about disintegrated utilities companies may be expected in the close future which will permit to derive more insights about specific risks along the value chain.

Branch: Electricity, gas and water

Another topic of interest is the relationship between systematic risk and the product offered to the customer, i.e. electricity, gas and water. Water generation compared to electricity or gas distribution is not affected by any price risk with regard to raw materials (oil, coal) or other generation costs. Electricity demand depends more heavily on production activities and as such on economic cycles than gas or water usage. Gas is subject to some transportation risk as the average regional distance between upstream/generation and consumption is often higher than for electricity and water. From all data gathered, average electricity asset beta is 0.46, average gas asset beta is 0.43 (both based on 7 studies) and average water asset beta is 0.34 (based on 2 studies, only UK values). Table 4 shows beta differences found in studies.

Table 4: Differences in beta

Studies	Asset Beta		
	Electricity	*Gas*	*Water*
Bower et al. (1984)[6]	0.71	0.58	-
Alexander et al. (1996)	0.56	0.51	0.46
Gray and Officer (2004)	0.59	0.59	-
Lally (2005)	0.27	0.22	-
Frontier Economics (2008)	0.45	0.42	-
Kema Consulting (2008)	0.37	0.41	-
PwC (2009)	0.29	0.28	0.22
Mean values	0.46	0.43	0.34

Frontier Economics (2008) describe beta differences between electricity and gas utilities of 0.03 comparable to the mean values indicated in Table 4, but find, testing for statistical effects, that differences are insignificant. The comparison with water betas is problematic, due to the fact that only few papers were published which focus on the UK. The differences of risk attributable to one or another product are however likely to be linked to the generation or (whole-)sales activities and are only to a very minor degree network specific.[7] A differentiation between the cost of equity for electricity or a gas distribution network companies hence does not appear to be necessary.

Regulation scheme and regulatory events

One further question of interest is, if regulation itself will increase or decrease systematic risk. The discussion is based on Peltzman's hypothesis (1976) that regulators will buffer shocks. Norton (1985) analyzes the impact of regulation on beta estimates, regulation being characterized by breadth of authority conferred by statues, commission staff and budget size

[6] Only equity beta values were available.

[7] One possible exception is the competition on the demand side between oil and gas heating leading to additional systematic risk.

and judicial decisions. He finds that the equity beta of strongly regulated utility firms is about 0.12 lower than that of unregulated firms. Alexander et al. (1996) present 1991 to 1995 data for a large number of companies and countries, discussing the link between the regulatory scheme and systematic risk (cf. Table 5). Besides the regulatory system, the authors identify ownership, competition, industry structure (degree of vertical integration) and the diversity of operation as main reasons why beta may differ.

Table 5: Comparison of different incentive schemes from Alexander et al. (1996)

Beta values (asset)	Electricity	Gas	Energy	Water	Telecom	Average
High-powered	0.57	0.84	-	0.67	0.77	0.71
Intermediate	0.41	0.57	0.64	0.46	0.70	0.60
Low-powered	0.35	0.20	0.25	0.29	0.47	0.31

For the impact of incentive schemes, they find that low powered ones imply average betas around 0.31, intermediate 0.60 and high powered 0.71. A high-powered incentive scheme can be characterized by few regulatory interventions (apart from setting the frame). In the recent environment of many network operators, characterized by unbundling and incentive regulation, it is unclear if this effect still exists. Systematic risks due to fluctuations in consumer demand or to market price of oil and coal risks have been significantly reduced by the separation of the value chain. The regulatory risk for network operators under incentive regulation, such as the non-acceptance of the regulated asset base, stranded investments and effects of network size and age structure are specific to firms and as such not represented in beta.[8] Consequently, Frontier Economics (2008) find that average asset beta for a network operator under incentive regulation is not significantly different compared to the value of an operator under a cost of service regulation. From these results, different conclusions are possible: Either no real differences exist or these differences are dominated by other effects, such as the rigor of the regulation authority, which obviously may be more important than the regulation regime itself.

A second topic of relevance has been studied intensely and leads to more straightforward results: The question if and how regulatory events impact systematic risk. Pettway (1978) found that beta increased significantly in 1975 and 1976 (to about 0.7) in the US due to some regulatory events before coming back to an initial level of about 0.3 to 0.5. Chen (1982) discusses the fact that betas are partly non-constant over time. In his sample, he finds that about 50% of the companies are characterized by non-stable betas. Based on more recent data, Buckland and Fraser (2001) study the same question. They find that betas vary significantly over time and are influenced by certain (political or regulatory) events. Table 5 gives an overview of risk influencing factors identified in empirical work.

Table 6: Comparison of studies analyzing risk changes due to regulation

Authors	Data	Years	Measure	Explanatory facts
Pettway (1978)	36 US electric utilities	1971-1976	Beta	Regulatory events
Chen (1982)	100 US electric utilities	1961-1977	Beta	GNP growth, financial leverage, dividend changes
Sawkins (1996)	10 UK water and sewerage companies	1989-1994	Stock price	Regulatory events
Norton (1985) / Binder and Norton (1999)	CRSP, 21 regulated companies	1975	Beta	Deregulation (measured by regulator budget and staff) increases risk
Kolbe and Burucki (1998)	49 US utilities	1994	Stock price	Switch from rate of return regulation to competition increases risk
Robinson and Taylor (1998)	12 UK regional electric companies	1990-1996	Stock price	Regulator’s intervention increase risk
Nwaeze (2000)	SIC 4911, SIC 4931	1976-1997	Beta	Regulator’s intervention increase systematic risk
Morana and Sawkins (2000)	10 UK water and sewerage companies	1989-1998	Stock price	Reduction of volatility due to revision of price caps

[8] Cf. Evans and Guthrie (2005) for a discussion of the link between different concepts for the regulatory asset base and the existence of specific risk due to demand fluctuations when investments are irreversible and Schober et al. (2011) for an analysis of idiosyncratic risks due to the network structure.

Buckland and Fraser (2001)	LSE, 10 UK water companies	1989-1999	Beta	Betas are a function of time, regulatory shocks increases beta
Kobialka and Rammerstorfer (2009)	4 German utilities companies	2005-2008	Beta	Only short term effects

Clearly, total risk is influenced by regulation. A reduction of regulatory risk, i.e. by adapting price caps, leads to a reduction of risk. Policies increasing firm risk, for instance switching from rate of return to incentive regulation, lead to higher betas. One can thus conclude that regulation itself is an important determinant of the cost of equity of utilities.

Default and distress risk (firm size, book-to-market ratio)

Banz (1981), Fama and French (1995) and others observed, that required equity cost is negatively related to firm size. This may be due to the fact that smaller companies are in general more risky, as bankruptcy is more costly for smaller than for bigger firms.[9] In a later article, Fama and French (1997) compute equity costs for different industries with interesting though irritating findings.[10] Their three-factor-model indicates important negative signs for the size parameter for energy, utilities and telecom companies while the mean value over all industries is positive. This means that from a cross-industry perspective, smaller firms have higher required equity returns than bigger firms but that somehow for some regulated businesses, this effect is reversed. These points at one major criticism towards empirically-focused models, namely the lack of explanatory theory. The results may for instance be explained by regulatory interventions. Regulation authorities can be suspected to investigate bigger firms more intensely than smaller firms. Nwaeze (2000) observes that the increase of risk related to regulatory events is higher for bigger firms. For utilities, a positive relationship between the book-to-market-ratio of equity value and the required return was moreover identified by Fama and French (1997). This means that firms with a relatively low market value of equity suffer of a distress risk due to poor earnings prospects and thus have higher costs of equity. Besley and Bolton (1994) find that US regulation authorities have not considered the size effect in rate setting.

Summarizing, the position in the value chain has an important impact on betas with network operators characterized by lower betas. The differentiation between transmission and distribution network operators however does not play a crucial role. Regulation has a significant impact as well, the effects being diverse and complex. Firm size effects are existent but not coherently explainable. Electricity and gas have slightly different betas, these differences being however not statistically significant. These results are taken into account when identifying the sample to compute network operators' betas in section 4.

3 Regulators' approach to risk and the cost of equity

Over the past decade, many regulation authorities have derived equity returns to be used when computing the cost of equity. This work offers ample evidence how regulation authorities value the cost of equity which can be interpreted as a proxy for required equity return. So far the question of how regulators set allowed equity return has not been intensely researched.[11]

[9] Warner (1977) reports direct bankruptcy costs decreasing with firm size in a sample of railroad companies that went bankrupt. He discusses the fact that his empirical evidence regarding bankruptcy, direct costs amounting to about 1% of market value prior to bankruptcy, are much lower than for instance the 20% bankruptcy costs reported in Baxter (1967). He concludes that this difference is another indicator for the scale effect the results in Baxter (1967) being based on data about personal bankruptcies.

[10] The further analyze the effect of the relation of market value to book-value (HML - high minus low). This effect is cross-industry close to 0, for electricity and utilities companies it is positive meaning that firms with higher market valuation have higher required equity returns. As this effect may be short-term, due to volatility of stocks, it will not be considered further. Frontier Economics (2008) support this reasoning, stating that the HML criterion is an especially interesting indicator with regard to firms with intangible assets.

[11] Hagerman and Ratchford (1978) represent an exception: Using a set of 87 US electric utilities, they analyze eight firm specific and political variables that might influence the allowed cost of capital. As economic variables, the authors test the effect of the firms' betas, the debt-equity-ratio, asset size (the authors assume that large firms have more experience dealing with regulators) and interest rates. The political variables analyzed are the compensation of the commissioner(s), the term of the commissioner(s), the fact whether the commissioner(s) is (are) appointed or elected and the number of commissioners. This is particularly interesting, because in theory, the allowed cost of equity will depend primarily on risk. The authors find that

Therefore research has been conducted on more than 20 regulation schemes. Table 7 summarizes the key findings on the identified regulatory approaches. All values given are nominal return rates (unless regulators set inflation-adjusted real values) in order to adequately capture actual regimes. Besides the numbers, this analysis provides further interesting insights into the regulatory process of defining the adequate return on equity.

Table 7: Regulators' approaches to network cost of capital - all interest rates real values

Country	**Reg.**	**Regulator**	**Period**	**β_e**	**β_a**	**Value**	**r_m-r_f**	**r_f**	**r_e** *post*	**r_e** *pre*	**Gearing**	**r_d** *pre*	**WACC** *pre*	**WACC** *post*	**WACC** *vanilla*
Australia	RC	AER	2009-2014	0.80	0.39	Nom.	6.5%	5.7%	**10.9%**	15.5%	0.60	**7.5%**	10.7%	7.5%	**8.8%**
Austria	RC	E-Control	2010-2013	0.69	0.33	Nom.	5.0%	4.2%	**7.6%**	**10.1%**	0.60	**5.0%**	7.0%	**5.3%**	6.0%
Belgium	RC	CREG	2007	0.88	0.38	Nom.	2.5%	3.8%	**7.2%**	11.0%	0.67	**4.5%**	6.6%	4.4%	5.4%
Czech Rep.	RC	ERU	2010-2014	0.54	0.35	Nom.	6.4%	4.6%	8.0%	9.9%	0.40	**4.9%**	**7.9%**	6.4%	6.8%
Estonia	PC	ECA	2010	0.74	0.34	Nom.	5.0%	5.5%	**9.2%**	9.2%	0.50	**6.3%**	**7.8%**	7.8%	7.8%
France	RoR	CREG	2010	0.66	0.33	Nom.	4.5%	4.2%	7.2%	**10.9%**	0.60	**4.8%**	**7.3%**	4.8%	5.7%
Finland	RoR	EMVI	2008-2011	**0.40**	0.30	Nom.	**5.0%**	3.8%	6.0%	7.4%	0.30	4.4%	6.5%	5.2%	5.5%
Germany	RC	BNetzA	2009-2013	0.79	0.40	Nom.	4.6%	4.2%	7.8%	**9.3%**	0.60				
Hungary	PC	HEO	2009-2012	0.43	0.26	Real	5.9%	4.6%	7.1%	**8.9%**	0.57	6.4%	7.5%	6.0%	6.7%
Ireland	RC	CER	2006-2010	0.80	0.40	Real	5.3%	2.4%	**6.6%**	0.08	0.50	**3.7%**	**5.6%**	**4.9%**	5.2%
Italy	PC	AEEG	2008-2011	0.60	0.33	Nom.	4.0%	4.5%	6.9%	8.6%	0.50	5.4%	**7.0%**	5.6%	6.1%
Kosovo	PC	ERO	2006-2010	0.90	0.41	Real	5.5%	5.5%	11.8%	**14.7%**	0.60	8.2%	10.8%	8.6%	9.6%
Luxembourg	RoR	ILR	2009	0.80	0.39	Nom.	4.6%	4.4%	8.0%	11.5%	0.60	5.2%	**7.7%**	5.4%	6.3%
Netherlands	PC	NMa	2010-	0.83	0.30	Nom.	5.0%	4.1%	8.2%	11.7%	0.60	5.3%	**7.9%**	5.5%	6.5%
New Zealand	PC	Co. Com.	2009-2013	0.75	0.35	Nom.	7.5%	5.4%	9.4%	13.4%	0.60	7.4%	9.8%	6.8%	8.2%
Norway	RC	NVE	2007-2011	0.88	0.35	Nom.	4.0%	3.3%	6.8%	9.4%	0.60				
Portugal	RC	ERSE	2009-2012	0.91	0.61	Nom.	4.0%	4.4%	8.0%	10.9%	0.61	5.1%	**7.4%**	5.4%	6.2%
Spain	RC	CNE	2009-	0.57	0.35	Nom.	5.5%	4.4%	7.6%	10.8%	0.37	5.1%	**8.7%**	**6.1%**	6.7%
Sweden	RC	EI	2008-2011	0.63	0.48	Nom.	4.9%	3.8%	7.9%	11.0%	0.29	4.8%	**9.2%**	**6.6%**	7.0%
Switzerland	RoR	UVEK	2010	0.88	0.35	Nom.	5.0%	3.0%	7.4%	9.3%	0.60	**2.5%**	5.2%	4.2%	**4.5%**
UK	RC	OFGEM	2010-2015	0.97	0.34	Real	4.0%	2.8%	**6.7%**	9.3%	0.65	**3.6%**	5.6%	**4.0%**	**4.7%**

Bold printed values are indicated as major results in the sources. Data were mostly directly provided by regulation authorities, indications for sources are given in Appendix A. Some further remarks are necessary: In Estonia, pre- and post-tax values are equal due to a special tax regime. Ireland values were based upon the approach for transmission operators. Kosovo considers an additional size premium of 1.5%. New Zealand uses a special form of the CAPM, the Lally-CAPM in which the market risk premium is corrected for taxes.

The numerical results differ significantly, the risk premium varying between 3% (Belgium) and 7.5% (New Zealand) and the asset beta ranging from 0.26 (Hungary) up to 0.61 (Portugal). Considering all approaches analyzed in the context of this study, some patterns become visible. [12]

the allowed rates of return depend positively on debt/equity-ratio (as a risk measure), inflation, asset size and the term of the regulation authorities' commissioners. Surprisingly, the firms' betas did not significantly influence the allowed cost of capital.

[12] Besides the content, some differences with regard to the time series (daily, weekly, monthly data and 1 to 5 years) and the methodology to account for the autocorrelation of beta (Vasicek, Blume or others). These will not be further discussed in this article.

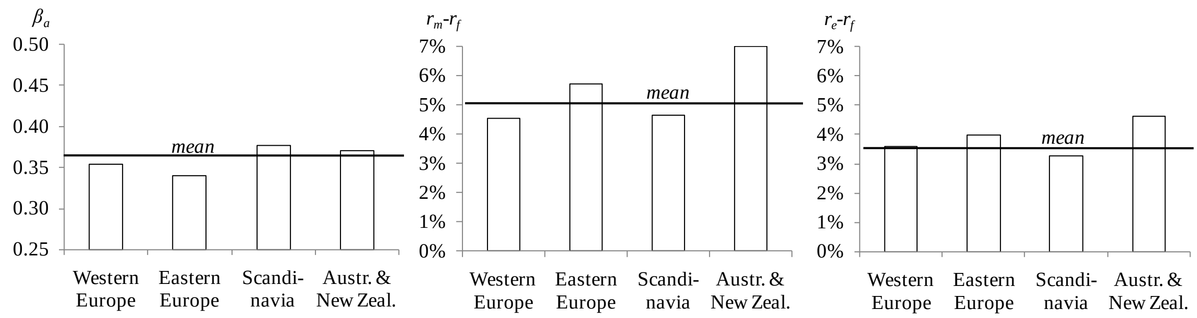

Figure 2: Average asset beta, market risk premium and network operator risk premium

First, the average asset beta corresponds to 0.36 with a low standard deviation of 0.06 (cf. Figure 2). Second, Western Europe regulators use homogenous approaches to set the return on equity: The standard deviation amounts to only 0.7% for the 13 Western European countries. Third, regulators often use lower values for the market risk premium than the values historically observed. Brigham et al. (1985) and Dimson et al. (2003) claim that expected risk premiums should be used rather than historical data, the latter estimating a forward-looking arithmetic mean risk premium at about 5% for a world series.[13] The arithmetic mean equity risk premium for network operators corresponds to 5.0% with a standard deviation 1.1%. With regard to the weighted average cost of capital, approaches to gearing, i.e. the ratios of debt to total capital, vary significantly between countries: the range is 0.3 to 0.7 with an average of 0.54 and a standard deviation of 0.11. The Western European group again is relatively homogenous with an average of 0.57 and a standard deviation of 0.09.

From a methodological point of view, some interesting patterns also may be revealed. First, all regulators considered use single-moment CAPMs. The only regulation authority that considered a DGM to validate CAPM-results was OFGEM. Second, only Kosovo adopted a size risk premium of 1.3%, but not based on the Fama and French (1995) approach. The results are thus comparable to the results of Besley and Bolton (1994) in the US. Third, practically all regulators that computed 'proper' betas in the process considered data from integrated utilities that include activities such as generation and wholesale. Fourth, many regulators computed separate betas for electricity and gas, which is probably due to the existence of large (vertically integrated) companies with a focus on either electricity or gas such as Scottish Power, Endesa, Gaz de France etc., which are listed in stock exchanges. Fifth, many regulators modify beta values after a regulation period has been terminated. As such, they are in line with the proposition of section 2 that regulatory events modify the systematic risk.

4 Comparison of valuation approaches for network operators

The aim of this section is to investigate whether the choice of regulators to use only CAPM is well founded. Therefore besides the classic CAPM, a TFM (comparable to Fama and French) and an Arbitrage Pricing Model with pre-specified factors based on Chen, Ross and Roll (1986) is presented.[14]

A Portfolio of Network Operators

The analysis is based on a portfolio of more than 20 network operators. As shown in the previous sections, the calculus of network operators' capital costs should not be based on the stock data of integrated utilities companies. Unfortunately most network operators worldwide, even with unbundling requirements in place for instance in the European Union, are part of conglomerates or even nationalized and thus not listed on stock exchanges. The following list

[13] Market risk premiums depend heavily on the time series used for its computation and on the methodology used for computing means (arithmetic or geometric), cf. Dimson et al. (2003). Implications of varying risk premiums are discussed more deeply in section 4.

[14] The models will be abbreviated with FF-TFM and CRR-APT in the following chapter. FF-TFM and CRR-APT have been chosen as alternatives to the CAPM due to their impact on research and to their prominence in classical textbooks such as Brealey et al. (2007), Pratt and Grabowski (2008) or Elton et al. (2009).

contains network operators listed in different stock exchanges worldwide that may be used for the computation of betas and network operators' equity costs.

Table 8: Network operators (without other activities)

Company	Country	Activity[15]	Trading symbol	Network size *thds. km*	Turnover *bn. €*
Transener	Argentina	ET, ED	TRAN:BUE	14	0.1
APA Group	Australia	GT, GD	APA:ASX;	36	0.7
DUET Group	Australia	ET, ED, GT, GD	DUE:ASX	97	0.7
Envestra	Australia	GT, GD	ENV:ASX	22	0.3
Spark Infrastructure	Australia	ED	SKI:ASX	174	0.2
SP AusNet	Australia	ET, ED, GD	SPA:ASX	62	0.9
Elia	Belgium	ET	ELI:BRU	8	0.8
Snam Rete Gas	Italy	GT, GD	SRG:MIL	82	2.5
Terna	Italy	ET	TRN:MIL	62	0.7
Enagas	Spain	GT	ENG:MCE	9	0.9
Red Electrica	Spain	ET	REE:MSC	35	1.2
National Grid	UK	ET, ED, GT, GD	NG:LSE	343	16.5
AGL Resources	US	GT, GD	AGL:NYQ	74	1.9
Atmos Energy	US	GT, GD	ATO:NYQ	123	4.0
ITC Holding	US	ET	ITC:NYQ	24	0.5
Kinder Morgen Energy P.	US	GT	KMP:NYQ	59	15.4
New Jersey Resources	US	GT, GD	NJR:NYQ	22	2.1
Nicor Inc	US	GD	GAS:NYQ	54	2.2
Northwest Natural Gas	US	GT, GD	NWN:NYQ	22	0.8
Piedmont Natural Gas	US	GT, GD	PNY:NYQ	49	1.3
TC Pipelines	US	GT, GD	TCLP:NYQ	6	0.1
WGL Holding Inc	US	GT, GD	WGL:NYQ	42	2.1

The total network length of the companies considered sums up to 1.4 Mio. km of network, which is roughly the overall network size of countries such as Germany. A second obvious observation is that turnovers heavily vary between operators (within one country) of about the same network size. One plausible explanation is that network sizes assume a 100% stake in the network while financial indicators do not.

Results for the CAPM

The first part of the analysis consists in computing CAPM betas via a time series regression of monthly data from 2000 up to 2010 using equally weighted portfolios.[16]

$$r_e = r_f + \beta_e \left(r_m - r_f\right) + \varepsilon$$

The network operators are regrouped into the Portfolios 'US NetOp', 'Europe NetOp' and 'Australia NetOp', all network operators from these three portfolios being represented in 'World NetOp'.[17] The Dow Jones Utilities, the Euro Stoxx Utilities and ASX 200 Energy are

[15] The abbreviation for the main business activities is as follows: 'G' stands for gas, 'E' for electricity, 'D' for distribution and 'T' for transportation. The company data was gathered in June 2010. Sources were the companies websites and Reuters.

[16] The approach of equally-weighting the portfolio elements is often used in empirical work due to its simplicity, even if from a theoretical point of view the value-weighted approach is more appropriate. Blume (1975) and Banz (1981) for instance use equally weighted portfolios in their paper, while Fama and French (1997) use value-weighted portfolios. Frankfurter and Vertes (1990) discuss the effect of the two underlying portfolio building rules, the naive equal weights (NEV) and naive market weights (NMV) selection rules. They find that value-weighted portfolios are biased downwards in risk, even for large portfolios

[17] Consequently, Transener is excluded from further analysis. The corresponding market indices used to compute beta are Dow Jones Industrial (US), Euro Stoxx 50 (Europe), S&P/ASX 200 (Australia) and the FTSE All World Index. Financial data were extracted from Reuters. 10 years of monthly returns from July 2000 until June 2010 are represented in the analysis. As some of the companies were not listed in 2000, the starting

included in the analysis to represent benchmark portfolios including mostly integrated utilities companies. Overall regression quality is average to low with regression coefficients mostly below 0.3. Results of empirical beta estimates are presented in Table 9.

Table 9: CAPM factors

Portfolio	β_e	t-statistic	R^2
Australia - NetOp	0.40	5.2***	0.19
Australia - Integr	0.51	4.4***	0.14
Europe - NetOp	0.30	5.1***	0.18
Europe - Integr	0.58	6.2***	0.24
US - NetOp	0.39	5.3***	0.19
US - Integr	0.76	6.3***	0.25
World - NetOp	0.34	7.4***	0.32

*** significant at 99%, ** at 95% and * at 90%

All betas are significantly different from zero with t-statistics above 4. Further tests were conducted in order to check if the activity in the value chain (transmission or distribution) and the product (electricity, gas) matters concerning beta.[18] The results showed only minor differences. The different risk profiles of integrated utilities and network operators are obvious with beta differences ranging from 0.11 (Australia) up to 0.37 (US).

Results for the FF-TFM

In the second part of the analysis, betas for a TFM were computed with a similar parameterization as the CAPM (portfolios, monthly data, etc.).

$$r_e - r_f = a + \beta_e \left(r_m - r_f\right) + s_e SMB + h_e HML + \varepsilon$$

SMB data are derived from monthly return differences between MSCI All-World Big Cap and MSCI All-World Small Cap (World), Dow Jones Industrial and S&P 600 Small Cap (US), Euro Stoxx 50 and Euro Stoxx Small (Europe), S&P/ASX 20 and S&P/ASX Small Ordinaries (Australia). HML data published by French (2010) with regards to the US, Europe (including UK) and Australia were used.[19] The results of the TFM with regard to each factor are presented in Table 10.

portfolios in 2000 represent only two stocks for the Australian and two stocks for the European portfolio. Enagas and Snam Rete gas are added to the European portfolio beginning 2001. The risk free interest rate is calculated based on one-month T-Bill (US), Euribor one-month (Europe) and Federal Reserve Bank accepted bills 30 days (Australia). A fictive World risk free rate is computed with weighting US, Europe and Australia data with market capitalizations.

[18] The companies were regrouped in four groups ‘electricity‘, ‘gas‘, ‘transmission‘ and ‘distribution‘. Companies with mixed activities that were not attributable to one group were excluded. Average beta per group was calculated based on values in table 8. A t-test for beta difference ‘electricity-gas’ and ‘transmission-distribution’ showed that the differences (which were roughly 0.01) are not significantly different from zero.

[19] In the classic Fama and French (1997) paper, SMB is derived separating NYSE, AMEX and NASDAQ assets in 6 portfolios considering size (small or big) and book-to-market (low, medium, high). SMB is the calculated as difference between the average of the big and small portfolios. The Index-based approach used in this paper is pragmatic, as the building of the portfolios and the value updating is handled by a financial intermediary. The results of both approaches (Index-based, portfolio-based) were tested with the US-data set and found to provide similar results. The missing years in the data set of Kenneth E. French (2008-2010 for Europe and Australia) were completed with US data.

Table 10: TFM factors

Portfolio	β_e	t-stat	s_e	t-stat	h_e	t-stat	R^2
Australia - NetOp	0.45	5.5***	0.12	1.8*	-0.02	-0.3	0.20
Australia - Integr	0.76	7.5***	0.62	7.5***	-0.29	-2.6**	0.42
Europe - NetOp	0.32	5.4***	0.14	2.3**	-0.04	-0.5	0.23
Europe - Integr	0.52	5.6***	0.09	0.9	0.40	2.9***	0.32
US - NetOp	0.30	4.4***	0.34	4.0***	0.04	0.6	0.30
US - Integr	0.73	5.9***	-0.09	-0.6	0.25	2.2**	0.27
World - NetOp	0.27	5.9***	0.18	2.1**	0.12	1.8*	0.37

*** significant at 99%, ** at 95% and * at 90%

Market return is the most statistically significant factor. Interestingly, HML is more relevant for integrated companies (higher sensitivities, higher t-statistics) than for network operators while the effect is the exact opposite regarding SMB. For six out of the seven time series analyzed, only one additional factor is significant (at a 95% level), while only for the World series for network operators all factors are found to be relevant. This signifies clearly that the use of additional factors improves the explanatory power of the model capturing also more variance. The sensitivity to SMB is positive for network operators which is in line with expectations but contrasts the results of Fama and French (1997) who found negative sensitivities for the utilities industry. The results for the portfolio 'US-Integr' are in line with FF, but the SMB factor is not significant.[20] Another interesting result is the negative sign of for 'Australia-Integr' which is significant. In the classic FF-paper, negative signs for are found among others for the sectors 'drugs', 'medical equipment', 'electronic equipment' and 'retail'. A negative sensitivity may be interpreted that assets of these sectors may serve as hedge if the risk premium for being a value stock increases.

Results for the CRR-APT

The third part of the analysis consists of the computation of an APT. There are two basic approaches for constructing APT-models, explanatory factor analysis (directly leading to factors and factor loadings, but without theoretical background about the nature of the factors) and the pre-specification of factors, followed by the computation of the factor loadings. The second approach is used here, as from a practitioner's point of view it is more intuitive to have an explicit understanding of the factors influencing the required return on equity. Based on the evidence presented in Chen, Ross and Roll (1986), a seminal paper in arbitrage pricing with pre-specified factors, the following explaining factors are included in the model[21]:

Table 11: Explaining factors in the Arbitrage Pricing Theory model

Risk	Significance	Measurement	Data source
Interest rate	Time preference	UTS(t) = Return (10 y gov. bond, t) - Return (1 month treasury bill, t-1)	US Federal Reserve, ECB, Reserve Bank of Australia
Confidence	Higher yields signify increasing risk aversion	URP(t) = Return (10 y gov. bond, t) - Return (BAA-securities Moody's, t)	US Federal Reserve
Unexpected inflation[22]	Impact depending on business	US: UI(t) = CPI(t)/CPI(t-1) - Expected inflation (t) Australia: No monthly inflation data available Europe: No expectations available	FED of Minneaopolis, University of Michigan Inflation Expectation

[20] The FF-results were re-examined by the author with data published by French (2010). For the time period from 2000 until 2009, the sensitivity for the utilities industry portfolio was negative with a beta of -0.15 (compared to -0.09 obtained), which is an important change compared to the -0.26 beta in the period 1963-1992. More importantly, t-statistic for the 2000-2009 period of 1.5 shows that the factor has lost significance compared to a t-statistic of 5.2 in the period 1963-1992.

[21] The CRR factors were used in an important number of other papers such as Bower et al. (1984), Burmeister and Wall (1986), Berry et al. (1988), Hamao (1988), Burmeister et al. (2003), Kaneko and Lee (1995) and Rjoub et al. (2009). A slight adaptation of the model, presented in Burmeister et al. (2003) was used. Consequently, market return is included as to capture all effects not accounted for by the other factors.

[22] As no inflation data is available for Australia and inflation expectation is not available regarding Europe, the factor is solely considered for the US portfolio.

Business cycle	Impact depending on business	MP(t) = Growth rate of industrial production vs. last month (t)	OECD monthly production data
Market timing	Effects not captured by the macroeconomic factors	MI(t) = Residual of indices used previously, part that is not explained by the four factors presented	Dow Jones, Euro Stoxx, ASX/S&P

The sensitivities of network operators asset returns to the macroeconomic factors are identified using the following multiple linear regression.

$$r_e = a + \beta_{e,UTS} \cdot UTS + \beta_{e,URP} \cdot URP + \beta_{e,UI} \cdot UI + \beta_{e,MP} \cdot MP + \beta_{e,MI} \cdot MI + \varepsilon$$

This part is indispensable for the analysis, as the influence of the factors and their significance are the baseline for comparison to the other models.

Table 12: APT factors

Portfolio	β_{UTS}	**t-stat$_{UTS}$**	β_{URP}	**t-stat$_{URP}$**	β_{UI}	**t-stat$_{UI}$**	β_{MP}	**t-stat$_{MP}$**	β_{MI}	**t-stat$_{MI}$**	R^2
Australia - NetOp	0.46	1.25	-0.10	-0.31			0.74	1.31	0.36	4.53*	0.19
Australia - Integr	0.15	0.28	-1.35	-2.82*			0.57	0.69	0.44	3.82*	0.20
Europe - NetOp	0.59	2.15**	-1.16	-2.88*			-0.18	-0.66	0.27	4.59*	0.24
Europe - Integr	0.60	1.35	-1.35	-2.05**			0.53	1.18	0.51	5.20*	0.27
US - NetOp	0.21	1.06	-0.74	-2.29**	-0.06	-0.09	-0.59	-1.59	0.35	4.88*	0.21
US - Integr	0.11	0.34	-1.32	-2.41**	-0.33	-0.28	0.19	0.30	0.69	5.59*	0.27
World - NetOp	0.23	1.30	-0.85	-3.92*			0.00	-0.01	0.28	6.13*	0.32

*** significant at 99%, ** at 95% and * at 90%

The explanatory power is in line with Berry et al. (1988) or Elton et al. (1994) who both find that the macroeconomic variables explain roughly one quarter of the indices' variation. Aside from market timing risk, the default risk premium is a significant factor in all portfolios (with the exception of Australian network operators). Betas for the risk premium URP are negative indicating that in the case of more risk averse investors, utilities will profit by lower required equity returns. Unexpected inflation (in the US) and monthly production have no significant explanatory power.

Comparison of the Quality of the Models

Table 13 presents an overview of the results obtained. TFM has always at least equal explanatory power than CAPM with mostly SMB significant for network operators. APT is in most cases superior to the CAPM but only once slightly better than the TFM. This may be due to the fact that the pre-specified factors do not work very well, either because they do not capture additional risks or due to measurement issues. An alternative might be to use factor analysis to generate factors that do not have an obvious economic interpretation. But given the reality of regulatory hearings it appears to be difficult to implement this methodology.

Table 13: Comparison of different approaches

	R^2			**Number of significant factors**								
				90%			*95%*			*99%*		
	CAPM	*TFM*	*APT*	*CAPM*	*TFM*	*APT*	*CAPM*	*TFM*	*APT*	*CAPM*	*TFM*	*APT*
Australia - NetOp	0.19	0.20	0.19	1	2	1	1	1	1	1	1	1
Australia - Integr	0.14	0.42	0.20	1	3	2	1	3	2	1	2	3
Europe - NetOp	0.18	0.23	0.24	1	2	3	1	2	3	1	1	2
Europe - Integr	0.24	0.32	0.27	1	2	2	1	2	2	1	2	1
US - NetOp	0.19	0.30	0.21	1	2	2	1	2	2	1	2	1
US - Integr	0.25	0.27	0.27	1	2	2	1	2	2	1	1	1
World - NetOp	0.32	0.37	0.32	1	3	2	1	2	2	1	1	2

The aim of this section has been to show whether alternatives to the CAPM may work well in the context of setting the cost of capital for a network operators. This is a question of interest both for regulation authorities and for the companies themselves. In the last part of this section, risk premiums are derived using the alternative model specifications.

Estimation of Risk Premiums

The estimation of risk premiums for each model is based on two major inputs, the sensitivities computed and the risk premiums for each factor. Risk premiums have been an intensively discussed field in empirical finance research, c.f. for instance Brigham et al. (1985). Dimson et al. (2003) present equity risk premiums over a time span from 1900 until 2002. Two facts stand out in this literature: The high standard deviations (generally larger than 15%) and the difference of results obtained when using geometric as compared to arithmetic means (at least 1.3%, sometimes up to 5.5%). With regard to the Fama and French factors, SMB and HML were computed based on a time span from 1925 until 2009 based on the French (2010) data (cf. Table 14).

Table 14: TFM-factor prices

Portfolio	r_e-r_f	SMB	HML
Geometric mean	5.9%	2.9%	3.3%
Arithmetic mean	8.1%	3.8%	4.4%
Standard deviation	20.8%	14.3%	14.3%

The subject of risk premiums is even vaguer when one gathers APT values. Table 15 summarizes average risk premiums published in different research papers. The important differences between results are obvious, not only regarding the level of risk prices but even their signs, sometimes being positive, sometimes negative.[23] The problem becomes obvious comparing the results of Chen et al. (1986) with Shanken and Weinstein (2006), which are computed using the same data set but slightly different methodologies regarding portfolio constructing rules. A regulation authority or the management of a network operator will be confronted with an unsolvable task of setting the adequate risk premium. An own analysis using the two stage approach of Fama and MacBeth (1973) was conducted with data from all companies listed in Dow Jones Industrial Average, Euro Stoxx 50 and S&P/ASX 50. With data for the period 2000-2010, no significant results could be computed.

Table 15: APT risk factor prices

Author	Data	UTS	URP	UI	MP	MI
Chen et al. (1986)	1958-1984	-6.6%	9.5%	-0.9%	16.0%	4.5%
Berry et al. (1988)	1972-1982	12.0%	5.3%	-0.5%	1.8%	6.1%
Elton et al. (1994)	1978-1990	5.8%	4.6%	-1.0%	3.8%	4.6%
Kaneko and Lee (1995)	1975-1993	3.3%	0.5%		-1.5%	8.3%
Burmeister et al. (2003)	Not indicated	-0.7%	2.6%	-4.3%	1.5%	3.6%
Shanken and Weinstein (2006)	1958-1984		14.3%	-1.2%	2.8%	1.1%

Detailed sources: Chen et al. (1986), means values table 4. Kaneko and Lee (1995), table 1. Inflation results are not presented here due to different definition with mean value different from zero. Shanken and Weinstein (2006), table 1, unrestricted values with n=20 and five-year prior betas.

To compute some exemplary results, the values published in Burmeister et al. (2003) will be used. This is due to their relative popularity, having being reproduced in textbooks such as Brealey et al. (2007), Pratt and Grabowski (2008) and Elton et al. (2009). Further, mean values will be considered in calculating risk premiums. An overview of all risk premiums

[23] This phenomenon appeared for instance in Elton et al. (1994, pp. 56) where the premiums change by factor 10 within 4 years. Another example is Chen et al. (1986, pp. 396) with UTS changing by a factor of about 30 from one 10 years period to another. Poon and Taylor (1991) indicate some problems in their work with APT, sometimes factors are priced, other times not. Martikainen et al. (1991) summarize in an application to Finnish data that it is difficult to find any stable economic interpretation from the pre-specified macro-economic factors. Shanken and Weinstein (1996) re-exanimate the pricing of the CRR-APT macro-variables and find that these are surprisingly sensitive to alternative approaches of calculating betas. In a time-series comparable to that of CRR, none of the risk factors are priced due to a switch in methodology.

used is given in the Appendix. The results of risk premiums calculated with CAPM, TFM and APT are summarized in Table 16.

Table 16: Comparison of risk premiums r_e-r_f

Portfolio	CAPM	TFM	APT (Burmeister)	APT (mean values)
Australia - NetOp	2.7%	3.3%	3.0%	6.4%
Australia - Integr	3.5%	6.0%	0.2%	-2.2%
Europe - NetOp	1.2%	1.6%	-2.6%	-5.5%
Europe - Integr	2.4%	3.7%	-1.1%	-2.3%
US - NetOp	2.1%	2.7%	-0.8%	-4.8%
US - Integr	4.0%	4.4%	1.8%	-2.8%
World - NetOp	1.5%	2.1%	-1.2%	-3.5%

The differences in risk premiums support the results discussed in Bower et al. (1984), Fama and French (1997) or Cragg et al. (2001), who all find significant differences between CAPM and other valuation approaches. The negative risk premium in the APT models is mostly due to an important sensitivity of all portfolios towards URP. This means that required equity return for network operators decreases if the default risk premium increases. Interestingly, the effect is solely due to the development of the risky bonds, the development of the long term government bond being insignificant. The sensitivities to URP are not abnormal, Berry et al. (1996) reporting similar values for the utility industry. To get a better understanding of this relationship, more long term data is required.

Summarizing, additional factors improve results. From a regulation authority's point of view, the use of a TFM does not add much complexity to the process of estimation of cost of capital and is especially useful due to the significance of SMB. The use of APT is more complex, as one has to either overcome difficulties in the setting of risk prices or rely on the factor analysis approach, which will be difficult to explain to the stakeholders of regulation. The problem of risk prices is less severe for TFM as published long term data (at least for the US) is available and risk prices are much less volatile over time.

5 A Simplified Two-Factor-Model with SMB for non-listed firms

The results of the previous section suggest the additional use of SMB in setting the equity returns for regulated network operators. The identification of s_e is based on a portfolio of network operators, that may significantly differ in size compared to the firms the regulator is setting the equity returns for. A regulator could thus identify required equity return based on following two-factor-model:

$$r_e - r_f = a + \beta_e \left(r_m - r_f\right) + s_e SMB + \varepsilon$$

The question arises if a portfolio of smaller network operators would be characterized by different values of s_e. If this is the case, the regulator might opt for a choice to set higher levels of s_e and thus attribute an additional size premium that smaller operators require to have a sustainable equity return. To analyze, if an important correlation between and network size l_e (measured in km of cables, overhead lines, pipelines and tubes) exists, the following relationship has to be significant.

$$s_e = a + b \cdot l_e + \varepsilon$$

If l_{target} corresponds to the target size, the regulation authority wish to sets equity returns for, and $\bar{l}_e$ represents the average network size, then the following equation for the required equity return results.

$$r_e - r_f = a + \beta_e \left(r_m - r_f\right) + s_e SMB + b\left(\bar{l}_e - l_{\text{target}}\right) SMB$$

To identify b, three cross sectional regressions were conducted based on the model described above. As expected, network size l_e and the sensitivity to SMB s_e are negatively correlated.

Table 17: Relationship between network size and s_i

Period length		t-statistic		t-statistic	R2
1 year	0.3784	3.3^{***}	-0.0006	-0.5	0.02
5 years	0.2388	4.4^{***}	-0.0008	-1.1	0.06
10 years	0.2879	5.0^{***}	-0.0010	-1.8^{*}	0.14

*** significant at 99%, ** at 95% and * at 90%

R^2 values are not impressive, but at a reasonable level at least for the 10 years perspective. The effect is relatively weak indicating that SMB impact is due to the business activity. The average network operator in our sample is characterized by a network length of about 65,000 km and an average of 0.18. For every 10,000 km of regulatory target size less, increases by 0.01. Having calculated the average risk premium for SMB at a level of 0.6%, if the regulator chose a target size of 5,000 km than an additional size premium of 0.2% would result, the total SMB risk premium being 0.8%. This approach shows that the SMB concept can easily be applied to network operators, even if the regulated network operators are significantly smaller than the firms used to evaluate the regulatory parameters.

6 Conclusion/Recommendation

This paper was meant to give a qualitative and quantitative overview of the cost of equity capital for utilities companies with the focus of network operators. The existing literature indicates that there exist significant differences in the valuation of the required equity return. The main drivers of these differences are the valuation model, leverage, the position in the value chain and firm size. Some further factors such as the nature of regulation (cost of service, incentive regulation), the branch (electricity, gas) do not turn out to have important impacts. Regulatory events surely influence betas and consequently required equity returns but it depends majorly on the type of these events, if the changes are long-lasting.

Recent approaches of 21 regulation authorities were thoroughly analyzed to see whether the regulators act accordingly to the results presented in section 2. The results are surprising. None of the regulation authorities, except OFGEM that had additional support by a Dividend Growth Model, uses alternative valuation models to have a second approach besides the CAPM. Many of the regulation authorities include integrated utilities companies in their sample (which is not recommended due to rather different business risks) but differentiate electricity and gas (which is not necessary according to the results provided). Only the regulation authority in Kosovo considers a firm size effect, but without theoretical link to the SMB concept.

With a data set of 20 network operators, CAPM, FF-TFM and CCR-APT models were built in order to compute required equity returns. If these models would all lead to approximately the same results with a comparable model quality, than the approach to use solely the CAPM might be appropriate. Yet both multi factor models are found to have more explanatory power than the single factor CAPM although at a certain price. The use of more factors leads to a reduction of intuitiveness and requires additional assumptions about risk premiums, which could be contested by regulated companies. As for the sensitivities of network operators to additional risks beside market risk, the default risk premium and the SMB have a very high significance with regard to network operators. Consequently, a consideration in asset pricing seems appropriate and would result in additional equity returns between 0.4 and 0.6%. This proves more difficult for the risk premium than for SMB as long term data is available for the US and can be computed easily for other countries either based on an index approach or by constructing adequate portfolios.

As for the use of the default risk premium, more research is necessary to compute long term estimates of the risk premium. The incorporation of the size effect in the computation of the required equity return is straightforward. An intuitive approach was developed, how to develop SMB-based size premiums for regulated network operators that differ in size significantly from the firms used to take into account the sensitivity to the size premium SMB. This work may thus help regulation authorities and network operators in future activities of setting required returns on equity.

Appendix

Appendix A

Country	Reference
Australia	AER (2009)
Austria	E-Control (2009)
Belgium	CREG (2008)
Czech Rep.	ERO (2009)
Estonia*	ECA (2010)
France	CRE (2009)
Finland	EMA (2007)
Germany	BNetzA (2008)
Hungary	HEO (2009)
Ireland	CER (2005)
Italy	AEEG (2008)
Kosovo	ERO-KS (2006)
Luxembourg	ILR (2008)
Netherlands	Oxera (2009)
New Zealand	Commerce Commisson (2010)
Norway	E-Mail document
Portugal	E-Mail document
Spain	CNE (2007)
Sweden	Icecapital (2009)
Switzerland	UVEK (2010)
UK	OFGEM (2009)

References

AEEG (2008): Tariffe per l'attivita' di tariffe distribuzione e misure del gas naturale per il terzo periodo regolatoria, Presentation in Milan, 20th of March 2008

AEEG Autorità per l'energia elettrica e il gas (2008): Annual Report to the European Commission on regulatory activies and the state of services in the electricity and gas sectors

AER Australian Energy Regulator (2009): Electricity transmission and distribution network service providers - Review of the weighted average cost of capital (WACC) parameters - Final Decision

Ahn, C. M.; Thompson, H. E. (1989): An analysis of some aspects of regulatory risk and the required rate of return for public utilities; Journal of Regulatory Economics (VOL. 1); pp.241-257

Alexander, I,; Mayer, C.; Weeds, H. (December 1996): Regulatory structure and risk and infrastructure firms: an international comparison; World Bank, Policy Research Working Papers (Nr. 1698); pp.1-72

Banz, R. W. (1981): The relationship between return and market value of common stocks; Journal of Financial Economics (VOL. 9); pp.3-18

Baxter, N. D. (1967): Leverage, Risk of Ruin and the Cost of Capital; The Journal of Finance (VOL. 22); pp.395-493

Besley, S.; Bolton, S. E. (1994): Rate Setting in the Utilities Industry: Does Size Make a Difference?; Financial Review (VOL. 29); pp.521-538

Berry, M.; Burmeister, E.; McElroy, M (1988): Sorting out Risks Using Known APT Factors; Financial Analysts Journal (VOL. 44); pp.29-42

Binder, J. J.; Norton, S. W. (1999): Regulation, Profit Variability and Beta; Journal of Regulatory Economics (VOL. 15); pp.249-265

BNetzA Bundesnetzagentur (2008): Beschluss BK4-08-068

Bowen, R. M.; Castanias, R. P.; Daley, L. A. (1983): Intra-Industry Effects of the Accident at Three Mile Island; Journal of Financial and Quantitative Analysis (VOL. 18); pp.87-112

Bower, D. H.; Bower, R. S.; Logue, D. E. (1984): Arbitrage Pricing Theory and Utility Stock Returns; The Journal of Finance (VOL. 39); pp.1041-1054

Brealey R. A., Myers. S. C.; Franklin, A. (2007): Principles of Corporate Finance; McGraw-Hill Irvin (9th edition)

Breen, W. J.; Lerner, E. M. (1972): On the Use of β in Regulatory Proceedings; Bell Journal of Economics (VOL. 3); pp.612-621

Brigham, E. F.; Crum, R. L. (1977): On the Use of the CAPM in Public Utility Rate Cases; Financial Management (Summer); pp.7-15

Brigham, E.F.; Shome, D.K.; Vinson, S. R. (1985): The Risk Premium Approach to Measuring a Utility's Cost of Equity; Financial Management (VOL. 14); pp.33-45

Buckland, R.; Fraser, P. (2001): Political and Regulatory Risk in Water Utilities: Beta Sensitivity in the United Kingdom; Journal of Business Finance & Accounting (VOL. 28); pp.877-904

Burmeister, E.; Roll, R.; Ross, S. A. (1994): Using Macroeconomic Factors to Control Portfolio Risk; In: A Practitioner's Guide to Factor Models - The Research Foundation of The Institute of Chartered Financial Analysts; pp.1-27

CER Commission for Energy Regulation (2005): 2006-2010 Transmission Price Control Review: Transmission Asset Owner (TAO) and Transmission System Operator (TSO)

Chen, C. R. (1982): Time-Series Analysis of Beta Stationarity and Its Determinants: A Case of Public Utilities; Financial Management (VOL. 11); pp.64-70

Chen, N. F.; Roll, R.; Ross, S. A. (1986): Economic forces and the stock market; The Journal of Business (VOL. 59); pp.383-403

Clarke, R. G. (1980): The Effect of Fuel Adjustment Clauses on the Systematik Risk and Market Values of Electric Utilities; Journal of Finance (VOL. 35); pp.347-358

CNE (2007): Consulta pública para la revisión de la metodología de estimación del coste de capital para actividades reguladas en el sector energético, Presentation, 13th of December 2007

Commerce Commission (2010): Cost of Capital Straw Person Example – Electricity distribution industry

CRE Commission de Régulation de l'Énergie (2009): Proposition de la Commission de régulation de l'énergie du 26 février 2009 relative aux tarifs d'utilisation des réseaux publics de transport et de distribution d'électricité

CREG Commission de Régulation de l'Electricité et du Gaz (2008): RAPPORT TE 2008 relatif aux 'tarifs du réseau de distribution appliqués par les gestionnaires de réseaux de distribution d'électricité au cours de l'exercice d'exploitation 2008'

Conine, T. E.; Tamarkin, M. (1985): Implications of Skewness in Returns for Utilities' Cost of Equity Capital; Financial Management (VOL. 14); pp.66-71

Cooper, I.; Currie, D. (1999): The Cost of Capital for the UK Water Sector; London Business School, Regulation Initiative Discussion Paper Series (NO. 28); pp.

Cragg, M.; Lehr, W.; Rudkin R. (2001): Assessing the Cost of Capital for a Standalone Transmission Company; The Electricity Journal (VOL. 14); pp.80-88

Dimson, E.; Marsh, P.; Staunton, M (2003): Global Evidence on the Equity Risk Premium; Journal of Applied Corporate Finance (VOL. 15); pp.27-38

Dixit, A. K.; Pindyck, R.S. (1994): Investment under Uncertainty; Princetown University Press, Princeton, New Jersey

ECA Estonian Competition Authority (2010): Guidelines for determination of Weighted Average Cost of Capital

E-Control (2009): Erläuterungen zur Systemnutzungstarife-Verordnung 2010, SNT-VO 2010

Elton, E.; Gruber, M.J.; Brown, S. J.; Goetzmann, W. N. (2009): Modern Portfolio Theory and Investment Analysis; Wiley, New York (Eight Edition)

Elton, E.; Gruber, M.J.; Mei, J. (1994): Cost of Capital Using Arbitrage Pricing Theory: A Case Study of Nine New York Utilities; Financial Markets, Institutions and Instruments (VOL. 3); pp.46-73

EMA Energy Market Authority (2007): ENERGIMARKNADSVERKET Appendix 1 – Methods for determining the return on electricity distribution network operations during the regulatory period starting on 1 January 2008 and ending on 31 December 2011

ERO Energy Regulatory Office (2009): Final Report of the Energy Regulatory Office on the regulatory methodology for the third regulatory period, including the key parameters of the regulatory formula and pricing in the electricity and gas industries

ERO-KS Energy Regulatory Office (2006): Weighted Average Cost of Capital - Position Paper

Evans, L.T.; Guthrie, G.A. (2005) Risk, price regulation, and irreversible investment; International Journal of Industrial Organization (VOL. 23); pp.109-128

Fama, E. F.; French, K. (1992): The Cross-Section of Expected Stock Returns; The Journal of Finance (VOL. 47); pp.427-465

Fama, E. F.; French, K. (1995): Size and Book-to-Market Factors in Earnings and Returns; The Journal of Finance (VOL. 50); pp.131-155

Fama, E. F.; French, K. (1997): Industry Costs of Equity; Journal of Financial Economics (VOL. 43); pp.153-193

Fama, E. F.; French, K. (1998): Value versus Growth: The International Evidence; The Journal of Finance (VOL. 53); pp.1975-1999

Frankfurter, G.; Vertes, P. (1990): Some empirical evidence of bias in random, market-value-weighted portfolios; The Journal of Economics and Business (VOL. 42); pp.213-222

Fraser, D. R.; Kolari, J. W.; Uselton, G. C. (1988): Intraindustry Risk Changes in Electric Utlitity Industry Since Three Mile Island; Journal of Business Research (VOL. 16); pp.225-234

French, K. (2010): http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

Frontier Economics (2008): Ermittlung des Zuschlags zur Abdeckung netzbetriebsspezifischer Wagnisse im Bereich Strom und Gas; Report for Bundesnetzagentur

Gerke, W. (2003): Risikoadjustierte Bestimmung des Kalkulationszinssatzes in der Stromnetzkalkulation - Kalkulationsgrundlagen in der Energieversorgung; VDEW (Band 1)

Golec, J. (1990): The Financial Effects of Fuel Adjustment Clauses on Electric Utilities; Journal of Business (VOL. 63); pp.165-186

Gombola, M. J.; Kahl, D. R. (1990): Time-series processes of utility betas: implications for forecasting systematic risk; Financial Management (VOL. 19); pp.84-93

Gordon, M. J. (1959): Dividends, Earnings and Stock Prices; Review of Economics and Statistics (VOL. 41); pp.99-105

Gray, S.; Officer, B. (12th of November 2004): The Equity Beta of an Electricity Distribution Business ; Draft Report prepared for CitiPower LTD and Powercor Australia Ltd (); pp.

Griffin, J. M. (2002): Are the Fama and French Factors Global or Country Specific?; The Review of Financial Studies (VOL. 15); pp.783-803

Hagerman, R. L.; Ratchford, B. T. (1978): Some Determinants of Allowed Rates of Return on Equity to Electric Utilities; Rand Journal of Economics (VOL. 9); pp.46-55

Hamao, Y. (1988): An Empirical Examination of the Arbitrage Pricing Theory; Japan and the World Economy (VOL. 1); pp.45-61

Higgins, R. C. (1974): Growth, Dividend Policy and Capital Costs in the Electric Utility Industry; The Journal of Finance (VOL. 29); pp.1189-1201

Hill, J.; Schneeweis, T. (1983): The Effect of Three Mile Island on Electric Utility Stock Prices: A Note; Journal of Finance (VOL. 38); pp.1285-1292

Icecapital (2009): WACC ÅR 2008, Study for Swedish regulation authority

ILR Institut Luxembourgeois de Régulation (2008): Résultat de la consultation publique se terminant le 16 mai 2008 sur les méthode de détermination des tarifs d'utilisation des réseaux, élaborées sur base de l'article 20(1) de la loi du 1er août 2007 relative à l'organisation du marché de l'électricité

Jobson, J. D. (1982): A Multivariate Linear Regression Test for the Arbitrage Pricing Theory; The Journal of Finance (VOL. 37); pp.1037-1042

Kaneko, T.; Lee, B.-S. (1995): Relative Importance of Economic Factors in the U.S. and Japanese Stock Markets; Journal of the Japanese and International Economies (VOL. 9); pp.290-307

Kema Consulting (2008): Ermittlung angemessener Kapitalzinssätze für deutsche Strom- und Gasverteilnetze; Report for VKU

Kihm, S. G. (2007): The Proper Role of the Cost-of-Equity Concept in Pragmatic Utility Regulation; The Electricity Journal (VOL. 20); pp.26-34

Kobialka, M.; Rammerstorfer, M. (2009): Regulatory Risk and Market Reactions – Empirical Evidence from Germany; ZfE Zeitschrift für Energiewirtschaft (VOL. 3); pp.221-227

Kolbe, A. L.; Borucki, L. S. (1998): The Impact of Stranded-Cost Risk on Required Rates of Return for Electric Utilities: Theory and an Example; Journal of Regulatory Economics (VOL. 13); pp.255-275

Lally, M. (2005): The Equity Beta for ETSA Utilities; Report

Lewellen, W. G.; Mauer, D. C. (1993): Public Utility Valuation and Risk Under Incentive Regulation; Journal of Regulatory Economics (VOL. 5); pp.263-287

Lindtner, J. (1965): The valuation of risk assets and the selection of risky investments in stock portfolios and capital budgets; Review of Economics and Statistics (VOL. 47); pp.13-37

Litzenberger, R. H.; Rao, C. U. (1971): Estimates of the Marginal Rate of Time Preference and Average Risk Aversion of Investors in Electric Utility Shares: 1960-66; Bell Journal of Economics (VOL. 2); pp.265-277

Malko, J. R.; Swensen, P.R.; Monteleone J.A. (2007): Some Thoughts on Estimating the Cost of Common Equity for a Regulated Business ; The Electricity Journal (VOL. 20); pp.56-61

Markowitz, H. (1952): Portfolio Selection; The Journal of Finance (VOL. 7); pp.77-91

Martikainen, T.; Yli-Olli, P.; Gunasekaran, A. (1991): Incremental significance of pre-specified macroeconomic factors in testing the arbitrage pricing theory: empirical evidence with Finnish data; Applied Financial Economics (VOL. 1); pp.139-147

McDonald, J. G. (1971): Required Return on Public Utility Equities: A National and Regional Analysis, 1958-1969 ; Bell Journal of Economics (VOL. 2); pp.503-514

McElroy, M. E.; Burmeister, E. (1988): Arbitrage Pricing Theory as a Restricted Nonlinear Multivariate Regression Model: Iterated Nonlinear Seemingly Unrelated Regression Estimates; Journal of Business & Economic Statistics (VOL. 6); pp.29-42

Miller, I.; Zhang, J. (2003): Estimating Risk Parameters for Water and Power Utilities in China; Journal of Structured Finance (Winter)

Miller, M. H.; Modigliani, F. (1966): Some Estimates of the Cost of Capital to the Electric Utiliy Industry, 1954-1957; The American Economic Review (VOL. 56); pp.333-391

Morana, C., Sawkins, J. C. (2000): Regulatory Uncertainty and Share Price Volatility: the English and Welsh Water Industry's Periodic Price Review ; Journal of Regulatory Economics (VOL. 17); pp.87-100

Mossin, J. (1966): Equilibrium in the Capital Market; Econometrica (VOL. 34); pp.768-783

Myers, S. C. (1972): The Application of Finance Theory to Public Utility Rate Cases; Bell Journal of Economics (VOL. 3); pp.58-97

Norton, S.W. (1985): Regulation and Systematic Risk: The Case of Electric Utilities; Journal of Law and Economics (VOL. 28); pp.671-686

Nwaeze, E. T. (2000): Deregulation of the Electric Power Industry: The Earnings, Risk, and Return Effects; Journal of Regulatory Economics (VOL. 17); pp.49-67

OFGEM (2009): Electricity Distribution Price Control Review, Final Proposals – Allowed Revenues and Financial Issues

Oxera (2009): Updating the WACC for the Energy Networks - Quantitative Analysis - Prepared for Energiekamer

Peltzman, S. (1976): Toward a More General Theory of Regulation; Journal of Law and Economics (VOL. 19); pp.211-240

Pettway, R. H. (1978): On the Use of β in Regulatory Proceedings: An Empirical Examination; Bell Journal of Economics (VOL. 9); pp.239-248

Poon, S.; Taylor S. J. (1991): Macroeconomic forces and the UK stock market; Journal of Business Finance & Accounting (VOL. 18); pp.619-636

Pratt, S. P.; Grabowski, R. J. (2008): Cost of Capital - Applications and Examples; Wiley, New York (Third Edition)

PwC (2009): Advice on the cost of capital analysis for DPCR5; Report for OFGEM

Riddick, L. A. (1992): The effects of regulation on stochastic systematic risk; Journal of Regulatory Economics (VOL. 4); pp.139-157

Rjoub, H.; Türsoy, T.; Günsel, N. (2009): The effects of macroeconomic factors on stock returns: Istanbul Stock Market; Studies in Economics and Finance (VOL. 26); pp.36-45

Robinson, T. A.; Taylor, M. P. (2002): The Effects of Regulation and Regulatory Risk in the UK Electricity Distribution Industry; Annals of Public and Cooperative Economics (VOL. 69); pp.331-346

Rocha, K.; Camacho, F.; Bragança, G. (2007): Return on capital of Brazilian electricity distributors: A comparative analysis; Energy Policy (VOL. 35); pp.2526-2537

Ross, S. A. (1976): The Arbitrage Pricing Theory of Capital Asset Pricing; Journal of Economic Theory (VOL. 13); pp.341-360

Sawkins, J. W. (1996): Balancing Multiple Interests in Regulation: An Event Study of the English and Welsh Water Industry; Journal of Regulatory Economics (VOL. 9); pp.249-268

Schober, D.; Schaeffler, S.; Weber, C. (2011): Implicit Discrimination in Regulation: The Role of Firm-Specific Risk due to Size and Age Distribution of Electricity Networks; Working Paper

Shanken, J.; Weinstein, M. I. (2006): Economic forces and the stock market revisited; Journal of Empirical Finance (VOL. 13); pp.129-144

Sharpe, W. F. (1964): Capital asset prices: A theory of market equilibrium under conditions of risk,; The Journal of Finance (VOL. 19); pp.425-442

Shome, D. K.; Smith, S. D. (1988): An Econometric Analysis of Equity Costs and Risk Premiums in the Electric Utility Industry: 1971-1985; Financial Review (VOL. 23); pp.439-452

Thompson, H.E. (1979): Estimating the Cost of Equity Capital for Electric Utilities: 1958-1976; Bell Journal of Economics (VOL. 10); pp.619-635

Uselton, G. C.; Kolari, J. W.; Frase, D. R. (1986): Long Term Trends in the Riskiness of Electric Utility Shares; Journal of Business Finance & Accounting (VOL. 13); pp.413-459

UVEK Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation, Bundesamt für Energie BFE - Abteilung Energiewirtschaft (2010): Erläuterungen zur Änderung von Art. 13 Abs. 3 Bst. b der Stromversorgungs-verordnung (StromVV) und dem neuen Anhang 1

Warner, J. B. (1977): Bankrupty Costs: Some Evidence; The Journal of Finance (VOL. 32); pp.337-347

Wright, S.; Mason, R.; Miles, D. (2003): A Study into Certain Aspects of the Cost of Capital for Regulated Utilities in the UK; OFGEM, Network Policy Papers (Reference number: 08/03))