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Risk-return relationship of the renewable energy industry

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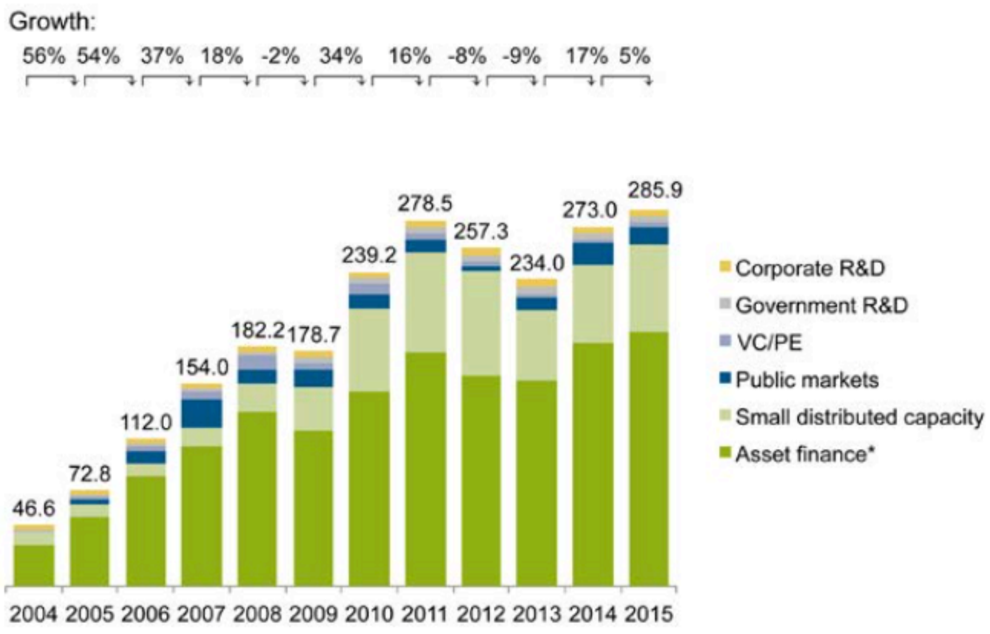
Abstract

This paper examines the risk-return relationship of the renewable energy industry by estimating the systematic risk and its determining factors. Using a variable beta model, we find that the systematic risk has decreased compared to previous research. However, an estimated beta of approximately 1.5 is still high given the low stock returns realized over the past decade. The empirical results of our restricted model show that return on assets increases the systematic risk, while growth opportunities have the opposite impact. Furthermore, we use our findings to address the overall question of whether the recent development of renewable investments is driven by profitability or sustainable investments. Although the industry is becoming more cost-competitive, it seems that sustainable investments and climate change policies also play an important role.

1. Introduction

New investments in renewable energy on a global scale reached an all time high in 2015, amounting to $285.9 billion. This entails a growth of 5% from 2014, which has been driven by developing countries. From 2013 to 2014, the growth in global investments was 17% (Bloomberg New Energy Finance, 2016).

Figure 1. Global new investment in renewable energy by asset class. In billion dollars. 2004-2015



*Asset finance volume adjusts for re-invested equity. Total values include estimates for undisclosed deals.

Source: UNEP, Bloomberg New Energy Finance. *Global trends in renewable energy investment 2016.*

Figure 1 shows the composition of the global new investment in renewable energy, with contributions by asset class. Asset financing clearly represents the lion's share of new investments, but public markets have joined the trend and contributed to a considerable larger degree over the past ten years – compared to pre-2006 levels. From 2004 to 2015 Bloomberg New Energy Finance reports that the compound annual growth rate of new public market investments was 42%, the highest rate of all the asset classes.

According to REN21, the renewable energy share (excluding hydropower) of global final energy consumption was 15.3% in 2014. Also excluding traditional biomass, the share was 6.4% (REN21, 2016). On the supply side, OECD reports that non-hydro renewables and waste accounted for 10% of the electricity generation mix in 2014. These numbers may seem small in the total mix of energy sources. However, what is striking – and hence our motivational starting point – is the recent development within the renewable energy industry. From 2013-2014 it was by far the largest growing energy source within the OECD electricity generation with a 9.7% increase, whereas the share of fossil fuel decreased by 2% (OECD, 2016 preliminary). Furthermore, renewable energy is seen as the fastest growing energy source in the future (International Energy Outlook 2016, EIA). For the next 25 years, the International Energy Agency see renewables to replace coal and decrease the demand for gas and oil (IEA, 2016). Bloomberg points to the rising interest and potential for battery storage as a means to balance the fluctuations in electricity generation, which is one of the challenges facing the renewable energy industry (Bloomberg New Energy Finance, 2016).

In light of these facts, it is interesting to ask whether the growth observed over the past few years has been driven by profitable investments or social responsibility. A complete answer to this question most likely lies beyond the scope of this article, and it may even be too soon to tell. Yet, our objective is to further investigate the profitability aspect of the question, and hopefully shed some light on the risk-return relationship of renewable energy investments over the past decade. The purpose of this paper is therefore to estimate the systematic risk of renewable energy companies, as well as the determinants of systematic risk using a variable beta model. Scholars emphasize the fast evolution in the renewable energy industry in addition to the limited data available, and encourage more research on the topic as the industry matures.[1] With a sample from 2006 to 2015 we aim to bring an updated view on the drivers of systematic risk of 'pure' renewable energy companies[2].

[1] See Donovan and Nunez (2010), Marquez et al. (2010), Wüstenhagen and Menichetti (2012).
[2] We define 'pure' renewable energy companies as companies that have renewable energy or technology as their major business activity. Hydro is excluded due to the maturity of the standards and technology.

Higher oil price has generally been viewed as an incentive to invest in renewables, see for instance Henriques and Sadorsky (2008), Marques et al. (2010) and Sadorsky (2012). However, the recent market circumstances with very low oil price and record-breaking investments in renewables seems rather puzzling if this relationship still were to hold. Sadorsky (2012) views the oil price as an input to production of non-oil companies, and finds a significantly positive relationship between oil price increases and systematic risk. Thus, given the recent development, we would expect to find this relationship to still be valid.

Our investigation of the risk-return relationship of renewable energy investments can therefore be divided into three more specific research questions:

1. Has there been a change in systematic risk of the renewable energy sector over the past decade compared to earlier findings?
2. Which factors influence the systematic risk?
3. Does the oil price still prove to be an important determining factor of systematic risk?

This paper is organized as follows. Section 2 presents relevant previous research concerning systematic risk of the renewable energy sector, and the sensitivity of renewables to other factors, in particular the oil price. Section 3 lays out the theoretical and empirical framework we base our methodological approach on. Section 4 explains our selection of data, and contains the descriptive statistics for our selected sample. Finally, section 5 presents and discusses our empirical results, and further connects our findings to the more overall question of profitability vs social responsibility of renewable energy investments.

2. Literature review

Within the academic literature in finance, our impression is that renewable energy is a fairly new topic of interest. Consequently, there are few studies concerning the systematic risk of renewable energy companies.

Henriques and Sadorsky (2008) study the short-term relationship between oil prices and the performance of renewable (alternative) energy sources. It is widely accepted that high oil prices are positive for alternative energy sources, yet there has been little statistical work done in the past to test this assumption. In this paper, Henriques and Sadorsky examine how sensitive the stock prices of renewable energy companies are to changes in oil prices, technology prices and interest rate, using a four variable vector autoregression model. Their results show that shocks to technology stock prices have the largest impact, while shocks to oil prices had little significance. Henriques and Sadorsky claim that investors may view renewable energy companies as comparable to technology companies and therefore oil prices are not so important as many believe. Moreover, they found that renewable energy companies have beta values close to 2.

Donovan and Nunez (2010) analyze the risk faced by renewable energy investors in large emerging markets. Motivated by a limited academic literature on the topic despite the rapidly growing subsidies to renewable energy projects, their aim is to estimate the cost of capital of clean energy firms, and thereby promote clarity about private sector hurdle rates. Hence, a central objective of the study is to provide guidance to those who evaluate funding decisions within the industry, such as regulators and corporate managers. Using various extensions to the standard CAPM, Donovan and Nunez estimate expected return on equity by focusing on the market risk factor. Their main finding is that renewable energy firms in Brazil, China and India expose multinational investors to the same risks as investing in emerging markets generally. Thus, this finding of near-average risk diverges largely from the findings of Henriques and Sadorsky (2008).

Sadorsky (2012) examine the relationship between systematic risk and return for publically traded renewable energy companies. To find out how different factors (such as oil price, market return, firm size, debt to equity ratio etc.) determine the systematic risk, he uses a variable beta model. Sadorsky finds two main sources of risk, sales growth and changes in oil price. Sales growth have a negative impact on systematic risk while increases in oil price have a positive impact, where Monte Carlo simulation showed that oil prices have the largest impact. In line with Henriques and Sadorsky (2008), he found beta values of approximately 2. The relationship between market risk and stock prices is examined by applying panel data techniques to fifty-two firms for the time period 2001-2007. Sadorsky conclude that market returns, oil prices and sales growth have the most impact on stock returns, respectively.

Although the methodology is not directly applicable for our paper, Marques et al. (2010) present relevant discussions when exploring the forces promoting renewable energy use in European countries. Motivated by a limited amount of empirical work, they aim to shed some light over the subject by applying panel data techniques to twenty-four European countries for the 1990-2006 period. In their study, they have included prices of conventional energy and expected to find that higher prices promote renewable energy use. In most of their models, there was no significant effect of changes in oil prices. However, for EU Member countries, they obtained a negative and significant relationship between oil prices and renewable energy use. In contrast to their anticipations, they found that higher oil prices promoted use of other conventional energy sources instead of renewables.

3. Empirical methodology

3.1 Modelling systematic risk

An investment in an asset is exposed to two types of risk; systematic and unsystematic. Systematic denotes the type of risk that is inherent to a particular market segment or to the market as a whole, and thus cannot be diversified away. Unsystematic risk, on the other hand, is specific to the asset itself and can according to theory be avoided by holding a well-diversified portfolio as the specific risks of the different assets are supposed to cancel out.

The capital asset pricing model (Sharpe, 1964) proposes a specific relationship between the systematic risk and the required return of an asset (Shapiro and Lakonishok, 1986). More precisely, it posits that the required or expected return of an asset is determined by the risk-free rate, the market risk premium and the asset's sensitivity to market instabilities:

$$E(r_i) = r_f + \beta_i(r_m - r_f) \qquad \text{(Eq. 1)}$$

where $E(r_i)$ is expected return, r_f the risk-free rate, r_m the market return, and β_i the asset sensitivity. Hence, according to CAPM, only the systematic component of total risk is rewarded. Eq. 1 describes the risk-return relationship as linear, with the well-known coefficient beta representing the asset risk's co-movement with the market risk. A beta above 1 indicates a higher risk of the asset relative to the market, and thus implies a higher expected – or required – return. The required return is also known as the cost of equity from a company point of view. If the stock of a company is more volatile than the market, then the investors should be rewarded for this extra risk exposure, and equity financing becomes relatively more expensive for the firm (Sadorsky, 2012).

Although this model is widely used, it has been subject to both theoretical and empirical criticism. A large number of authors have found that the basic CAPM is not able to explain stock returns, see for example Fama and French (1993). Several extensions have therefore been suggested in order to cope with the weaknesses of the classical model. Abell and Krueger (1989) find that a variable beta model provides more accurate beta forecasts than do historical betas. The feature of this model is allowing beta to vary with a set of macroeconomic and fundamental company characteristics over time. By examining the sensitivity of the beta estimates to the chosen variables, we can therefore get a sense of the determinants of the systematic risk of a particular asset or portfolio.

The variable beta model is constructed from Sharpe's (1964) single index model by incorporating a linear relationship between beta and a number of explanatory variables into the basic single index model equation:

$$r_t = \alpha + \beta_t r_{mt} + \varepsilon_t \qquad \text{(Eq. 2)}$$

$$\beta_t = b_0 + b_1 x_{1t} + \ldots + b_n x_{nt} + v_t \qquad \text{(Eq. 3)}$$

Combining Eq. 1 and Eq. 2 gives the following relationship:

$$r_t = \alpha + b_0 r_{mt} + b_1 x_{1t} r_{mt} + \ldots + b_n x_{nt} r_{mt} + e_t \qquad \text{(Eq. 4)}$$

which is the general version of the model we aim to estimate for the renewable energy industry. Note that b_0 is different from β_t in the single index model (Eq. 2); $b_0$represents the separate influence of the market after taking into account the influences of the other factors on systematic risk (Abell and Krueger, 1989).

3.2 Influencing factors and predictions of their impact on systematic risk

Our choice of variables to investigate is based on theoretical relationships and assumptions, previous research as well as data availability. The relationship between systematic risk and corporate financial variables has been scrutinized by researchers since the 1960s. Although a clear common view on the most important influencing factors is difficult to establish[3], there exist several 'usual suspects' throughout the pile of previous research. Profitability, size and leverage are variables that regularly have been analyzed by scholars, and are therefore considered relevant for our analysis of systematic risk in the renewable energy sector.[4] Furthermore, we include Tobin's q as the industry is up-and-coming, with growth opportunities that might influence the degree of risk associated with it.

As our research to a large extent build on the previous work of Sadorsky (2012), we would like to investigate whether the significantly positive relationship between oil price increases and systematic risk still holds for our sample. In addition, we include the variables gas return and coal return to see whether there is a link between the beta of renewables and the cost of other possible traditional energy sources.

The influence of profitability has proved to be ambiguous. Logue and Merville (1972) and Lee and Yang (2007) find that profitability is negatively related to systematic risk, whereas Iqbal and Shah (2012) find the opposite. Higher profitability can increase expected returns, which points towards a positive impact on beta (Thompson II, 1976). However, higher profitability might also be a signal of stable earnings, more efficient exploitation of resources and technological improvements, thereby decreasing the risk facing investors and bringing the cost of equity down. Given the relatively young age of the alternative energy sector, we expect the latter relationship to be more relevant. Our hypothesis is therefore that the relationship is negative. Size is generally considered to have a negative impact on systematic risk, and we expect the same. Larger firms are likely to have more resources, experience and higher profitability (Sadorsky, 2012). Leverage is however expected to increase systematic risk. Higher debt-to-equity ratio makes a

[3] The results largely depend on selected industries, variable definitions and measurement errors (Thompson II, 1976).
[4] See for example Logue and Merville (1972), Thomson II (1976), Bowman (1979), Lee and Yang (2007), Iqbal and Shah (2012), Sadorsky (2012), and Tan et al. (2015).

firm riskier and more prone to financial distress. Tobin's q represents growth opportunities, thus we expect this variable to be negatively related to beta. Finally, based on Sadorsky (2012), oil price increases are expected to relate positively to systematic risk. By classifying renewable energy firms as 'non-oil related companies', the oil price is interpreted as an input or a cost to production and transportation, making the systematic risk sensitive to 'the cost of doing business' (ibid). Given this interpretation, we expect the same positive relation for gas and coal returns.

4. Data and methodology

4.1 Data selection, variables and samples

In order to get a comprehensive sample of firms in the global renewable energy industry, we based our list of companies on four clean energy indices: Wilderhill New Energy Global Innovation Index, Wilderhill Clean Energy Index (Eco), S&P Global Clean Energy Index, and Ardour Global Alternative Energy Index; as well as renewable energy companies listed on Damodaran online. Through a careful selection, we ended up with a list of 'pure' renewable energy companies by excluding all firms that do not have clean energy activities as their main line of business. Furthermore, we have excluded all firms with hydro as the main focus of operations due to the well established technological standards within this segment. A complete list over company names can be found in Appendix (1). We acknowledge the fact that we are excluding major players within the renewable energy industry, as many well established companies both within and outside the energy sector have increased their focus towards renewables and the associated new technology. However, we justify this exclusion by emphasizing that we aim to estimate the systematic risk of the renewable energy sector in isolation. Separating or weighting the renewable division of these companies would be difficult and perhaps less accurate.

Company data and oil price are downloaded from Datastream, while prices of indices, coal, gas and tech are retrieved from Bloomberg. Our market index is the MSCI ACWI Small Cap Price Return USD Index, which captures companies in both developed and emerging markets (MSCI, 2017). Based on the size of the firms in our dataset, we found the small cap index to be the most relevant market index for our sample. Furthermore, we used the Crude Oil WTI Spot Cushing USD Per Barrel, which is a common benchmark in oil pricing. Gas price is represented by the Henry Hub Natural Gas Spot Price, and coal by the Stowe Global Coal Index. The latter is described by Bloomberg to include significant participants, and measures the performance of the global coal industry. For tech, we used the price-weighted multi-industry New York Stock Exchange Arca Tech 100 Index.

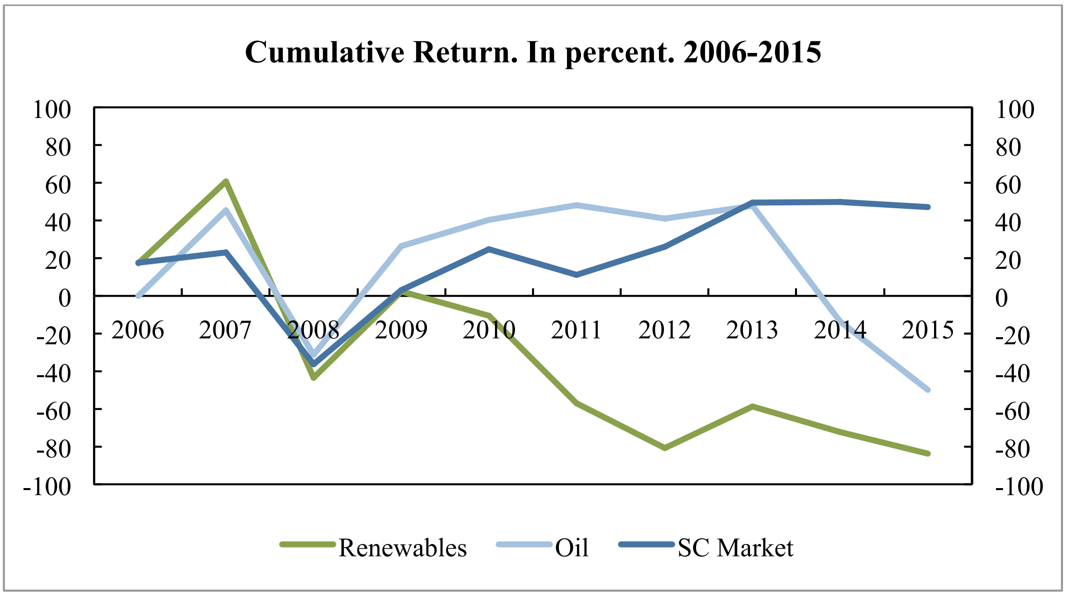
As for the corporate financial variables, we have chosen to include two measures of profitability: return on assets (roa) and earnings per share (eps). The former is calculated as net income over total assets, whereas the latter is given by Datastream. Size is measured by the log of total assets (size), and leverage by debt-to-equity (dtoe). Finally, Tobin's q (tobq) is calculated as market-to-book value of assets. All data is downloaded dollar denominated. As opposed to Sadorsky (2012), we were unfortunately not able to obtain sufficient data on sales or r&d expenditures.

After a selection based on engagement in the clean energy industry, we had to trim our company list as the necessary data was not available for all the listed firms. The resulting sample is a complete dataset for 67 equally weighted companies that covers the entire time period of interest, 2006-2015. Given that a lot of renewable energy firms has gone public in the years after 2006, we decided to incorporate these into two additional subsamples; one for 2009-2015, and one for 2012-2015. The subsamples allow us to explore possible changes in systematic risk over the years as new firms enter the industry. Hence, the inclusion of new listed firms leaves us with a total of 105 companies in the 2009-2015 subsample, and 127 in the 2012-2015 subsample. Our main focus is however on the full sample, 2006-2015.

4.2 Descriptive statistics

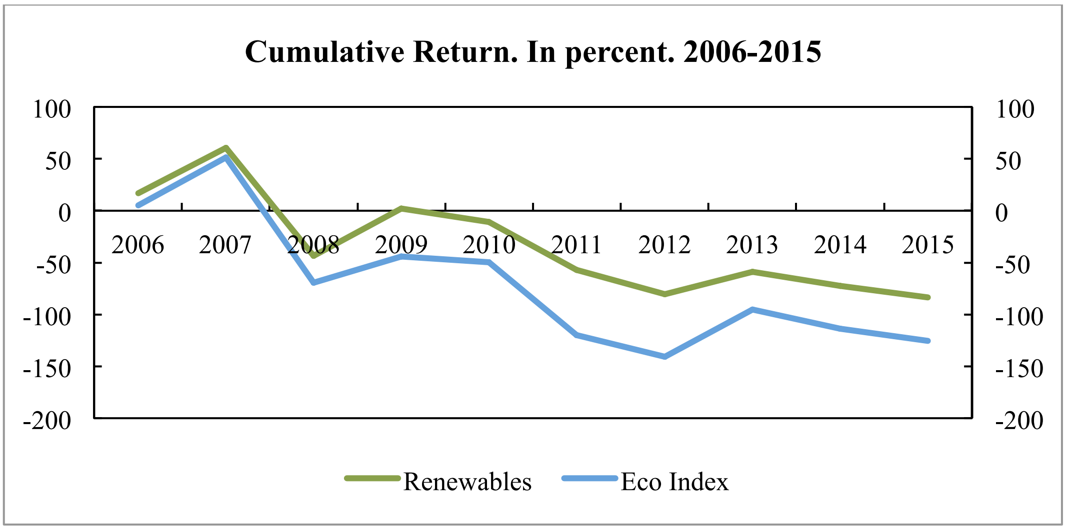
Figures (2) and (3) show the cumulative average returns over the sample period for the main sample (denoted Renewables) compared to oil and small cap market return, as well as the Wilderhill Clean Energy Index (Eco Index).

Figure (2): cumulative return



Sources: Bloomberg and Datastream

Figure (3): cumulative return



Sources: Bloomberg and Datastream

Despite recent record-breaking investments and promising forecasts, the cumulative average return of renewables has been negative from 2009 and throughout the rest of the sample period. In contrast, the small cap market return recovered from the financial crisis after 2009. Renewable energy stocks therefore seem to have been relatively less profitable for investors over the past few years. However, our sample of pure renewable energy stocks has on average outperformed the Eco Index, which was the first index to capture the clean energy sector and now serves as a benchmark (WilderShares, 2017). Oil, market and renewables seem to co-vary to a much larger extent between 2006-2009 than after

2009. This may point towards a more detached relationship between oil price and renewable return after the crisis. Consequently, higher oil prices are perhaps a less important incentive for investments in renewable energy as previously claimed by scholars.

Summary statistics and correlations for the main sample are reported in Tables (1) and (2), respectively.

Table (1): summary statistics

	Obs	Mean	Median	Max	Min	St.dev	Skewness	Kurtosis
ret	642	-0,089	-0,068	2,62	-3,55	0,783	-0,204	4,473
mret	642	0,046	0,052	0,392	-0,593	0,258	-1,234	4,19
oil	642	-0,052	0,092	0,576	-0,767	0,409	-0,216	2,159
coal	642	-0,138	-0,319	0,91	-1,047	0,598	0,276	2,172
gas	642	-0,137	-0,259	0,304	-0,549	0,278	0,324	1,651
tech	642	0,085	0,133	0,358	-0,431	0,21	-1,162	4,122
dtoe	642	1,166	0,454	158,823	-47,603	7,775	13,822	281,195
eps	642	0,283	0	19,14	0	1,027	11,723	192,19
roa	642	-1,544	0	26,645	-209,918	13,442	-11,021	137,033
size	642	11,897	12,372	16,073	1,609	2,631	-1,305	5,264
tobq	642	0,031	0,001	10,166	3.77E-06	0,425	21,714	506,783

Description of variables: ret is the continuously compounded annual company stock return, mret the continuously compounded annual market return, and oil (coal, gas, tech) the continuously compounded annual return of the corresponding price index. dtoe is debt-to-equity, eps is earnings per share, roa is return on assets (net income/total assets), size is log of total assets, and tobq is Tobin's q calculated as market-to-book value of assets.

Table (2): correlations

	ret	mret	oil	coal	gas	tech	dtoe	eps	roa	size	tobq
ret	1										
mret	0,467	1									
oil	0,409	0,73	1								
coal	0,424	0,709	0,869	1							
gas	0,251	0,326	0,502	0,374	1						
tech	0,434	0,96	0,677	0,662	0,401	1					
dtoe	-0,1	-0,043	-0,02	-0,05	-0,06	-0,03	1				
eps	0,059	-0,003	0,012	0,033	-0,03	-0,02	-0,01	1			
roa	0,06	-0,005	0,015	0,013	-0,03	-0,01	0,022	0,034	1		
size	0,048	0,009	-0,04	-0,07	0,01	0,041	0,075	0,092	0,378	1	
tobq	0,148	-0,049	-0,01	-0,03	-0,03	-0,04	-0,017	-0,02	-0,204	-0,26	1

Correlations are calculated in EViews. There are 642 observations. See Table (1) and Section 4.1 for a description of the variables.

Notice that renewable energy companies have the highest standard deviation among all the indices and comparable energy sources. Meanwhile, the average annualized return is lower for renewable companies compared to the market and oil. This could imply that investors in renewable energy have a fairly high tolerance for risk, however they might not be rewarded for this additional risk. The variable roa has a negative mean, which implies that on average, the companies in our sample have realized losses, or invested a lot of capital while at the same time generated little income.

All variables, except debt-to-equity, have a positive relationship with company return. Notice that small cap market return and tech return are almost perfectly correlated. The correlation between size and roa is positive, but only 0.38. The table of correlations is used as a guideline for which variables to include in the model in order to avoid multicollinearity, which can spur the regression results. Consequently, tech return was removed.

4.3 Methodology

Data frequency is an important issue to consider in the analysis method. Daily data have the advantage of more observations and could therefore provide a more comprehensive picture of the relationship between risk and return. However, a higher frequency of data is typically noisier in a statistical sense (Brooks, 2014). This issue has been resolved by running our models twice, first on daily data, then on annual data. Our sample of renewable energy stocks seems to be traded less frequently, resulting in longer periods of zero return and a possibly important autocorrelation problem when using daily data. In this paper, we therefore chose to consider annual data.

The sample has been converted to a panel data format, which makes it possible to address a broader range of issues and tackle more complex data (Brooks, 2014). Panel data also have the advantage of helping to mitigate problems of multicollinearity and certain forms of omitted variables. The most common classes of panel estimator approaches are fixed effects models and random effects models. To determine which models are appropriate for the three samples, we performed a redundant fixed effects test and a Hausman test for random effects. The results indicate that random effects model is to be preferred for the full sample. For the two subsamples, we found neither fixed nor random effects to be appropriate, thus pooled regression was chosen. In order to avoid spurious regressions, the data was tested for panel unit root and cointegration in Eviews, following Brooks (2014, 555-557).

5. Results and discussion

5.1 Results for main sample, 2006-2015

For the main sample, results are reported in table (3). The dependent variable in all three models is the continuously compounded annual company stock returns. Model 1, the traditional CAPM, is the benchmark:

$$r_{it} = \alpha_i + \beta_{it} r_{mt} + \varepsilon_{it} \quad (1)$$

The estimated coefficient on market return in the benchmark model indicates that the renewable energy segment is 1.43 times as risky as the market. This is substantially lower than the market beta estimation in previous research, which has been found to lie around 2, see Sadorsky (2012) and Henriques and Sadorsky (2008). Model 2 allows for time varying risk, and it contains all independent variables except from tech return:

$$r_{it} = \alpha_i + b_i r_{mt} + b_{1i} oil_{it} r_{mt} + b_{2i} coal_{it} r_{mt} + b_{3i} gas_{it} r_{mt} + b_{4i} dtoe_{it} r_{mt} + b_{5i} eps_{it} r_{mt} + b_{6i} roa_{it} r_{mt} + b_{7i} size_{it} r_{mt} + b_{8i} tobq_{it} r_{mt} + e_{it} \quad (2)$$

Table (3): regression results for the main sample (2006-2015)

Model	Rm	oilxRm	coalxRm	gasxRm	dtoexRm	epsxRm	roaxRm	sizexRm	tobqxRm	constant	Adj R^2
1	1.427***									-0.152***	0.209
	(13.262)									(-5.378)	
2	2.253***	0.707	-0.478	0.233	-0.011	-0.025	0.033***	-0.057	-1.243***	-0.171***	0.270
	(4.154)	(0.695)	(-0.717)	(0.327)	(-0.467)	(-0.184)	(3.507)	(-1.297)	(-3.457)	(-4.945)	
3	1.535***						0.042***		-0.208**	-0.154***	0.261
	(14.648)						(5.433)		(-2.470)	(-5.397)	

Panel least squares estimation technique with random effects has been used. Rm denotes market return. T-statistics are reported in the parentheses. *, **, *** denote significance at the 10%, 5% and 1% level, respectively.

After performing backward elimination of insignificant variables (Abell and Krueger, 1989), we obtained Model 3, which is a restricted version of Model 2:

$$r_{it} = \alpha_i + b_i r_{mt} + b_{1i} roa_{it} r_{mt} + b_{2i} tobq_{it} r_{mt} + e_{it} \qquad (3)$$

As in Model 2, both roa x market return and Tobin's q x market return are statistically significant in the restricted model. Thus, there is consistency regarding the determinants of systematic risk between the two time varying models. Roa x market return is positive and significant at the 1% level, indicating that an increase in roa increases systematic risk. This result contradicts our prediction, but as we have explained previously, the influence of profitability has proved to be ambiguous. The coefficient Tobin's q x market return is negative and significant, indicating that an increase in Tobin's q reduces systematic risk, consistent with our prediction. However, the magnitude of the coefficients changes from Model 2 to Model 3. Tobin's q seems to have a considerably lower impact on systematic risk in the restricted model, whereas profitability (measured by roa) has a slightly increased influence.

In contrast to Sadorsky (2012), we do not find oil price (or coal, gas) to have a significant impact on the systematic risk. This could indicate that renewable energy companies are less affected by changes in the oil (coal, gas) price than before, and that the interpretation of oil as a 'cost of doing business' has become less relevant for the renewable energy industry. Yet, it is important to emphasize that there are differences regarding the samples used in this paper and the one used in Sadorsky (2012). Our company list is constructed by manual selection, and encompasses what we have considered to be 'pure' renewable energy firms. The chosen companies have been selected from various indices, and all firms bear equal weight. Sadorsky (2012) draws his weighted (both on industry and company level) company list from The Wilderhill Clean Energy ETF, which includes clean energy firms that not necessarily have renewable energy as their main business focus. These firms may be relatively more dependent on the oil price as an input to production and transportation.

In Model 3, the influence of the market on systematic risk is estimated to be 1.535, down from 2.253 in the unrestricted Model 2. Hence, our estimated parameterized beta can be expressed, using the estimation coefficients from Model 3, as:

$$\beta = 1.535 + 0.042\, roa - 0.209 tobq$$

This equation indicates that systematic risk of the renewable energy industry has decreased compared to previous estimation results[5], and is close to the market beta of the benchmark model. This decrease in systematic risk can reflect the low level of average returns the industry has seen particularly towards the end of our sample period – a development that is consistent with theory. As described above, we find profitability and growth opportunities to be the determining factors of systematic risk, in addition to the market.

As a robustness check of our resulting Model 3, we performed a Wald test based on the unrestricted regression (Model 2) with the following hypothesis:

$$\mathrm{H_0} = \text{all coefficients of insignificant variables can be restricted to zero}$$

$$\mathrm{H_A} = \text{all coefficients of insignificant variables cannot be restricted to zero}$$

The test-statistic Chi-square was 3.23 with a p-value of 0.78, and we can therefore not reject the null hypothesis. Our restricted model (Model 3) thereby seems to appropriately reflect the determinants of systematic risk for the renewable energy sector.

5.2 Results for subsamples

To further examine the systematic risk over the past few years, we have chosen to consider two subsamples, which include firms that entered public markets during 2009 and during 2012. By running our restricted regression on updated samples, we aim to check whether the found relationship in the parameterized beta still holds. Although we are not able to formally test possible changes, given that the samples are different, it could provide us with valuable information about the development in the renewable energy sector.

[5] Both Sadorsky (2012) and Henriques & Sadorsky (2008) find betas of approximately 2, while Donovan and Nunez find near-average risk exposure for renewable energy investors in large emerging markets.

Table (4): correlations subsample 1 (2009-2015)

	ret	mret	oil	coal	gas	tech	dtoe	eps	roa	size	tobq
ret	1										
mret	0.276	1									
oil	-0.020	0.400	1								
coal	-0.028	0.526	0.494	1							
gas	0.211	0.644	0.353	-0.050	1						
tech	0.240	0.925	0.340	0.590	0.638	1					
dtoe	-0.028	-0.087	0.024	-0.001	-0.037	-0.087	1				
eps	-0.008	-0.063	0.033	-0.001	-0.036	-0.051	0.005	1			
roa	0.074	-0.016	0.023	0.026	-0.043	-0.013	0.017	0.005	1		
size	0.070	-0.016	-0.004	-0.011	-0.012	-0.016	0.020	-0.023	0.344	1	
tobq	0.186	-0.002	-0.009	-0.057	0.030	-0.018	-0.014	-0.004	-0.092	-0.357	1

Correlations are calculated in EViews. There are 605 observations. See description of the variables in Table (1) and Section 4.1.

Table (5): correlations subsample 2 (2012-2015)

	ret	mret	oil	coal	gas	tech	dtoe	eps	roa	size	tobq
ret	1										
mret	-0.144	1									
oil	-0.262	0.889	1								
coal	0.180	0.503	0.052	1							
gas	-0.219	0.961	0.981	0.246	1						
tech	-0.015	0.916	0.631	0.807	0.771	1					
dtoe	-0.056	-0.044	-0.006	-0.083	-0.023	-0.069	1				
eps	0.140	-0.031	-0.019	-0.032	-0.025	-0.036	-0.007	1			
roa	0.146	-0.006	-0.008	0.003	-0.008	-0.002	0.023	0.035	1		
size	0.290	-0.025	-0.018	-0.019	-0.022	-0.026	0.040	0.157	0.415	1	
tobq	0.018	0.069	0.062	0.034	0.067	0.063	-0.012	-0.020	-0.088	-0.303	1

Correlations are calculated in EViews. There are 351 observations. See description of the variables in Table (1) and Section 4.1.

Correlations are reported in tables 4 and 5, while summary statistics can be found in Appendix (2). Notice that renewable company return is now negatively correlated to oil, although insignificantly so for subsample 1. This shift in correlation may be a manifestation of the detached relationship between higher oil prices and higher returns for renewable energy companies, as depicted in Figure (2) in Section 4.2.

Table (6): regression results subsample 1 (2009-2015)

Model	Rm	oilxRm	coalxRm	gasxRm	dtoexRm	epsxRm	roaxRm	sizexRm	tobqxRm	constant	Adj R^2
1	1.329***									-0.268***	0.068
	(6.846)									(-8.890)	
3	1.456***						0.057***		-0.178**	-0.271***	0.099
	(7.511)						(3.657)		(-2.205)	(-9.048)	

Panel least squares estimation technique has been used. Rm denotes market return. T-statistics are reported in the parentheses. *, **, *** denote the significance at the 10%, 5% and 1% level, respectively.

Table (7): regression results subsample 2 (2012-2015)

Model	Rm	oilxRm	coalxRm	gasxRm	dtoexRm	epsxRm	roaxRm	sizexRm	tobqxRm	constant	Adj R^2
1	-0.680**									-0.007	0.010
	(-2.218)									(-0.180)	
3	-0.632**						0.068***		0.045	-0.006	0.027
	(-2.038)						(2.755)		(1.135)	(-0.138)	

Panel least squares estimation technique has been used. Rm denotes market return. T-statistics are reported in the parentheses. *, **, *** denote the significance at the 10%, 5% and 1% level, respectively.

As we can see from Table (6), the regression output for subsample 1 show similar results as the ones reported for the main sample. Roa x market return and Tobin's q x market return are still significant at a 1% and 5% level, respectively. Yet, the benchmark model shows a slightly lower market beta for subsample 1 relative to the main sample. Here, the renewable energy segment is reported to be 1.33 times as risky as the market. The impact of market on systematic risk in the restricted model is also somewhat decreased, whereas profitability proves to have a minuscule increase in influence. Tobin's q still affects the systematic risk negatively, but to a smaller degree. With such minor changes, it therefore seems that the found relationship between systematic risk and influencing factors reflected in the parameterized beta still holds. However, we note that the R^2 of the model is now significantly lower, meaning that this model holds less explanatory power.

The estimated relationship does nonetheless not hold for subsample 2, see Table (7). Both the benchmark model and the restricted model report negative coefficients related to market return, and Tobin's q is no longer significantly impacting systematic risk. We suspect these results to be largely affected by the small sample size, with only three years (observations) of company data for the 127 companies included in the sample.

5.3 Discussion

The systematic risk of renewable energy companies has decreased compared to previous studies, and when adding firms that went public during 2009 (subsample 1), we find a further decrease. Consistent with theory, this is accompanied by lower returns. The average return of renewables has been negative from 2009 and throughout the rest of the sample period. We find a high level of heterogeneity among the firms, meaning that there are large variations, especially in terms of performance. Overall, our results indicate that investments in renewable energy are not optimal in terms of risk and return. The investors will need to have a fairly high tolerance for risk, yet they might not be rewarded for this additional risk. This raises an important question, namely what other forces are promoting investments in renewable energy?

One possible explanation could be that investors are more motivated by sustainable investments than profitable investments. Sustainable investors apply both financial and ESG (Environmental, Social and Governance) criteria when considering an investment. During the last decade, awareness of sustainable investments has increased rapidly. According to the Global Sustainable Investment Association (2014; 2016), sustainable investment assets in Europe, U.S., Canada, Australia, and Asia rose 61% from 2012 to 2014, with a further increase of 25% at the outset of 2016. In most of the regions, professional institutional investors such as pension funds, mutual funds and insurers are dominating the market. These large agents have incorporated sustainable investments into their investment policy statements, while aspiring to keep the risk-return relationship at status quo. Within asset allocations, there are large variations from market to market. In Canada and Europe for instance, most assets were allocated in bonds as of 2016, whereas equities were dominating two years before. According to the GSIA, this shift is reflecting the recent rise in green bonds.

Bloomberg New Energy Finance (2016) states that climate change policies such as ‘green stimulus’ programs, government and corporate spending on R&D have contributed to the boost in investments, especially in 2011. A drawback of our model is that we have not accounted for subsidies or policies, however, neither have previous studies. Instead, they have used their results to recommend improvements of renewable energy investment policymaking. It is also important to note that fossil fuel energy industries have been, and still are, highly subsidized[6]. Nonetheless, subsidies and green stimulus set aside, large investments in renewables despite low fossil fuel prices points towards a rising cost-competitiveness of renewable energy. Renewable power technologies have experienced a substantial decrease in levelized costs of electricity, enabling the sector to increase its share of world electricity generation at the expense of carbon-emitting sources. Levelized costs typically incorporates all costs associated with the development, construction, financing and operation of a project or power plant. The indisputable driver of this movement is solar photovoltaics, which has seen a spectacular drop of 61% in the levelized cost of crystalline-silicon from end-2009 to end-2015, (Bloomberg New Energy Finance, 2016). Another aspect contributing to the competitiveness is the speed of the installation process. Building wind farms and solar parks takes 3-9 months, compared to fossil fuel plants, which can take several years. This explains why renewables are particularly gaining grounds in developing countries where there is a rush in the need for new capacity, (ibid).

The determinants of systematic risk found in our study do not include changes in oil other energy prices, which supports the rising cost-competitiveness of renewables discussed above. Marques et al. (2010) also found no significant relationship between oil prices and renewable energy in most of their models. They suggest however that this result is affected by the fact that their study ends in 2006, prior to the *large* rise in oil prices. Henriques and Sadorsky (2008), on the other hand, have a rather different interpretation. They argue that oil prices are not as important because investors may view renewable energy companies as similar to other technology companies, which makes sense given that the industry (excluding hydro) is based on new technology compared to traditional models. This brings up another essential issue, namely that conventional energy and

[6] See for example International Energy Agency: World Energy Outlook (2016) and Financial Times: A world map of subsidies for renewable energy and fossil fuels (2016)

renewable energy industries are very different, and therefore it is crucial to clearly distinguish them.

Several authors have stressed the importance of understanding industry life cycle and how certain conditions can affect the firms within the industry. For instance, Karniouchina et al. (2013) examine the industry life cycle in three stages: growth, maturity and decline. The industry of renewable energy is in the growth stage, which is characterized by high levels of heterogeneity between firms and market share instability. Further, a high rate of new firms entering will result in even larger differences and thus more heterogeneity, which is reflected well in the summary statistics. Our samples of renewable energy companies have the highest standard deviation compared to market, tech- and traditional energy firms. We also observe large variations in the firm specific variables, with kurtosis as large as 600. These differences will ultimately lead to substantial variance in market position and performance. For wind and solar, the technology requires that most of the costs are incurred upfront rather than during operation (Bloomberg New Energy Finance, 2016). This can help explain the negative values we have observed for the measure of performance as well as the undesirable risk-return relationship. As the industry of renewable energy matures, changes will become less radical and more incremental (Karniouchina et al. 2013). Established industry norms will become more standardized and the weaker companies will exit, leading to less variation and a decline in total risk.

Given the large within-sector volatility, there are evidently certain very successful renewable energy firms that may be relatively easy to identify for investors seeking profitable investments. Meanwhile, the abovementioned features of a young industry still bring a high degree of uncertainty to an investor’s renewable energy investment decisions. Technological solutions have yet to become standardized, and economies of scale might have to be realized to a larger extent before public markets become more confident about the path renewable energy will take. In general, the uncertainty characterizing the young industry as of now makes it more difficult for investors to do a proper assessment of individual companies and the sector as a whole. Whether renewable energy companies should be compared to traditional energy companies or other tech companies also highlights the complexity of establishing a clear benchmark to which investors can measure the performance of the sector.

6. Conclusion

Given the recent development in the renewable energy sector, the risk-return relationship is a highly relevant and important area of study that can help shed some light over the profitability of renewable energy investments.

In this paper, we have used a variable beta model to estimate the systematic risk of renewable energy companies, as well as the determinants of systematic risk. Our results show a risk-return relationship that is not optimal, with negative return and high beta values of approximately 1.5. This can, at least to some extend, be explained by certain conditions of the renewable energy industry life cycle, such as a high degree of heterogeneity.

The determinants of systematic risk are crucial for understanding the companies' financial performance. Our results show that an increase in roa increases the systematic risk, while Tobin's q decreases systematic risk. In contrast to the study performed by Sadorsky (2012), we do not find oil price (or other energy prices) to have a significant impact on the systematic risk. This points toward a more detached relationship with conventional energy and a rising cost-competitiveness of the renewable industry.

Overall, our results indicate that there are other forces besides profitability promoting the investments in renewable energy. Increased focus on sustainability is one important aspect that motivates both individual and institutional investors to making greener investment decisions. Different climate change policies such as green stimulus programs can also help explain the boost in investments. Finally, asset finance seems currently to be a crucial funding source for the large upfront costs associated with the industry, and may help renewable energy companies overcome the startup phase. But with time, public markets will probably further increase the share of financing, and sustainable investments may eventually prove to also be profitable investments.

Further research can benefit from improved data availability as the industry of renewable energy matures and perhaps overcome the limitations of this study. Our data selection was restricted due to missing variables and incomplete financial reporting. To obtain a more comprehensive picture of the risk-return relationship, one may also consider different segments within the renewable energy industry separately (such as solar and wind).

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8. Appendix

Appendix (1): Company lists

<u>Main sample: 2006-2015. Total 67 companies</u>

3Power Energy Group, Inc
Albioma
Alerion Clean Power S.p.A
American Superconductor Corp
Amtech Systems Inc
Boralex Inc
CP New Energy
C&G Environmental Protection Holdings Limited
Capital Stage AG
Carmanah Technologies Corp
China Everbright International Ltd
China Renewable Energy Investment Limited
China Ruifeng Renewable Energy Holdings
Limited
Concord New Energy Group Ltd
Covanta Holding Corp
EcoBio Holdings Corp
Electrovaya Inc
Ellomay Capital Ltd
Energiekontor AG
Engie Brasil Energia
Enlight Renewable Energy Ltd
E-Ton Solar Tech Co Ltd
Etrion Corporation
Falck Renewables S.p.A
First National Energy Corporation
Futuren S.A.

Gamesa Corp Technologica SA
Greentech Energy Systems A/S
Inter Far East Energy Corporation Public Company
Limited
Jun Yang Financial Holdings Limited
K.R. Energy S.p.A
Kalina Power Limited
Kong Sun Holdings Ltd
MDI Energia S.A.
Motech Industries Inc
Naikun Wind Energy Group Inc
New Sources Energy NV
Ning Xia Yin Xing Energy Co., Ltd
Nordex SE
NZ Windfarms Limited
Odelic Co Ltd
Ormat Technologies, Inc.
Pacific Ethanol Inc
PannErgy Plc
Petratherm Limited
Plug Power Inc
PNE Wind AG
Polaris Infrastructure Inc.
Polish Energy Partners
REC Silicon ASA
PwrCor, Inc.
Renu Energy Limited
Sea Breeze Power Corp.
Shodensya Co., Ltd.
Sichuan Chuantou Energy Co., Ltd
Simplo Technology Co Ltd
Sino-American Silicon Products Inc
Solar Alliance Energy Inc.
Solartron PLC
SPCG Public Company Limited

SunPower Corp

Trention AB

U.S. Geothermal Inc.

United Photovoltaics Group Limited

Vestas Wind Systems A/S

Voltalia SA

West Holdings Corporation

<u>Subsample 1: 2009-2015. Total 105 companies</u>

All companies from main sample

+

Alterra Power Corp.

Canadian Solar Inc

Comtech Solar Systems Group

Ltd

Edisun Power Europe AG

EDP Renováveis, S.A.

Energy Development Corporation

ErgyCapital S.p.A.

Fersa Energías Renovables, S.A.

First Solar Inc

GCL-Poly Energy Holdings Ltd

Gintech Energy Corp

Goldwind

Green Energy Technology Inc

Hanwha Q Cells Co Ltd

Indowind Energy Limited

Innergex Renewable Energy Inc.

JA Solar Holdings Co Ltd

Juhl Energy, Inc.

Kandi Technologies Group Inc

Meyer Burger Technology AG

Nacel Energy Corporation

Neo Solar Power Corp

REACT Energy plc
ReneSola Ltd
Sao Martinho SA
Singyes Solar
SMA Solar Technology AG
Solargiga Energy Holdings Ltd
Solaria Energia y Medio
Ambiente SA
Solartech Energy Corp
Solegreen Ltd
Sunflower Sustainable
Investments Ltd
Terna Energy S.A.
Tianneng Power International Ltd
Veer Energy & Infrastructure
Limited
Verbio Vereinigte BioEnergie
AG
Wind Works Power Corp.
Yingli Green Energy Holding Co
Ltd

Subsample 2: 2012-2015. Total 127 companies

All companies from main sample
+
All companies from subsample 1
+
Advance Metering Technology
Limited
Aega ASA
Ameresco Inc
Arise AB
Aventron AG
China Datang Corporation Co, Ltd.

Danen Technology Corp

Daqo New Energy Corp

Electrawinds SE

Energixs-Renewable Energies Ltd.

Enphase Energy Inc

Gigasolar Materials Corp

Huaneng Renewables Corporation
Limited

JinkoSolar Holding Co Ltd

Karma Energy Limited

KTG Energie AG

Mytrah Energy Limited

New Global Energy, Inc.

Orient Green Power Company
Limited

Renewable Energy Group Inc

Shunfeng International Clean Energy
Ltd

Tesla Inc

Appendix (2): Summary statistics for subsamples

Summary statistics subsample 1 (2009-2015)

	Obs	Mean	Median	Max	Min	St.dev	Skewness	Kurtosis
ret	605	-0.159	-0.133	3.627	-3.550	0.683	0.029	6.555
mret	605	0.074	0.002	0.236	-0.136	0.136	-0.188	1.554
oil	605	-0.151	-0.074	0.141	-0.614	0.274	-0.748	2.007
coal	605	-0.326	-0.362	0.264	-0.898	0.335	0.052	2.962
gas	605	-0.151	-0.259	0.237	-0.372	0.247	0.663	1.574
tech	605	0.133	0.133	0.294	-0.019	0.114	-0.157	1.631
dtoe	605	1.518	0.721	158.823	-69.247	8.954	9.392	179.372
eps	605	2.089	0.000	1010.000	0.000	41.068	24.496	601.689
roa	605	-1.151	-0.002	26.645	-209.918	11.874	-11.344	200.087
size	605	12.525	13.052	16.701	0.000	2.622	-1.815	7.669
tobq	605	0.201	0.000	46.935	3.77E-06	2.510	15.090	247.236

See Table (1) on page 11 and Section 4.1 for description of variables.

Summary statistics subsample 2 (2012-2015)

	Obs	Mean	Median	Max	Min	St.dev	Skewness	Kurtosis
ret	351	-0.030	-0.031	2.853	-2.920	0.671	0.128	5.784
mret	351	0.069	0.002	0.236	-0.026	0.117	0.716	1.558
oil	351	-0.308	-0.363	0.069	-0.614	0.281	0.344	1.530
coal	351	-0.532	-0.377	-0.319	-0.898	0.261	-0.668	1.481
gas	351	-0.136	-0.259	0.237	-0.372	0.263	0.649	1.553
tech	351	0.134	0.133	0.294	-0.019	0.128	0.058	1.516
dtoe	351	1.355	0.812	75.829	-69.247	7.049	-0.569	74.489
eps	351	0.260	0.000	5.950	0.000	0.841	4.559	23.345
roa	351	-1.190	0.002	26.636	-118.647	10.813	-9.903	104.389
size	351	12.686	13.201	16.794	0.000	2.655	-1.917	8.221
tobq	351	0.259	0.000	74.130	3.22E-06	3.994	18.141	335.294

See Table (1) on page 11 and Section 4.1 for description of variables.