INCORPORATING CO_2 RISKS IN VALUATION PRACTICE: A CAPITAL MARKET APPROACH FOR EUROPEAN UTILITIES[a]

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April 2009

ABSTRACT

In 2005 the European Union (EU) has implemented an Emission Trading Scheme (ETS) as a market for carbon emissions. While investors have already identified emission allowances as a new asset class, utilities have to adapt their business strategies in order to optimise future carbon price risk of their generation portfolios. However, investors and utilities need to know their carbon risk exposure in order to define their investment strategies. On the investor side, investment professionals are looking for approaches to incorporate CO_2 risks in valuing utilities in particular. According to the Carbon Disclosure Project their current approaches are limited to computing ratios in order to analyse competitors in terms of emission levels. (see Carbon Disclosure Project 2008). A valuation methodology based on capital market theory has been neglected so far. Hence, we use a capital market approach for our analysis. Based on our sample of European utility firms we identify carbon as systematic risk factor. Therefore, we analyse its determinants to quantify the carbon risk exposure in order to allow for a fair adjustment of the cost of capital for the individual utility. Utilities as well as investment professionals could use the approach for analysing their investment projects or for company valuation.

KEYWORDS: Carbon Beta, Valuation, CAPM, APT, Cost of Capital

JEL CLASSIFICATION: G12, G39, Q 49, Q51

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I. INTRODUCTION

We quantify the carbon[1] risk of European utilities using capital market data. We conduct our study for the utility sector, as more than half of total emissions refer to the energy industry. Besides utilities are fully parts of the Emission Trading Scheme (ETS) of the European Union (EU) whereas other industries are not. Since utilities used to generate windfall profits, future emission standards have been tightened by the regulatory authority. Consequently, the alteration of the regulation will affect utilities' future cash flows. While investors should add the carbon risk of a utility to their required risk premium for valuation, utilities need to know their carbon exposure in order to define future investment strategies. To determine specific risk factors we construct a portfolio of European utilities. We examine eighteen utility companies, which cover around half of total power production in Europe.[2] As generation portfolios differ between European utilities, capital markets should price less carbon intensity in electricity generation to high carbon intensity of a utility. However, capital markets have not anticipated generation mix due to the specific design of the regulatory framework of the EU within the first trading period. Meanwhile the emission regulation is set for the future and will affect stock returns to change of carbon prices. In a multivariate regression of stock returns of utilities on the market returns and carbon price returns, controlling for oil, gas, power and coal, the coefficient is positive for utilities emitting much carbon.

To our knowledge existing studies based on capital market theory rather adjust cash flows of a firm as discount rates for considering carbon risk. We test the model for a peer group of European utilities in order to determine company specific carbon risk from a capital market perspective. Therefore we enlarge existing research in that field by conducting the analysis for individual firms (micro level). We suggest an approach to adjust the equity cost of capital. Consequently, the carbon adjusted cost of capital can be easily integrated in valuation practice or be used for investment planning by utilities.

II. LITERATURE REVIEW

The exposure of utility stocks has been a popular research field. While Bower et al. (1984) favour the *Arbitrage Pricing Theory* (APT) to estimate expected returns of utility stocks, other researchers base their theoretical considerations on the *Capital Asset Pricing Model* (CAPM). For instance, Litzenberger et al. (1980) estimate the cost of equity for a public utility company using the CAPM. Riddick (1992) shows that regulation reduces the systematic risk of a utility causing lower cost of equity capital.

Research in the field of emission trading and climate policy has been soaring recently. While studies have been carried out to examine the price behaviour of emission certificates (Benz/ Türk 2008), and to analyse market efficiency of carbon markets (Daskalakis et al. 2008), the influence of emission regulation on corporate valuation has rather been scarce. Hart and Ahuja (1996) conclude that a poor environmental performance affects the firm's cost of capital negatively.

[1] In the following paper we use carbon as synonym for CO_2.
[2] Namely, British Energy (UK), Centrica (UK), CEZ (CZ), Edison (I), EDF (F), EDP (P), Endesa (E), Enel (I), E.on (D), Fortum (FIN), GDF Suez (F), Iberdrola (E), International Power (UK), RWE (D), Scottish & Southern Energy (UK), Public Power Corporations (GR), Union Fenosa (E), United Utilities (UK).

To take emission regulation into account for valuation purpose, the determinants of carbon prices should clearly be identified in a first step. Referring to Bataller et al. (2006) the most emission intensive energy sources (for instance oil, gas, the ratio between gas price and coal price), and extreme climate conditions in terms of extraordinary temperatures and precipitation determine the carbon price. We believe this could be an appropriate starting point for questioning how to incorporate carbon risk in company valuation. Therefore, an investor knowing the price drivers of emission certificates could easily compare those to the plant mix of a utility. The sensitivity is an indicator for potential carbon risk, but does not account for cost-shifting opportunities though. Thus, a capital market approach is necessary to consider carbon risks in company valuation. Recently McKinsey and Carbon Trust (2008) have adjusted company cash flows for climate policy effects before conducting a Discounted Cash Flow (DCF) company valuation. The interactions between capital markets in terms of stock returns and price returns of emission certificates are still neglected. Therefore the aim of the presented paper is to fill that gap and conduct further research on a company level.

Kahn and Knittel (2003) analyse the impact of the U.S. 1990 Clean Air Act to stock market returns of American utilities and coal mining firms. Following to their study, returns of electricity firms do not fall, as utilities are either able to pass cost through to customers or due to specific electricity price regulation. According to Veith et al. (2009) carbon price returns are positively correlated to the return of European utility stocks for the first trading period from April 2005 to August 2007. Oberndorfer (2008) shows that the EU emission trading scheme has effectively an impact on financial markets and therefore economic consequences, which affect the corporate value. However, the analyses of Oberndorfer as well as Veith et al. are based on equally-weighted portfolios of utilities and do not consider an examination on a micro level. They conduct their analysis for the first emission trading period and refer to daily returns, although daily stock returns are not normally distributed. We conduct our analysis for the period between April 2005 to March 2009. The extended data sample allows for the use of weekly returns, which conforms to the assumption of normal distribution. Moreover we take excess returns into account, consistent to the *Capital Asset Pricing Model* (CAPM). We suppose capital markets price the structure of the generation mix of a utility company. Using capital market data we suggest an approach to incorporate carbon risk into company valuation by adjusting the cost of equity capital.

Carbon returns are positively related to the stock returns of utility companies. Hence, rising carbon prices go along with increasing returns of the affiliated utility stock. From a corporate valuation point of view the increase in equity cost causes a lower equity value and vice versa. The beta of the carbon factor[3] for a portfolio of high-emitting utilities is larger compared to a sample of low emittance.[4] Following capital market theory, investors request a risk premium for pervasive risk or systematic risk factors, namely market risk and carbon risk. The carbon risk defined as the sensitivity of changes in carbon return to stock returns differs for the sample. In our study we quantify the specific carbon risk of a utility. The product of carbon coefficient and excess carbon return determines the carbon premium. Therefore, the cost of equity capital is the sum of the risk-free rate and the risk premiums. The latter compensates taking the market risk and the carbon risk.

[3] We define the beta of the carbon factor as co- movement of the utility stock return and carbon price return.

[4] The results are based on a portfolio analysis. However, the results do not hold for utility portfolios using emission intensities instead of total emission. Since emission certificates have been freely allocated between 2005 and 2007, stock returns go along positively with carbon price changes due to windfall profits.

The remainder of this paper is structured as follows: Section 3 describes the framework of emission regulation in Europe, and section 4 presents the theoretical considerations. Section 5 deals with the empirical analyses; in section 6 we summarise the implications of the empirical results. The paper closes in section 7, a conclusion and outlook for further research.

III. THE EUROPEAN FRAMEWORK OF EMISSION REGULATION

In 2005 the EU has implemented an ETS as a market for emission certificates with the main objective to reduce emissions cost-efficiently by companies.[5] For the period 2008 until 2012 the average emission reduction in the EU is set to 8 percent compared to the total emission level in 1990. This rate is based on economic factors of each member state and therefore varies from state to state. Meanwhile the ETS of the EU is the world largest market in terms of transactions (more than 2 billion tones of CO_2) and value (roughly US-$ 50 million) for CO_2 emission allowances in 2007 (Daskalakis et al., 2007).

To transpose the European directive into national law, the National Allocation Plan (NAP) has been passed to set the reduction targets for the industry. The ETS distinguishes three different trading periods. The first lasted from 2005 until 2007. After the trial period the second trading period has started in 2008 and will last until 2012. Correspondingly an individual NAP does exist for each trading period, NAP I, NAP II and NAP III respectively. The EU emission trading scheme applies to different industry sectors.[6] However, the electricity generators are dominating as more than half of all emission certificates are transferred to utilities. While the allocation of the total emission budget for each industry is set on the macro level, the micro plan regulates the allocation for each plant. During phases one (2005 until 2007) the emission allowances were allocated by comparing a plant with the state of the art technology (“best available technology”). Within that regulation period the emission allowances were allocated freely. This allocation mechanism will change in phase two (2008 until 2012). The EU directive recommends auctioning 10 percent of the total emission budget for utilities in the process. Power plants, which are built during that time, will receive the certificates for free.

It is important to note that the ETS is a trading system, which does not distinguish between the national market participants. Therefore an emission certificate is valid in each country. Also, if a utility company uses less emission certificates for operation than budgeted, it is allowed to transfer the certificates to the next year (“banking”). Otherwise the utility has to buy the certificates on the market (“borrowing”). While banking was restricted in the first phase, the second phase facilitates the market participants to emission allowances to the following year. Most likely, the banking rule will stabilize the price level including future price expectations. In that case the price volatility will decrease and the transparency of the market will increase (EWI, 2008).

The climate policy for the period after 2012 was main topic on the European Summit in December 2008. The governments of the European Union came to a mutual agreement on the design of future regulation. Overall the

[5] The ETS is legally based on the EU-directive 2003/87/EC.
[6] The following sectors are part of the ETS: Energy industry, refineries, coke oven plants, steel, cement, glass, ceramic, pulp and paper industry.

European Union’s total reduction objective in 2020 amounts to 21 percent compared to 2005. The emission cap will decrease by 1.74 percent annually, starting in 2013. Contrary to the allocation process of the first trading period, European utilities have to purchase the emission allowances. Yet, exemptions for European utilities do exist.[7] The auctioning of emission certificates will prevent windfall profits. Moreover the climate package of the European Union aims at incorporating other industry branches to emission trading. Currently, the objective is to increase 20 percent of emission auctioning for the industry to 70 percent in 2020 (Kobes, 2008). Since the EU has already published plans for the continuation of the EU trading scheme, it is very likely that the trading scheme will exist after 2012 and be the framework for a global carbon market (Wagner, 2007).

The regulation regarding emissions has forced the owner of electricity generation capacities to include the cost of a carbon certificate in their operative decision for existing power plants as well as for investment decisions. From a company valuation point of view, the price risk of carbon certificates has to be considered.

IV. PRELIMINARY THEORETICAL CONSIDERATIONS

The tightening of emission regulation for utilities will influence companies’ business strategies on the one hand and investors decisions on the other. If a utility company does not adapt its business strategy in order to optimise future carbon price risk of its generation portfolio, competitors are better off. Hence, a utility company has to know its individual carbon exposure for defining an investment strategy. Typically, a utility’s generation portfolio consists of fossil (i.e. coal, gas, oil) and non-fossil power plants (water, wind, solar). However, the generation mix differs between utilities. Taking the future emission regulation into account, utilities have to make sure to operate efficient power parks in terms of emissions per MWh.

On the investor side, investment professionals are looking for approaches to incorporate CO_2 risks in company valuation. According to the German *Carbon Disclosure Project* (CDP) 2008 their current approaches are limited to computing ratios in order to analyse competitors in terms of emission levels (see CDP-Report 2008).[8] A common approach is the calculation of the CO_2 intensity of a company as ratio between kg CO_2 and kWh. This indicator is then converted into a maximum revenue related CO_2-risk, which is the product of CO_2 intensity and the price of emission certificates. Before applying these results to the EBITDA of the company, freely allocated certificates have to be taken into account from revenue related CO_2-risk. Finally, the ability to pass on costs resulting from the CO_2 obligations to customers or suppliers have to be analysed. The analysis indicates the need for further research in that field allowing a practical approach for valuation.

The *Capital Asset Pricing Model*, which initially refers to the work of Sharpe (1963), Lintner (1965) and Mossin (1966), postulates a linear relationship between the expected return on an asset and the assets’ beta as measure of risk. According to the equilibrium model of the CAPM, stocks with larger betas will have larger expected

[7] Regulatory authorities are obliged to grandfather up to 70 percent of emission allowances to utilities, if one of the following two conditions is fulfilled: More than 30 percent of the national power generation refers to fossil fuel, or gross domestic product per head is less than half of the average of the European Union.

[8] We have analysed reports of the following investment banks: Bernstein, CA Cheuvreux, Citigroup, Golman Sachs, JP Morgan, Merrill Lynch and Société Générale.

returns, as they bear more risk relative to the market. In practice, a market model is used to determine the expected return or the equity cost of a stock. While the CAPM measures the beta of a stock relative to the market portfolio, the single factor (market) model assumes that the return of stock depends just on the return of the market index (i.e. MSCI World). The beta coefficient as measure for the systematic risk determines the fair premium for taking the risk of investing in a stock. Therefore, the risk premium covers the pervasive or systematic risk of a stock. The idiosyncratic risk of a stock is not priced according to capital market theory, as an investor is able to eliminate the risk through diversification.

Multiple factors are more powerful than the market model, as they take various factors as sensitivities of a stock return into account. According to Fama and French (1993), the exposure of a security is related to the excess return of the market, market capitalisation and book to market ratios. The theoretical foundation of multiple factor models is the *Arbitrage Pricing Theory*, (APT) which states that the reward for the investment risk in a security depends on several macroeconomic factors (Ross, 1976). A clear identification of these factors is not given, though.

A practical approach requires simplicity. Hence, we believe in concentrating on the pervasive factors, which allow a quantification of the carbon risk of a company. Therefore we focus on the excess returns on the market index (here MSCI World) and the excess return of carbon price (here Carbon futures) changes to cover market risk and carbon risk, respectively. Including these two factors in the model, the cost of equity capital expressed as expected return on the utility stock can be estimated. For the analysis we rely on the following methodology, which is generally expressed as:[9]

$$\mu_i = r_f + (\delta_1 - r_f) \times \beta_{i1} + (\delta_2 - r_f) \times \beta_{i2} + ... + (\delta_k - r_f) \times \beta_{ik} \quad (1)$$

According to equation (1), the expected return of a stock, μ_i, is equal to the risk-free interest rate, r_f, and k risk premiums based on the stock's sensitivities expressed as β to the k factors with an expected return of δ.

V. EMPIRICAL ANALYSES

We examine a group of eighteen utility stocks with available data over a sufficient long time from April 25th, 2005 to March 30th, 2009. The financial collapse of investment banks in September 2008 caused an eruption at global stock markets leading to extraordinary high volatilities. Thus, we adjusted the observations by eliminating the data points with at least 3 times standard deviations above or below the mean of the market index. In total 202 data points for each utility firm are included.

The stock prices, which are on a Euro basis and adjusted for capital actions and dividends, are taken from Thomson Financial DataStream. The risk-free interest rate is approximated by an AAA-Eurobond with a

[9] See Sharpe et al (1999), pp. 291-292.

maturity of 10 years.[10] Moreover, DataStream is used as data source for the commodity prices, like power, gas, oil and coal. To gain the data for CO_2 certificate prices, we rely on the European Climate Exchange (ECX) and BlueNext.[11] According to Benz (2008), the trading of spot emission allowances in Europe is mainly performed through the BlueNext, former French Powernext, with 79 percent of spot market transactions. Emission allowances futures are primarily traded in ECX, which achieved a market share of 43 percent in 2007. We believe, due to the design of the different trading phases, it is more reliable to conduct the analysis with future price data compared to spot market data. The latter collapsed in 2006, when operators disclosed 2005 verified emission data causing an oversupply of allowances. One year later spot prices moved towards zero again, as verified emissions in 2007 were below the 2006 yearly allocation (Alberola et al., 2007). Although futures prices were affected from the disclosure as well, they take expectations of market participants into account. Hence, carbon futures are more suitable as proxy for the carbon price risk than spot market data.

We use excess returns on a weekly basis for each utility stock, which we calculate continuously compounded. The Morgan Stanley Capital Indices (MSCI) World acts as market index within our empirical analysis. Weekly excess returns continuously compounded of future prices traded at ECX are used as proxy for the European carbon risk.[12]

Our empirical analysis is threefold. Firstly we start our research by testing our hypothesis for the whole sample of utilities. Therefore, we construct a value-weighted and equally-weighted portfolio. While the first approach is consistent with the CAPM, the second approach gives more weight to smaller stocks. Although power markets have been liberalised in Europe since 1998, national power markets are still dominated by a few players (i.e. EDF in France, E.on in Germany). Moreover global utilities have been growing extremely of late by Mergers & Acquisitions leading to higher market capitalisation on stock exchanges and enlarging the spread within European utilities in terms of market value.[13] As a result, it is necessary to conduct the research for an equally-weighted portfolio as well. Secondly we split the sample into two groups of power companies, using the median of their total emissions as a divide. Both portfolios – one consisting of “high-emitting” and one of “low-emitting“ utilities– are then tested once value-weighted and once equally-weighted. Thirdly, we analyse single utility stocks.

The objective of our study is to introduce an approach for adjusting equity cost of capital for company specific carbon risk in order incorporating carbon risks into company valuation. The portfolio analysis is necessary to test the hypothesis first before entering the micro-level by analysing single utility stocks. We are aware of the fact that beta estimations of portfolios are more reliable as single stocks. However, the utilities taken into account have a market capitalization of more than Euros 5,000 billion and are rather liquid compared to other industry stocks. Therefore a possible thin trading bias should be avoided.

[10] Generally speaking, government bonds with best rating and long running are used in valuation practice. Yet, for empirical research bonds with short maturities are used instead. We conduct the empirical analysis including bonds with different maturities. The empirical results do not alter.

[11] The ECX as well as BlueNext offer an unrestricted access to data of carbon prices.

[12] Due to the design of the European emission regulation, splitting the market into different phases (please refer to the Emission regulation section), we use future prices of 2009. The price development of futures consider future expectations of the market participants. From our perspective using carbon spot prices cause bias, as prices slumped in April 2007.

[13] For instance: Acquisition of Essent by RWE in 2009, acquisition of Union Fenosa by Gas Natural in 2008, acquisition of British Energy by EDF in 20008 and Iberdrola’s acquisition of Scottish Power in 2007.

DESCRIPTIVE STATISTICS

The descriptive statistics of the dependent and independent variables are presented in Table 1 and Table 2, respectively.

Tab. 1 Descriptive statistics: weekly returns of dependent variables (April 25th, 2005 to March 30th, 2009)

Dependent variables	Mean	Min.	Max.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
British Energy*	0.0035	-0.0915	0.1318	0.0461	0.1480	2.9117	0.43
Centrica	-0.0003	-0.2692	0.0940	0.0386	-1.7733	13.8330	1093.60
CEZ	0.0035	-0.1749	0.1337	0.0474	-0.4980	4.3700	24.15
EDF**	-0.0005	-0.1819	0.1458	0.0498	-0.6266	4.5350	27.98
Edison	-0.0023	-0.1425	0.1124	0.0377	-0.4380	5.0540	41.97
EDP	0.0013	-0.2425	0.1170	0.0366	-1.3348	12.7637	862.34
Endesa	0.0010	-0.1525	0.1242	0.0385	-0.5865	6.2604	101.05
Enel	-0.0028	-0.1621	0.0895	0.0311	-1.4853	9.2561	403.69
E.on	0.0007	-0.1177	0.0962	0.0354	-0.5722	4.0750	20.75
Fortum	0.0024	-0.1289	0.1710	0.0449	-0.1589	4.1081	11.18
GDF Suez***	-0.0002	-0.1482	0.1262	0.0401	-0.4180	3.7768	10.31
Iberdrola	0.0017	-0.1283	0.1763	0.0405	0.0482	5.0305	34.78
International Power	0.0000	-0.2066	0.1600	0.0463	-0.3364	5.1228	41.74
PPC	-0.0015	-0.3793	0.1823	0.0565	-1.3951	12.7666	868.37
RWE	0.0009	-0.1268	0.0786	0.0333	-0.7172	4.0249	26.16
Scottish & Southern Energy	-0.0001	-0.1226	0.1006	0.0287	-0.4169	4.6086	27.63
Union Fenosa	0.0045	-0.0908	0.2259	0.0320	1.9443	14.6337	1266.40
United Utilities	-0.0023	-0.1181	0.1560	0.0323	0.2401	6.5566	108.41

Instead of 202 data points *, ** and *** indicate data points of 108, 171, 190, respectively. This is due to shorter time period of listing at stock exchanges.

Utility stocks attract defensive investors aiming to realise stable returns by moderate volatility. The volatility of utility stocks is rather low compared to other industry stocks. Yet, slumping prices on stock markets in autumn 2008 have increased volatility and affected returns negatively.

Tab. 2 Descriptive statistics: weekly returns of independent variables (April 25th, 2005 to March 30th, 2009)

Independent variables	Mean	Min.	Max.	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
MSCI World	-0.0011	-0.0799	0.0773	0.0233	-0.2972	3.9310	10.27
Eurobond*	0.0007	0.0006	0.0009	0.0001	-0.0231	2.2414	6.64
Carbon	-0.0003	-0.5087	0.2069	0.0771	-1.6808	12.0028	777.27
Oil	0.0008	-0.1954	0.2706	0.0482	0.2897	8.2800	237.46
Gas	-0.0012	-0.4469	0.3645	0.1106	0.2993	4.9168	33.94
Coal	0.0007	-0.4376	0.4741	0.0895	-0.3011	12.5166	765.31
Power	-0.0015	-1.6309	1.8633	0.3569	-0.0622	8.6906	272.68

* weekly return of a AAA-Eurobond with a maturity of 10 years

For instance, the weekly return of the MSCI World was -0.11 percent over the examined time period, which corresponds to an annual return of -5.56 percent. Investors tend to favour anti cyclical stocks like power companies as soon as the economy is ailing. However, most of the utility stocks have realised negative returns over the period from April 2005 to March 2009. Similar to the market index, the carbon futures have performed negatively as well. The annualised weekly return of the carbon future equalises -1.55 percent. For a proper empirical methodology we examine the distribution of the return of the utilities, the market portfolio and the return of the carbon futures. The values of skewness and kurtosis of the utility stock returns are not necessarily

consistent with the assumption of normal distributed returns. Therefore we conduct a non-parametric test to verify our results.[14]

Before running the regression analysis, we examine the correlation between the excess returns of the independent variables.[15] Our test indicates a rather high correlation of oil (0.2582) and gas (0.1875) to the carbon futures. We find a negative correlation between coal and carbon, which is attributed to the shift of fuel in the power generation. If carbon prices rise, a power plant operator is better off running gas fired turbines than coal plants.

The carbon and market factor explain utility stock returns properly. Hence, the interaction between these factors is important for the methodology. Our test indicates a correlation of 0.0479 between carbon and the MSCI World market index.[16] To avoid multicollinearity, we run a regression using carbon as regressand and the MSCI World index as regressor. The R^2 (0.0023) of the regression is input for the calculation of the Variance Inflation Factor (VIF). We find a VIF, roughly speaking, of bigger than one, taking as evidence of non-existence of multicollinearity.[17] Therefore, neither the value of R^2 nor the variance of adjusted R^2 will be biased.

Tab. 3 Correlation matrix of independent variables

	Carbon	Oil	Gas	Coal	Power	MSCI World
Carbon	1.0000					
Oil	**0.2582******	1.0000				
Gas	**0.1875******	**0.1462******	1.0000			
Coal	-0.0028	-0.0260	0.0416	1.0000		
Power	0.0077	0.0284	-0.0336	-0.0336	1.0000	
MSCI World	0.0479	0.1071	0.1226	**0.122585***	0.0002	1.0000

*and ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

METHODOLOGY AND HYPOTHESIS DEVELOPMENT

We start our empirical analysis by determining two risk factors: One is the excess return of the market index as proxy for the market risk and the other the excess return of the carbon futures as proxy for CO_2 risks. Consequently, we adjust equation (1) for the simple OLS regression analysis in the following way.

(2) $$\tilde{r}_i = \alpha_i + \beta_{iM} \times I_M + \beta_{iC} \times I_C + \varepsilon_i$$

Within the equation (2) I_M and I_C represent the market and carbon risk factors, respectively. While the intercept is determined by α, the error term is denoted by ε. To be consistent with the methodology, the following assumptions have to be fulfilled. First, non-existence of multicollinerity. Secondly, non-systematical bias of the error term. Like the risk factors, the error term has to be uncorrelated to keep up the validity of the model. Lastly, the risk factors and error terms have to be uncorrelated.

[14] We test the results of our empirical approach with the Kolmogorov-Smirnov test.
[15] We use the excess returns of Crude-Oil Brent, ICE Natural Gas, Coal Index (delivered cost of coal into Rotterdam) and EEX-Phelix Base as proxy for oil, gas, coal and power, respectively.
[16] The correlation is similar to the returns of holding SO_2 allowances and stock indices for the U.S. market (Ellermann et al, 2005).
[17] Generally, a VIF larger than 10 is viewed as evidence of multicollinearity.

We expect that return of a utility stock is affected by changes to carbon prices. Since utility companies pursue different strategies regarding their generation mix, we suppose that the carbon beta coefficient is not zero. If we consider an emission regulation set by the regulator authority in which all emission certificates have to be bought on markets, windfall profits are avoided. Therefore the sensitivity of price changes of emission certificates affects the profitability of the utility causing stock returns. This sensitivity is captured by the beta of the carbon coefficient. In a world without any free allocation of emission certificates by the national regulative authority, the carbon coefficient has to be negative for low-emitting utilities and positive for high-emitting utilities.
As soon as power firms have to purchase their total need of emission certificates, power firms operating low emitting power plant parks are better off compared to high-emitting utilities. Consequently, capital markets will request a higher premium for investments in high-emitting utilities. We question whether capital markets have already anticipated the regulative change and if the carbon exposure expressed as beta of the carbon coefficient differs within our sample. Therefore we test the following null-hypothesis:
Carbon is a pervasive risk factor for European utilities. Equivalently, the beta of the carbon factor is non- zero.

ANALYSES ON A PORTFOLIO BASIS

The results of our study are presented in Table 4.[18]

Tab. 4 Results of regressions of portfolio returns on the market and carbon returns

Dependent Variable		Intercept		Market Portfolio		Carbon	
		Coeff.	t-Statistic	$Beta_{iM}$	t-Statistic	$Beta_{iC}$	t-Statistic
Portfolio		0.0007 (0.0012)	0.6045	0.6200** (0.0473)	13.0946	0.0658** (0.0150)	4.3899
R^2	0.4971						
Adjusted R^2	0.4920						
S.E. of regression	0.0164						
F-Statistic	98.3492						
Prob (F-statistic)	0.0000						
High-emitting Portfolio		0.0006 (0.0017)	0.3457	0.6583** (0.0699)	9.4146	0.0719** (0.0221)	3.2520
R^2	0.3397						
Adjusted R^2	0.3331						
S.E. of regression	0.0242						
F-Statistic	51.1902						
Prob (F-statistic)	0.0000						
Low-emitting Portfolio		0.0017* (0.0014)	1.2546	0.6488** (0.0562)	11.5492	0.0355* (0.0178)	1.9999
R^2	0.4128						
Adjusted R^2	0.4069						
S.E. of regression	0.0194						
F-Statistic	69.9590						
Prob (F-statistic)	0.0000						

* and ** indicate significance at the 5% and 1% levels, respectively.

For the whole sample, constructed as value-weighted portfolio, the beta coefficients for the market index as well as the beta coefficient for carbon are highly significant on a 1 percent level. This means utility returns can be

[18] Our regression based on equally-weighted portfolios confirms the results presented in Table 4.

explained by the market and carbon returns. Both coefficients are positive, stating that investors should request risk premiums for market and carbon risks for the sample of utility firms. Thus, we can confirm that utility stocks are affected by carbon price changes over the period from April 25th, 2005 to March 30th, 2009.

However, we are particularly interested in differences between power companies. Therefore we split the sample by using the median of absolute emissions. The results correspond to our expectations, expressed in the section above. The utility stocks, which can be characterised as high-emitting, request a higher carbon risk premium than low-emitting portfolios.[19] Thus, the stocks in the high-emitting portfolio are more sensitive to carbon price changes as the sample of the low-emitting portfolio. The results are consistent with our expectation that high carbon risk corresponds with an additional risk premium, which raises equity costs causing a lower equity value. Consequently, stocks of the low-emitting portfolio have lower equity cost, which corresponds to a higher equity value.[20]

In order to test whether we have neglected independent variables as risk factors, we repeat the regression analysis controlling for oil. The t-test states that oil is statistically significant and should be added for the portfolio analysis. The results are summarised in Table 5:

Tab. 5 Results of regressions of portfolios' excess returns on the market, carbon and controlling for oil

Dependent Variable		Intercept		Market Portfolio		Carbon		Oil	
		Coeff.	t-Statistic	$Beta_{iM}$	t-Statistic	$Beta_{iC}$	t-Statistic	$Beta_{iO}$	t-Statistic
Portfolio		0.0008	0.6637	0.6081**	12.9621	0.0557**	3.6473	0.0682**	2.5814
		(0.0011)		(0.0469)		(0.0153)		(0.0264)	
R^2	0.5135								
Adjusted R^2	0.5061								
S.E. of regression	0.0161								
F-Statistic	69.6533								
Prob (F-statistic)	0.0000								
High-emitting Portfolio		0.0007	0.3979	0.6417**	9.2456	0.0579**	2.5615	0.0955**	2.4420
		(0.0017)		(0.0694)		(0.0226)		(0.0391)	
R^2	0.3590								
Adjusted R^2	0.3493								
S.E. of regression	0.0239								
F-Statistic	0.0239								
Prob (F-statistic)	0.0000								
Low-emitting Portfolio		0.0018	1.2823	0.6416**	11.3856	0.0294	1.6046	0.0414	1.3058
		(0.0014)		(0.0564)		(0.0183)		(0.0317)	
R^2	0.4179								
Adjusted R^2	0.4090								
S.E. of regression	0.0194								
F-Statistic	47.3729								
Prob (F-statistic)	0.0000								

* and ** indicate significance at the 5% and 1% levels, respectively.

Analogical to portfolio analysis carbon still is a pervasive risk factor for European utilities. However, the beta coefficient has slightly changed compared to the regression excluding oil as independent variable. Referring to the correlation matrix, Table 3, we test for multicollinearity, as the correlation between carbon and oil amounts

[19] We classify CEZ, EDF, Edison, Endesa, Enel, E.on, GDF Suez, PPC, RWE as high-emitting and British Energy, Centrica, EDP, Fortum, Iberdrola, International Power, Scottish & Southern Energy, United Utilities and Union Fenosa as low-emitting in terms of absolute emissons.

[20] The regression for an equally-weighted portfolio confirms the results.

to 0.2582. Therefore, we test carbon and oil for interaction, by running another regression, taking oil as dependent and MSCI World and carbon as independent variables. We calculate the VIF by taking the reciprocal of the difference between 1 and R^2, which amounts to 0.0756. As the VIF (1.08) is lower than 10 we accept this as evidence of non-existence of multicollinearity. Furthermore, we have tested other control variables, like coal, gas and power. None of them is statistically significant. The redundant tests via F-statistic and Log-likelihood ratio confirm the results.

Including oil as independent variable causes a slight decrease in the carbon coefficient of the portfolio which is characterised as high-emitting. However, the carbon coefficient is still statistically significant on a 1 percent level. Moreover, the carbon risk factor remains higher than for the low-emitting sample. The carbon and oil risk factor for the latter are not statistically significant, though. That means oil is not a suitable risk factor for every utility company. Therefore, we focus on the market and carbon as risk factors for the analysis on a micro level in order to sustain comparability between the utilities.

By considering total emission as indication for constructing portfolios, the emission intensity of the utility is neglected. In that case small utilities are automatically defined as clean, which does not hold, if the firm emits tons of carbon to generate one MWh electricity. Therefore we have constructed two portfolios by taking the emission intensity[21] into account. The portfolio of utilities characterised by high emission intensity has a positive carbon beta coefficient, which is statistically significant.[22] However, it is lower (0.0451) compared to the results of the carbon factor of the high-emitting sample.[23] Although the results differ from our expectations in that point, we believe that taking emission intensity into account will hold to quantify carbon risk in the long run.

ROBUSTNESS

In order to test the empirical analysis for robustness we use alternative proxies taken as risk factors. Instead of the MSCI World we run the regression for value-weighted and equally-weighted portfolios including the MSCI Europe as market index. Using the MSCI Europe as market index does not alter the prediction power of carbon as pervasive risk factor for European utilities. The beta of the carbon factor remains to be statistically significant.[24] While carbon futures with a maturity 2010 from ECX confirm the results for the different portfolios, carbon spot prices from BlueNext reject the null-hypothesis of carbon as pervasive risk factor for European utilities. Referring to the European framework of emission regulation the carbon spot price is not reliable for empirical analysis.

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[21] We define emission intensity as kg carbon per MWh.

[22] We classify Centrica, CEZ, EDP, Edison, Endesa, International Power, PPC, Union Fenosa, RWE and British Energy, EDF, Enel, E.on, Fortum, GDF Suez, Iberdrola, Scottish & Southern Energy, United Utilities to the portfolio of high emission intensity and of low emission intensity, respectively.

[23] The carbon coefficient for the sample with low emission intensity is statistically significant as well. Compared to the sample, which characterises a high emission intensity, the beta of the carbon factor is higher The results refer to the emission regulation in first trading phase. As long as emission certificates are grandfathered, utilities emitting much carbon in total are better off.

[24] Moreover we test MSCI Europe for a high-emitting, low-emitting, high-emitting intensity, and low-emitting intensity portfolios, value-weighted and equally-weighted, respectively. The results are similar to the presented results using MSCI World as market index apart from the low-emitting portfolio. In that case the carbon factor is not statistically significant.

Furthermore we are interested whether the carbon coefficient will change if we focus our analysis on the second trading period. Therefore, we run the regression for the period from January 7th, 2008 to March 30th, 2009, including 61 observations in total.[25] The results are summarised in Table 6:

Tab. 6 Results of regressions of portfolios' returns on the market and carbon returns (January 7th, 2008 to March 30th, 2009)

Dependent Variable		Intercept		Market Portfolio		Carbon	
		Coeff.	t-Statistic	$Beta_{iM}$	t-Statistic	$Beta_{iC}$	t-Statistic
Portfolio		-0.005567**	-1.9958	0.5146**	6.7575	0.1553**	3.7353
		(0.0028)		(0.0762)		(0.0416)	
R^2	0.5193						
Adjusted R^2	0.5027						
S.E. of regression	0.0206						
F-Statistic	31.3292						
Prob (F-statistic)	0.0000						
High-emitting Portfolio		-0.0065	-1.4451	0.5154**	4.1986	0.2222**	3.3174
		(0.0045)		(0.1227)		(0.0670)	
R^2	0.3431						
Adjusted R^2	0.3205						
S.E. of regression	0.0331						
F-Statistic	15.1491						
Prob (F-statistic)	0.0000						
Low-emitting Portfolio		-0.0267	-0.7532	0.5931**	6.1304	0.0495	0.9383
		(0.0035)		(0.0967)		(0.0528)	
R^2	0.4035						
Adjusted R^2	0.3829						
S.E. of regression	0.0261						
F-Statistic	19.6176						
Prob (F-statistic)	0.0000						

* and ** indicate significance at the 5% and 1% levels, respectively.

The carbon coefficient for the whole sample as well as for the high-emitting portfolio is still statistically significant, indicating carbon as pervasive risk factor for European utilities. Similar to the previous results, the carbon coefficient for the high-emitting portfolio is larger than for the low-emitting portfolio. Apparently, the tightening of emission regulation has affected stock market returns, as we identify a significant increase of the carbon coefficient compared to the results covering the full period (April 2005 to March 2009).[26] Yet, capital markets have not started to appraise emission intensities[27]. However, we are aware of limited data points which obviously reduce the informational value of the empirical analysis.

[25] None of the control variables, namely oil, gas, coal and power appear to be statistically significant for that period.

[26] Finland , Czech Republic, France received more emission allowances as verified for 2008, 1 percent, 7 percent, 5 percent, respectively. Contrary, Germany received 18 percent less emission allowances as verified for the same year. The calculation is based on data of the European Commission (http://ec.europa.eu/environment/climat/emission).

[27] The results for portfolios characterised by high and low emission intensity are in line with the empirical results covering the full period. Equally-weighted portfolios confirm the results out of the regression for value-weighted portfolios

ANALYSES FOR INDIVIDUAL UTILITIES

After having conducted the portfolio analysis, we run the regression for the individual utility stocks from the sample. Our results are presented in the Table 7:

Tab. 7 Results of regressions of utilities' returns on the market and carbon returns

Dependent Variables	Intercept		Market Portfolio		Carbon			
	Coeff.	t-Statistic	Beta $_{iM}$	t-Statistic	Beta $_{iC}$	t-Statistic	R^2	SER
Brititish Energy	0.0054 (0.0044)	1.2471	0.5100*** (0.1443)	3.5347	**0.1409**** (0.0688)	2.0493	0.15	0.0440
Centrica	-0.0003 (0.0025)	-0.1018	0.6400*** (0.1029)	6.2224	-0.0011 (0.0325)	-0.0346	0.16	0.0355
CEZ	0.0041 (0.0030)	1.3880	0.8412*** (0.1211)	6.9456	**0.1441***** (0.0383)	3.7617	0.25	0.0418
EDF	0.0006 (0.0036)	0.1646	0.6133*** (0.1392)	4.406	**0.1458***** (0.0481)	3.0313	0.15	0.0463
Edison	-0.0021 (0.0025)	-0.8551	0.6771*** (0.1006)	6.7307	-0.028 (0.0318)	0.8657	0.19	0.0348
EDP	0.0007 (0.0025)	0.2763	0.4490*** (0.1042)	4.3091	0.0359 (0.033)	1.0900	0.09	0.0360
Endesa	0.0005 (0.0025)	0.1960	0.7842*** (0.1028)	7.6309	0.008 (0.0325)	0.2458	0.23	0.0355
Enel	-0.0027 (0.0019)	-1.4579	0.6538*** (0.0768)	8.5146	-0.0002 (0.0243)	-0.0062	0.27	0.0265
E.on	0.000673 (0.0022)	0.3642	0.6667*** (0.0911)	7.3213	**0.0913**** (0.0288)	3.1698	0.25	0.0315
Fortum	0.0019 (0.0028)	0.661	0.6834*** (0.1150)	5.9427	**0.1967***** (0.0364)	5.4060	0.25	0.0380
GDF Suez	0.0012 (0.0026)	0.4436	0.7300*** (0.1047)	6.9705	0.0443 (0.0339)	1.3065	0.21	0.0357
Iberdrola	0.0017 (0.0026)	0.6693	0.9172*** (0.1056)	8.6848	0.012 (0.0334)	0.3586	0.28	0.0365
International Power	0.0003 (0.0028)	0.094	0.9108*** (0.1157)	7.8691	0.0608 (0.0366)	1.6612	0.25	0.0400
PPC	-0.0016 (0.0040)	-0.398	0.7089*** (0.1621)	4.374	0.02756 (0.0513)	0.5375	0.09	0.0560
RWE	0.001302 (0.0020)	0.65358	0.6043*** (0.0837)	7.2156	**0.0826**** (0.0265)	3.1164	0.24	0.0289
Scottish & Southern Energy	0 (0.0017)	-0.0109	0.5965*** (0.0696)	8.5648	0.0177 (0.0220)	0.8051	0.27	0.0241
Union Fenosa	0.0046** (0.0022)	2.1157	0.3988*** (0.0884)	4.5123	**-0.0484*** (0.0280)	-1.7325	0.10	0.0305
United Utilities	-0.002 (0.0019)	-1.0494	0.7502*** (0.0766)	9.7992	0.0013 (0.0242)	0.5268	0.33	0.0265

* and ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

The results confirm our expectations and are consistent with the results of the portfolio analysis. However, outliers exist. According to the results, investors request a higher premium for carbon risk for CEZ compared to other European utilities. The electricity generation of CEZ mainly relies on lignite and hard coal. Due to the power plant mix and the separate emission regulation treatment of utilities from Eastern Europe, CEZ benefits

from the emission allocation process.[28] Therefore, carbon price changes cause higher returns for CEZ stocks. From the corporate valuation point of view, the premium for carbon risk has to be added on the market risk premium. Higher opportunity cost of equity will lead to a lower equity value, reducing the fair value of the CEZ stock. Similar to the power plant park of CEZ, the generation mix of RWE consists mainly of fossil running plants. Consequently, the carbon beta coefficient (0.0826) is statistically significant, confirming the validity to add a carbon premium on the discount rate. While RWE and CEZ are rather high in terms of emission intensity, EdF and Iberdrola are low. The French utility firm operates mainly with nuclear energy causing very low emissions per MWh. However, the carbon beta coefficient of EdF is positive. Apparently, the capital market appraises the total amount of carbon emissions, explaining the carbon coefficient of EdF. Investors in the stock of Iberdrola do not request a premium for carbon risk. This is consistent with our theoretical explanations. The major stake of Iberdrola in Iberdrola Renovables supports the conjecture. However, the sample shows results we had not expected. For instance, the Finnish power generator, Fortum, is rather clean, thanks to operating nuclear plants. Even though Fortum is characterised by low emission per MWh and is much smaller than EDF, the carbon beta coefficient (0.1967) is statistically significant and higher compared to the other utilities out of the sample. Fortum received more emission allowances than needed in the allocation process for the first trading period. Therefore the long position in emission allowances is one explanation for Forums' carbon beta coefficient.[29]

A few utilities, namely Centrica, Edison, Enel and Union Fenosa, show a negative relationship between carbon prices and stock returns. Yet, the carbon coefficient of Union Fenosa is the only negative coefficient, which is statistically significant. The result indicates that higher carbon prices cause a lower stock return of Union Fenosa, which leads to lower equity cost and consequently, a higher equity value. The other Spanish utility firms indicate a low carbon beta coefficient as well. While a clean power generation mix is one possible explanation, the characteristics of the Spanish power market is another. Compared to other European power markets, the Spanish power generation market is rather competitive. Consequently, the pass-through of carbon costs to customers is less likely.

The results signify the need of future research taking the specific characteristics of the national power markets into account. Moreover, the emission trading market is young compared to other markets. Therefore, the analysis should be repeated with data covering the full second trading period. We suppose the result from the empirical analysis will change as soon as the emission market gets more established. As soon as the auction process will start in the third trading period beginning in 2013, the analysis should be conducted again verifying the theoretical model.

[28] Please, refer to section 3 „The European framework of emission regulation“.
[29] According to data of the European Commission (http://ec.europa.eu/environment/climat/emission), Finland received 11.3 percent more emission allowances as verified for the first trading period. France, Czech Republic, Germany received 17.3 percent, 14.5 percent and 3.1 percent more, respectively. Yet, the allocated emission allowances are massively reduced for 2008.

VI. IMPLICATIONS FOR THE VALUATION PRACTICE

Discounted Cash Flow (DCF) methods are broadly accepted by academics and practitioners for company valuation as well as appraisal for investment projects. Since future cash flows are discounted to determine the Net Present Value (NPV) of the company's equity or an investment project, the cost of capital has to be derived first. From our point of view, the incorporation of carbon risks in company valuation should be effected out by adjusting the cost of capital. A capital market approach is based on objective criteria. On the contrary, an adjustment of the cost of carbon via the cash flow is rather subjective.

The deviation of the cost of capital requires a peer group, which carries similar risk as the valuation objective. The beta coefficients of the firms from the peer group are used to estimate the beta coefficient of the valuation target. After unlevering the betas to eliminate financing risks, the beta coefficient is relevered using the capital structure of the valuation object. To transfer the approach for quantifying carbon risk of a company, we suggest constructing a peer group based on an analysis using emission ratios like emissions and emission intensity in the long run. Therefore the relevant peer group, which covers a similar carbon risk structure, is used to determine the carbon risk of the valuation target.

In that case, the cost of equity capital can be calculated as the sum of the risk-free interest rate and risk premiums for market and carbon risks:

(3) $$r_{Equity} = r_f + (r_{Market} - r_f) \times \beta_{iMarket} + (r_{Carbon} - r_f) \times \beta_{iCarbon}$$

In practice, the risk-free interest rate is usually approximated by local government bond yields. The market risk premium is calculated by measuring and extrapolating historical excess returns (Koller et al., 2005).[30] We recommend estimating the carbon risk premium by extrapolating the carbon excess returns. To calculate carbon adjusted equity costs, we assume a market risk premium of 5 percent, a carbon risk premium of 6 percent, and a risk-free rate of 4 percent. In that case CEZ's equity cost of capital will amount to:

(4) $$r^{CEZ}_{Equity} = r_f + (r_{Market} - r_f) \times \beta_{CEZ\_Market} + (r_{Carbon} - r_f) \times \beta_{CEZ\_Carbon}$$

(5) $$r^{CEZ}_{Equity} = 0.04 + 0.05 \times 0.84 + 0.06 \times 0.14 = 0.09$$

According to equation (5), roughly speaking, 10 percent of the equity costs of CEZ refer to the carbon risk premium. The carbon adjusted equity costs are used to calculate the Weighted Average Cost of Capital (WACC) in order to compute the equity value of CEZ or as company hurdle rate for appraising investment projects.

The opportunity to pass carbon cost to customers depends on the degree of competition on the affiliated power market. From a valuation perspective we would recommend to consider this ability of a firm in the Free Cash Flow (FCF) planning.

[30] For the estimation of the beta coefficients, please refer to the section of the empirical analysis.

The suggested approach is based on total emissions rather than emission intensities. We think in the long run a portfolio analysis, which takes emission intensities into account will more suitable for investors compared to total emissions. Emission intensities' are an important indication of the efficiency of a power plant park of a utility company.

VII. CONCLUSIONS

We introduce a capital market approach to incorporate carbon risks in company valuation. Therefore, we conduct an empirical analysis taking eighteen utility companies into account. Based on our sample of European utility firms we identify carbon as systematic risk factor by portfolio analyses. Therefore, we can not reject the null-hypothesis of carbon as risk factor. According to capital market data investors request a higher carbon premium for utilities, which emit a high amount of carbon. On the contrary utilities, which emit a low amount of carbon cause a lower carbon premium, leading to lower cost of equity. Consequently, the equity value of these utilities rises. The results are robust to an equally-weighted portfolio. However, the design of emission regulate including the grandfathering of emission allowances as allocation process, still drives the stock return. We recognize increasing carbon beta coefficients for the sample in the second trading period compared to the results covering the full period. According to our study, capital markets appraise total emissions rather as efficiency in terms of low emission intensity. This is due to the fact of windfall profits. As soon as the regulation scheme will change, the results of the empirical analysis will turn out to be different. Future research in that field is needed to create an approach which approves reliability for the quantification of carbon risks in order to conduct company valuation or project valuations.

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