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Regulation Effects on Company Beta Components

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ABSTRACT

This paper introduces a general model to analyze the effects of regulation on company risk. In particular, we consider two determinants of systematic risk: the company's overall risk and the correlation between the regulated company's value and the market. Theoretical findings indicate that as regulation gets stricter, the company's abnormal returns will turn negative, whereas the two systematic risk components will increase, and vice versa. We use event analysis elements and a time-varying beta estimation to verify the regulation impact on risk and returns in the English electricity distribution industry. We find that systematic risk varies significantly during the period considered in our analysis. Furthermore, the analysis points to negative relationships between abnormal returns and both market correlation and overall risk variations.

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1 Introduction

There is a multitude of debates, in both theoretical and empirical terms, on how regulation affects risk in the public utility industry. According to Parker (2003), regulatory risk depends on the different types of regulatory rules and practices applied. Alexander and Irwin (1996) compare the price cap and the rate of return regulation and suggest that the latter implies a lower risk, since it provides a higher guarantee for profit than does the price cap regime. Another source of regulatory risk is the regulatory system “maturity” (Parker, 2003): the more the regulator knows about a regulated company, the lower the regulatory risk involved.

Peltzman (1976) provides one of the most relevant contributions about the relationship between regulation and risk. Based on this theory, known as the Peltzman’s hypothesis, the regulators’ objective is to maximize political support. Consequently, they buffer extra-cash flows generated by regulated companies between shareholders and customers. As a result, if regulators dampen profits, the company’s expected profitability decreases whereas risk increases, and vice versa.

A question of the utmost importance is whether regulatory decisions affect systematic risk. This has important policy implications since systematic risk changes cannot be diversified away and thus regulators should compensate shareholders for bearing such risk (Grout, 1995).

The purpose of this study is to overcome some literature limitations. First, most of the previous papers analyze the relationship between regulation and systematic risk by taking into account betas as a proxy of the company’s systematic risk. Oxera (1996) and Wright et al. (2003) showed that price cap regulation generally increases the betas of regulated firms. Binder and Norton (1999) successfully tested the Peltzman’s hypothesis by considering long-term beta estimations, and by partially employing accounting information as explanatory variables. However, based on the CAPM assumptions, there are two different factors determining betas: the company overall risk and the market correlation. Literature lacks formal analyses of how these two variables influence betas. We are presenting a theoretical model to assess the regulatory impact on overall risk and market correlation. In particular, we show that market correlation is a significant proxy of the “pressure” regulators place on companies.

Second, we propose an alternative time-varying approach to analyse the impact of regulation on systematic risk and beta components. Some works address the issue of time-varying betas using the cross-sectional regression analysis approach (see Binder and Norton, 1999). In particular, they estimate the asset betas of different companies in different periods using traditional methodologies.

They then regress the estimated betas to a set of explicatory firm-specific variables. However, there are main drawbacks to this methodology: when any problem with heteroskedasticity, dependence or residual non-normality occurs, both the power and significance of the classic regression approach decrease. Other papers use step-dummies (Buckland and Fraser, 2001 and 2002; Robinson and Taylor, 1998) to study regulatory long-term impacts on betas. However, when other beta-modifying events occur in the following step-dummy period, results will be biased. Additionally, there is a greater probability of leaving out significant risk-varying events when companies do not operate exclusively in regulated industries. To address these drawbacks, we employ the classic hypothesis-testing approach to study the impact of regulation on beta components.

Our results show that the company's systematic risk varies significantly after regulatory events. In particular, we find negative relationships between abnormal returns and both market correlation and overall risk variations, as predicted by our model.

This paper is organized as follows: the second section reports a model for the relationship between company value, betas, overall risk and market correlation; the third section analyses our methodology; the fourth section introduces our sample companies, the regulatory events selected, and the main empirical results of our analysis. The final section concludes by summarizing our main findings.

2. The Model

Finding a suitable definition of a regulatory event is not a simple task. Most authors (Binder, 1985) define regulatory events as regulation process actions resulting from Authority, Government, and Parliament interventions. In this study we agree with this definition of regulatory event: what really matters is the object of the event, not the body that announces it.

A clear example of a regulatory event is the Authority intervention to set or modify the price-cap parameters such as the initial asset base or the X factor¹.

When the regulator allows an unexpected increase in the X-factor, and therefore setting a tighter regulation, one would expect to witness negative abnormal returns since due to a significant

¹ For an introduction on the price cap methodology and the X factor see Armstrong et al. (1994) and Bishop et al. (1995).

reduction in expected cash flows². Our question is then: do regulatory events affect betas and consequently the cost of capital for regulated industries?

Generally, beta changes are due to overall risk or correlation variations between the company's value and the market index, as showed in the following expression:

$$[1] \beta_i = \frac{\rho_{i,m} \sigma_i}{\sigma_m}$$

β_i stands for the company beta, σ_i for the company overall risk, $\rho_{i,m}$ for the correlation between the company and the market index, and σ_m for the market index return standard deviation³. Under the assumption that σ_m does not depend on regulatory events⁴, the company's overall risk and its correlation with the market are the only two variables affecting beta.

In the following paragraphs we first analyse how regulatory events affect overall risk σ_i . In appendix A we show in particular that, after considering the issues of limited liability, financial distress and bankruptcy costs, the correlation between revenues and overall risk is negative. This important result sounds as common sense but it is only valid after taking into account financial distress and probability of bankruptcy. Indeed, one would expect that if regulation becomes tighter, then the probability of bankruptcy would increase and thus the overall risk would also increase. On the other hand, if regulation becomes softer, then probability of bankruptcy would decrease and consequently the overall risk will decrease too. However, overall risk variations do not always have an impact on betas since the latter only measures systematic risk.

Changes in correlation between the company's share price and the market index account for a good deal of variations in beta. We employ elements of the option theory to try and find a relationship between regulatory events and market correlation. Specifically, the main idea is based on the comparison between two identical monopolistic companies of which only the first is under price regulation.

² One would think that stricter regulation represents a higher incentive towards efficiency and then it may induce cost reduction in the long-term. However, the incentive effect is mainly induced by the presence of a price cap mechanism. In the context of this paper, a price cap regulation is already in place. Our objective is to analyse the incremental effects of modifying the cap. For these reasons, we assume that the reduction of expected cash flows is the direct consequence of a stricter regulation and vice versa. Our assumption holds for industries with natural monopolistic elements and cannot be generalised to any industry under regulation.

³ For more information about the CAPM see, among others, Black (1972) and Ross (1976).

⁴ This assumption may be not true in the general case since many regulatory industries have a strong impact on the overall market. In this case, we may assume that the impact of the UK distribution electricity industry on the overall UK financial market is not significant.

The company under regulation cannot freely change goods or service prices, whereas the other can change them without constraints. In other words, a significant difference between the two companies, that strongly impacts their relative value, is that the regulator has the option to change product prices of the regulated company, whereas that option is owned by the un-regulated company itself. The assumption is, therefore, that only regulation allows for price changes not controlled by the company, such as those due to changes in input costs.

Analytically, let V_r be the value of the regulated company and V the value of the non-regulated company:

$$V_r = V - \text{opt}$$

The term “opt” stands for the regulatory option. The value of this option depends directly on the difference between the expected allowed revenues and costs: the lower this difference, the higher the incentive for the unregulated company to increase prices and, thus, the higher the option value. An unregulated monopoly will set price so that marginal costs equal marginal revenues whereas regulators will set prices to a lower level, theoretically equal to marginal costs subjected to the constraint to recover at least average costs. In the latter case, the difference between revenues and costs is lower and then the option value is higher.

Another way to reinterpret this option is to consider it as an indicator of the “competitive pressure” under which a company operates. Whereas in competitive environments it is the market that directly imposes that pressure on companies, in regulated industries the regulator itself manages the pressure.

The tighter the regulation, the lower the value of the regulated company and the higher the option value.

As seen above, the option value under market conditions is higher than under monopolistic conditions, since the difference between revenues and costs is generally lower in the former case. Then, the option value for regulated companies would be in between the two extreme cases described above.

It is important to observe that the regulator itself (not the regulated company) owns the option described above: the higher the option, the lower the value of the regulated company.

The option value can be interpreted as an indicator of the “distance” from unregulated monopoly conditions. It depends on the strength of regulation: the softer the regulation, the lower the option value. This model explains why the correlation between the market and the regulated company will

increase when regulation becomes tighter, and vice versa. Figure 4 summarizes the main findings of this section.

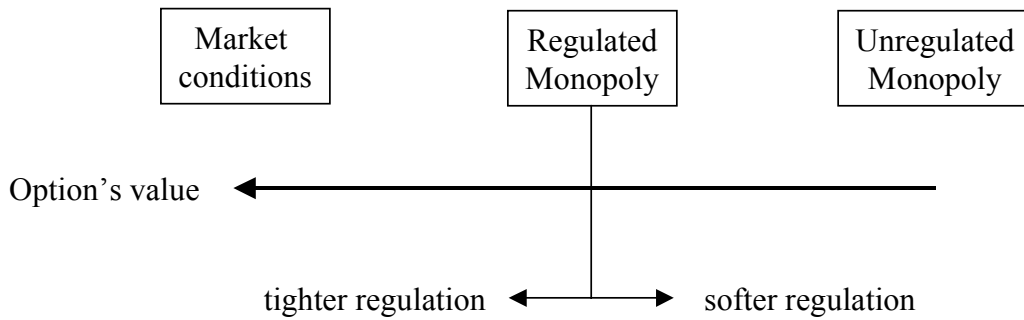


Figure 4. Relationship Between Strategic Option Values and Regulatory Pressure For A Regulated Company. In the regulated monopoly case, regulators own that option. The higher its value, the higher the pressure regulators put on companies.

Under the simplifying assumption that σ_m is not affected by regulatory events, it is possible to differentiate expression [1]:

$$[2] \quad d\beta_i = \frac{d\rho_{i,m}\sigma_i}{\sigma_m} + \frac{\rho_{i,m}d\sigma_i}{\sigma_m}$$

Betas remain unvaried if $d\beta_i=0$. In this case, the above expression becomes:

$$[3] \quad \frac{d\rho_{i,m}}{\rho_{i,m}} = -\frac{d\sigma_i}{\sigma_i}$$

For little variations, if the overall risk plus the correlation percentage variation equals zero, betas will not change. If both overall risk and market correlation variation are positive, then betas will certainly increase, and vice versa. Consequently, it is possible to model how regulation affects overall risk and correlation, as shown in figure 5.

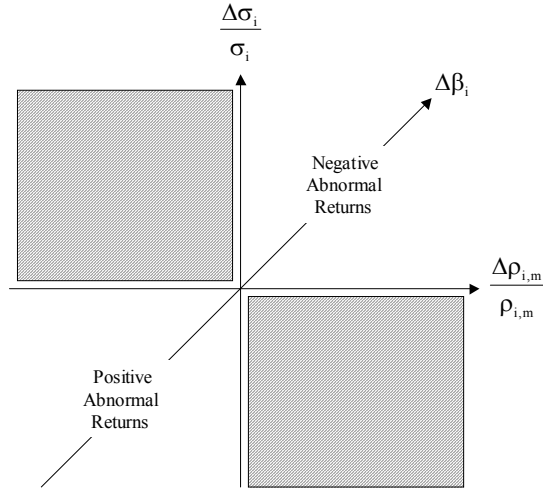


Figure 5. Relationship Between Overall Risk, Market Correlation, Betas and Abnormal Returns For Regulatory Events. $\Delta\beta_i$ stands for the beta variation, $\Delta\sigma_i/\sigma_i$ and $\Delta\rho_{i,m}/\rho_{i,m}$ stand for the overall risk and market correlation percentage variations respectively.

The discounted cash flow model (DCF) may present our model findings in a different way. With DCF, we may write company value V_i as follows:

$$[4] V_i = \sum_{j=1}^{\infty} \frac{R_j - C_j}{[1 + r_i(\sigma_i, \rho_{i,m})]^j}$$

Where R_j and C_j stand for the company's expected revenues and costs respectively; r_i is the company cost of capital employed to discount expected cash flows, and j is the time variable. In our model the cost of capital r_i depends on overall risk σ_i and market correlation $\rho_{i,m}$.

When regulation becomes softer (stricter) there are two different implications on V_i variables:

- 1) Revenue R_j increases (decreases) (Cash flow implication);
- 2) Beta determinants, σ_i and $\rho_{i,m}$, decrease (increase) (Risk implication).

Clearly, in the case of regulatory events, both the above consequences increase (decrease) company value V_i , while yielding positive (negative) abnormal returns.

Here is a summary of the model's implications. For regulatory events, if regulation becomes tighter, abnormal returns will be negative, whereas correlation and overall risk will increase. Vice versa, if regulation becomes softer, abnormal return will be positive, whereas correlation and overall risk will decrease. These implications confirm the Peltzman's suggestions that there is a positive correlation between abnormal returns and beta variations. Furthermore, our work has theoretically explained how regulatory events affect the two beta components: overall risk and market correlation. However, the model considers the impact of price-cap changes and cannot explain the

long-period trend of systematic risk if other events of different nature occur. Under this perspective the model is static, or in other words all other effects are considered “ceteris paribus”, as for example those of political (exogenous) and of business (endogenous) nature. In the next section we analyze the methodology and the sample companies used to test the above model.

3. The Methodology

Our empirical analysis is composed of two parts. First, we apply the event analysis approach in order to determine the impact of regulatory events on abnormal returns and beta variations, overall risk and market correlation, and whether that impact is statistically significant.

The methodological approach of event analysis using market stock prices is the most widespread to measure the effects of regulation (Binder, 1985 and 1998; Antoniou and Pescetto, 1997). The main problem with the event analysis approach consists in identifying the event timing. Boardman et al. (1997) use an information diffusion model to estimate the impact of regulatory events. Brown and Warner (1980 and 1985) were the first to argue that event period uncertainty decreases the power of empirical tests. We may assume that in stock price regulatory event analyses, we can measure the unexpected components of the announcements (Binder, 1985; Schumann, 1988).

The abnormal return benchmark model (Binder, 1998) considered in this study is the CAPM of Lintner (1965) and Sharpe (1964). Regulators and academics widely apply this model when addressing risk and return behavior in most network utilities. The return generating process of the CAPM, assuming a fixed risk–return relationship, presents the following expression:

$$[5] R_{it} = R_{ft} + \beta_{it}(R_{mt} - R_{ft}) + e_{it}$$

Where R_{it} stands for the continuously compounded return from a risky asset (i), R_{ft} for the continuously compounded return from a risk-free asset, β_{it} for the systematic risk measure of asset i. According to this model, the random error term is e_{it} .

The main difference when compared to the classic event analysis methodology (Fama et al., 1969) is that here betas are not constant over time. Several works (Antoniou and Pescetto, 1997; Buckland and Fraser, 2001; Cooper and Currie, 1999; Groenewold and Fraser, 1999; Morana and Sawkins, 2000; Robinson and Taylor, 1998) support the time-varying beta hypothesis.

In particular Antoniou and Pescetto (1997) and Buckland and Fraser (2001 and 2002) use that methodology to estimate the regulatory impact on both abnormal returns and betas. They show that well-defined regulatory events have a strong impact on betas.

We take into consideration a time varying ‘state–space’ model that employs the Kalman Filter procedure for beta estimation (Buckland and Fraser, 2002; Fisher and Kamin, 1985). For technical details see Appendix D.

In our model, abnormal returns AR_{it} are determined by the difference between the actual returns and the CAPM expected returns:

$$[6] AR_{it} = R_{it} - E(R_{it}) = R_{it} - [R_{ft} + \beta_{it}(R_{mt} - R_{ft})]$$

This approach is significantly different from Buckland and Fraser’s, since we only need to estimate the CAPM beta coefficients and not the alphas because, anyway, the CAPM alpha coefficient is the risk-free-investment return R_{ft} .

By using the Kalman filter, we can not only estimate betas but also the overall risk and market correlation. Therefore, through a hypothesis-testing event analysis, we can also test whether regulatory events significantly impact abnormal returns, betas and their components.

In particular, event analysis testing normally applies to abnormal returns, since they are average stochastic variables with average expectation equal to zero. Then we turn betas, overall risk and market correlation into variables that have average expectation equal to zero by considering their percentage variations period-by-period. For example, beta varies as follows⁵:

$$\Delta\beta_{it} = \beta_{it}/\beta_{it-1} - 1$$

Analogously, we can obtain overall risk and market correlation variations, $\Delta\sigma_{it}$ and $\Delta\rho_{it}$ respectively.

In testing the zero-average null hypothesis, we consider both a one-day and a three-day event period,⁶ and a 300-day estimation period. For a multi-day event period, we test cumulated abnormal returns (CAR), and cumulated beta, overall risk and market correlation variations.

There are a few problems we would like to address, such as the residual lack of normality, heteroskedasticity, and cross-sectional dependence. Therefore, we consider five different statistic tests jointly. In particular, we take into account the classic event analysis test (Fama et al., 1969), the dependence-adjusted test (Brown and Warner, 1980 and 1985), and the heteroskedasticity-adjusted standardized test (Patell, 1976). For what concerns residual non-normality, we apply two non-parametric tests: the sign test (Cowan, 1992) and the rank test (Corrado, 1989).

⁵ In the empirical analysis we consider the regulatory effects on equity betas even if the theoretical discussion reported above refers to the overall beta of the company, which also depends on debt betas and gearing (Oxera, 1996). However, since no variation in gearing happened during the analysed events, considering only equity beta changes does not undermine the results on our analysis.

⁶ From the day before to the day after the official event date.

The objective of the second part of our empirical analysis is to test the relationships predicted in section 2. In particular, for each Regional Electricity Company and for each event, we consider the relationship between abnormal returns AR_i , market correlation variations $\Delta\sigma_j$ and overall risk variations $\Delta\rho_j$. These variables are obtained in the first part of the empirical analysis. Our model is represented in the following equation⁷:

$$[7] AR_j = \sum_{i=1}^{12} \alpha_i D_i + \gamma \Delta\sigma_j + \delta \Delta\rho_j + e_i \quad j=1, \dots, 264 \text{ observations}^8$$

We also consider company-specific variables: D_i stands for the impulse-dummy company-specific variable.

We decide to use the linear form since equations 2, for small changes, seems to indicate a linear relationship between beta, overall risk and market correlation variations. However, we successfully tested this model against non-linear functional forms using the reset test (Thomas, 1985, pp. 140-157).

We expect the regression coefficients related to market correlation variations and overall risk variations, γ and δ respectively, to be negative. Following section 2, company-favoring regulatory events induce positive abnormal returns and negative overall risk and market correlation variations (vice versa also applies).

4. The Empirical Analysis

We consider the company sample consisting of the 12 Regional Electricity Companies (RECs) operating in the UK electricity distribution field (see Appendix C for the company list). The source of the twelve RECs' stock price data is Datastream. In particular, we examine the period from December 10th, 1990, their first listing day, to October 2nd, 1995, Southwestern Electricity's last listing day, before being acquired by Southern Electric, a US public utility company. Different studies (Buckland and Fraser, 2001 and 2002; Dnes et al., 1998; Robinson and Taylor, 1998) analyze this period, since it offers a unique opportunity for comparing stock price behaviors of

⁷ It appears as if revenue variable R were missing in the econometric model. There are several reasons explaining that: i) it is not easy to measure a revenue variable and ii) even if we could measure it, there would be a strong correlation with the other two explaining variables. In other words, the revenue variation effect is embodied into the two explaining variables, i.e., overall risk and market correlation variations, as you can see in the model section.

⁸ We have 22 events for any of the 12 RECs for a total of 264 observations.

several price-cap regulated firms. By the end of 1998, other public utility companies, mainly from the USA, had acquired and thus de-listed all the RECs.

Please find a regulatory event list in Appendix B. We selected 22 regulatory events by using the following information sources: Financial Times articles, Authority and Government official statements, and other papers (Buckland and Fraser, 2002; Dnes et al., 1998). In Appendix B, for each event, we also formulate our hypotheses in terms of abnormal returns, beta variations, overall risk variations and market correlation variations according to our theoretical implications of section 2. We considered the FTSE All Share as a market index⁹. As explained below, the main problem with empirical analysis is that it is not always clear whether an event is regulatory or political.

Since another recurrent problem in event analysis is to correctly identify when new information is released to the market, we propose a technique to test the robustness of our event dates. For each event we construct an index in the following way:

$$\frac{|AR_i|}{\text{MAX}_{j \in P} |AR_j|}$$

AR_i represents the abnormal return during the event date i . P represents the days of the testing period which is defined as a set of days close to the event day. If the index is higher than 1, it means that the event day itself is more significant than the days of the testing period. For our analysis we consider 2 days before the event date and 2 days after the event date as testing period. Taking longer testing periods could result in mixing the effects of other events, not necessarily due to regulation. Since we analyse regulation effects not just on abnormal returns but also on systematic risk, we also calculate an analogue index with reference to beta variations. The two indexes are shown in table 1.

When the two indexes are both lower than 1, it means that the event day has a lower impact than its testing period days on both abnormal returns and beta variations. In this case the event may be incorrectly identified, as shown in the last column of table 1. We selected 8 events as potentially incorrectly identified. However, the condition of both indexes being lesser than one is just a necessary but not sufficient condition for incorrect identification. In other words, the two indexes may be lower than 1 just because the event has no significant impact and not because it is incorrectly identified. In particular, events number 4, 5, 8, 13 and 16 are not significant, as shown in table 2, nor are significant other days of their testing periods. The remaining three events possibly

⁹ We made the assumption that the considered regulatory events do not affect the market index return.

incorrectly identified are the number 10, 15 and 18. Even if they are statistically significant, a further analysis shows that the most significant day in these three cases is the day after the event. That does not mean the three events are not correctly identified but only that the market reaction is not instantaneous but lasts more days. Our analysis shows evidence that the event days selected for our analysis are not incorrectly identified.

No.	Date	AR Index	Beta Variation Index	Potential Incorrect Event Identification
1	01/04/1992	5,61	103,46	
2	07/07/1992	1,61	2,49	
3	02/09/1992	0,72	1,24	
4	08/10/1992	0,39	0,27	x
5	10/12/1992	0,05	0,04	x
6	29/01/1993	1,76	2,93	
7	09/07/1993	2,25	1,76	
8	04/08/1993	0,95	0,24	x
9	26/10/1993	0,82	1,37	
10	14/02/1994	0,57	0,23	x
11	22/06/1994	1,82	0,33	
12	28/06/1994	1,49	0,23	
13	08/08/1994	0,04	0,06	x
14	11/08/1994	2,39	2,09	
15	29/09/1994	0,15	0,13	x
16	28/10/1994	0,27	0,18	x
17	15/11/1994	0,75	2,11	
18	22/02/1995	0,69	0,14	x
19	23/02/1995	1,45	2,83	
20	07/03/1995	2,48	19,69	
21	24/03/1995	2,44	3,39	
22	06/06/1995	0,73	1,46	

Table 1. Potential Incorrect Event Identification. For each event, two different indexes are calculated to quantify the relative significance of the event day with respect to the days of the testing period, for abnormal returns and beta variations respectively. A testing period of two days before the event and two days after the event is considered. Events in which both the indexes are lower than 1 may be incorrectly classified.

Table 2 shows the results of the first phase of the empirical analysis. In this table we report abnormal returns, beta, overall risk, and market correlation variations for each regulatory events using both a one-day and a three-day event period¹⁰. The statistical significance reported is that of

¹⁰ We also repeated the analysis for a five-day event period and obtained results coherent with those in **Errore. L'origine riferimento non è stata trovata.**

the Patell standardized test (Patell, 1976) which, addressing the issue of heteroskedasticity among RECs, is the best alternative for our sample¹¹.

Event Date	Single-Day Event				Three-Day Event			
	Abnormal Return	Beta Var.	Overall Risk Variation	Market Correlation Variation	Abnormal Return	Beta Var.	Overall Risk Variation	Market Correlation Variation
1-Apr-92	-4,78%***	23,86%***	29,16%***	4,04%**	-5,12%***	23,63%***	27,62%***	2,41%
7-Jul-92	1,71%***	3,07%	4,13%*	2,90%	3,45%***	1,08%	1,82%	5,46%
2-Sept-92	-3,15%***	-3,29%	2,70%	-6,07%	-6,28%***	-6,22%	2,08%	-6,10%
8-Oct-92	0,76%	-1,09%	-1,19%	-1,00%	0,00%	-4,81%	-2,41%	-5,42%**
10-Dec-92	-0,06%	0,14%	-0,95%	1,81%	-1,71%	4,81%	-1,59%	9,84%
29-Jan-93	-2,09%***	28,43%***	6,70%	27,45%***	-3,37%***	31,16%**	5,81%	28,91%***
9-Jul-93	2,04%***	-9,42%***	3,04%***	-11,33%***	2,07%***	-9,76%***	0,39%	-11,09%***
4-Aug-93	-0,73%	0,96%	-0,64%	0,18%	-0,72%	-1,45%	-3,36%*	1,53%
26-Oct-93	0,95%***	-7,34%***	-0,18%	-6,72%**	1,59%***	-6,85%	-2,09%	-6,39%
14-Feb-94	-2,21%***	1,35%**	2,20%***	-2,22%	-2,09%***	6,61%***	2,86%***	3,15%
22-June-94	-1,99%***	-1,71%***	1,55%**	-4,24%***	-0,79%	-4,30%***	-0,61%	-3,98%**
28-June-94	3,11%***	-1,18%**	5,14%***	-7,32%***	5,13%***	4,26%***	8,02%***	0,04%
8-Aug-94	0,09%	0,08%	-1,20%	-0,13%	-0,17%	-0,43%	-3,45%	-0,09%
11-Aug-94	6,13%***	-17,30%***	17,43%**	-27,01%***	7,12%***	-9,01%***	20,54%***	-21,89%***
29-Sept-94	-0,44%	1,34%*	-0,90%	5,51%***	-1,39%*	0,01%	-2,89%	7,03%***
28-Oct-94	0,63%	0,89%	-0,73%	1,04%	3,21%	6,51%	2,12%	7,34%
15-Nov-94	-0,55%	-1,22%	-1,53%	2,04%	0,23%	-1,87%	-4,24%	2,14%
22-Feb-95	-2,15%***	-1,32%	1,26%	-3,78%	-5,31%***	-10,80%***	2,39%*	-11,74%***
23-Feb-95	-3,11%***	-9,49%***	2,52%***	-7,85%***	-4,15%**	-14,17%***	2,58%*	-11,20%***
7-Mar-95	-15,40%***	113,36%***	112,84%***	17,67%***	-22,25%***	110,93%***	115,30%***	11,00%
24-Mar-95	-1,87%***	-1,45%	-1,10%	-1,32%	-2,58%***	-1,62%	-3,99%	-1,36%
6-June-95	2,01%***	-1,30%	0,69%	-3,21%***	4,36%***	-2,05%	2,63%	-5,19%***

Table 2. Event Study Hypothesis Test Results: abnormal returns, betas, overall risk and market correlation variations for each regulatory event. *** statistically different from zero at the 99% level, ** statistically different from zero at the 95% level, * statistically different from zero at the 90% level. Abnormal returns, beta variation, overall risk variation and market correlation variation are expressed as percentage values. When considering the three-day event study, we refer to cumulated abnormal returns, cumulated beta variations, cumulated overall risk variations, and cumulated market correlation variations. We employed the Patell standardised test (Patell, 1976).

¹¹ The other four tests give similar outcomes, with the exception of the sign test whose significance level is generally higher. Their results are available on request from the authors.

The relationship between abnormal returns and beta variations generally follows the model described above: the higher the abnormal returns, the less the beta variations. Furthermore, betas change significantly in seven events over twenty-two, thus confirming the time-varying hypothesis. The Northern Ireland Electricity vesting day event, on 1st April 1992, indirectly increased competitive pressure on RECs. The REC average abnormal return was 4,78%, whereas betas increased by 23,86% on average.

On 29th January 1993, a Trade and Industry Committee report called for a reduction on the RECs' return on capital. Average abnormal returns were equal to -2,09%, and betas increased by 28,43%. On 9th July 1993, the Authority established the new supply business X factor, and it was less than expected. Consequently, abnormal returns were positive and risk decreased. On 26th October 1993, a favorable consultation paper on the RECs' assets cost of capital and operating cost was released. Consequently company value increased (+0,95%), and betas decreased considerably (-7,34%). On 11th August 1994 the Authority's new distribution price proposal, strongly favourable to RECs, had a considerable impact. Average abnormal returns were +6,13%, and betas went down by 17,30% on average. On 7th March 1995, the electricity director announced his intention of anticipating the new price revision. This event had the strongest impact on abnormal returns and betas: average abnormal returns were -15,40%, and betas more than doubled (+113,36%).

The only significant regulatory event that apparently did not follow the theoretical relationship described above occurred on 23rd February 1995. Indiscretions made known in advance the price revision event, which eventually happened on 7th March 1995. In this case, average abnormal returns were negative (-3,11%), and betas decreased (-9,49%). This can be explained by observing that before this event there had been public debates about the possibility of limiting the RECs' huge profits due to weak regulatory pressure. Even though RECs expected a regulatory intervention, none knew exactly the extent. When the market eventually learned about the regulatory intervention type, risk decreased.

The above counter-example raises the analysis' main shortcoming: it is generally difficult to classify an event as regulatory. As seen above, a regulatory event concerns only the regulation process. Although the underlying general idea is straightforward, events may have not only regulation but also policy implications. Clearly the decision to anticipate the regulatory revision has several possible policy implications. For examples, it could prelude to radical regulatory shifts towards other stricter methodologies, regulation governance systems or, at the extreme point, some

forms of re-nationalization. Alternatively, it could anticipate unforeseeable profit-cutting interventions, such as Tony Blair's wind-fall tax.

Thus, the negative relationship between betas and abnormal returns applies to almost any regulatory event, as predicted by the above model.

One would ask whether the regulatory effect on betas is only transitory or has a long-term effect on the cost of capital. The event study methodology cannot be extended to long periods since there is a high probability to mix the effects of events of different nature. Figure 6 shows the time-varying beta estimation for the equal-weighted portfolio of RECs in the period between 1991 and 1995.

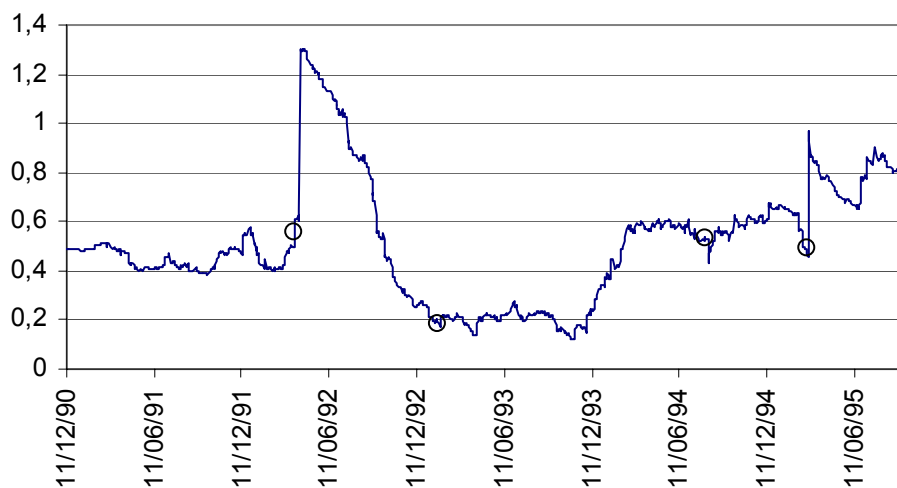


Figure 6. Time-varying Beta Of the RECs Equal-Weighted Portfolio In the 1991-1995 Period.

The first date marked in the figure is related to the 1st April 1992 event in which a strong increase in betas is observed. It is not simple to isolate the effect of this event since after 9 days a general election took place, in which the Conservative party unexpectedly won, causing a further increase in betas. Such event is not specifically considered in our analysis since it does not regard price-cap regulation. However, in September 1992 the beta returned below the initial level.

The second and the third date marked in the figure are related to other two very significant events in which betas changed, 29th January 1993 and 11th August 1994 respectively. Also in these cases, the beta returned, at the previous level in a few weeks, at least in qualitative terms.

The last mark in figure 6 is related to the strongest event considered in our analysis, 7th March 1995, in which the Director of Electricity broke the price-cap contract before expiration causing a sharp

increase in betas. In this case, at the end of 1995, betas did not move substantially from the post-event level.

In the period 1991-1995, the beta of the equal-weighted portfolio of RECs increased from a 0,5 level to a 0,8 level. It is not possible to say that this change is due to the sole regulatory action. The equity beta may be influenced by other factors, respect to which regulatory action is not influent; for example the level of debt can be considered constant only in the short term and geographical and industry diversification strategies can alter the systematic risk of equity in absence of regulatory interventions. In this case we cannot affirm beforehand that the effect of regulatory actions – that according to the empirical analysis of the paper do indeed exist – are transitory, mainly for the very reason that regulatory events are not the sole cause of variations in equity beta.

Thus, a priori, the regulator cannot know if its intervention is temporary or not, and thus it cannot ignore the results.

Table 2 also shows the regulatory event impact on market correlation and overall risk. It appears that market correlation variations generally follow beta variations. When regulation becomes softer, abnormal returns will be positive, betas will decrease, and market correlation will be expected to decrease too. For example, on 11th August 1994, betas and market returns significantly decreased, and abnormal returns were positive. On the other hand, overall risk changes do not seem to follow the above-mentioned relationship.

Furthermore, the impact of events on overall risk does not seem to yield the expected results. For example, on 11th August 1994, overall risk increased significantly, whereas beta and market correlation variations were negative. This seems to contradict theoretic expectations: based on the above model, we expect to find a positive relationship between beta and overall risk variations. To explain this anomaly, we have to consider, as several authors have pointed out (Boehmer et al., 1991; Patell, 1976), that the event itself may increase price volatility. Following the event-induced variance hypothesis, one would expect that overall risk (measured as the return standard deviation) would increase, whenever a regulatory event occurs, and not only when regulation becomes stricter. Nevertheless, according to the above model, one would expect that if regulation becomes stricter, overall risk will increase more than in the company-favorable regulatory event case. It is clear that event analysis is useless to test this correlation. In the second phase of empirical analysis we try to employ a regression analysis to examine whether company-favorable events yield higher overall risk than company-unfavorable events.

So far, market correlation seems to be the most beta-affecting component: we can interpret it as the competitive pressure the regulator puts on regulated companies as seen above. Figure 7 shows the market correlation of the RECs equal-weighted portfolio. It ranged between 50%, in the middle of 1992, and 10%, at the end of 1993. The latter minimum market correlation date stands as a turning point in regulatory policy: after that, regulation became gradually stricter. First, the regulator reviewed distribution prices cutting them by 10-15%, even though regulated companies expected a stronger reduction. Second, just after one year of the new regulatory period, the regulator changed distribution prices again by increasing the X factors from 2% to 3%. The extent to which the regulator tried to increase pressure on companies is well documented in figure 6: up to the end of 1995, market correlation increased from 10% to 30%.

In this sense, regulator behaviour is not atypical. Following Baldwin and Cave (1996) when utilities are privatised, the price caps to which they are subjected are usually set too high. They find the main reason in the information asymmetry between regulators and regulated firms. The management of a regulated firm is better versed in matters concerning it than the regulator, and can use this advantage in order to procure a lax cap. This asymmetry will diminish over time as the regulator gathers experience.

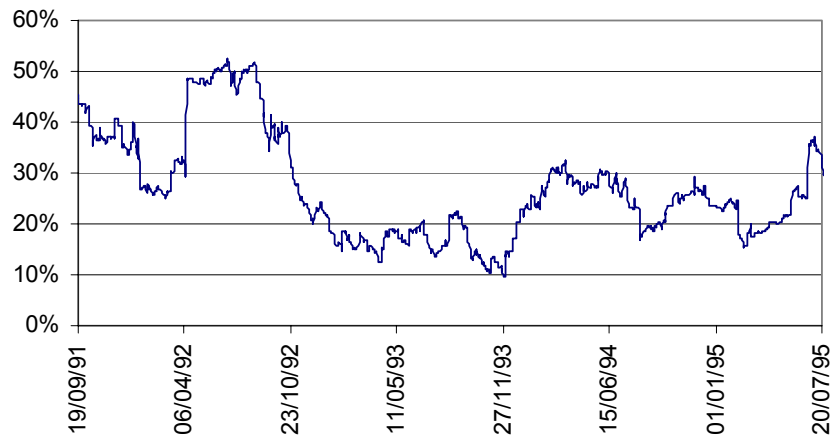


Figure 7. Market Correlation Of the RECs Equal-Weighted Portfolio In the 1991-1995 Period.

The second phase of our empirical analysis tests the model introduced above. In particular, for each REC and for each event, we consider the relationship between abnormal returns, market correlation and overall risk variations, as reported in equation [7] and considering a one-day event period.

The first part of table 3 shows the regression results: the coefficients of the overall risk variation and the market correlation variation, γ and δ respectively, are negative and statistically significant.¹² The higher the abnormal returns, the lower the market correlation and overall risk variations, and vice versa. Interestingly, dummy coefficients α_i are not significant for any company. Empirical findings confirm our model.

Variable	One-day event period F=38,8*** R ² =68,5%		Three-day event period F=21,5*** R ² =54,7%		Five-day event period F=15,5*** R ² =46,6%	
	Coefficient	t-value	Coefficient	t-value	Coefficient	t-value
$\Delta\sigma$	-0,109***	-18,739	-0,155***	-15,950	-0,128***	-13,114
$\Delta\rho$	-0,132***	-10,975	-0,126***	-6,139	-0,101***	-5,331
D ₁	0,001	0,205	0,006	0,710	0,008	0,857
D ₂	0,000	0,034	0,002	0,221	0,002	0,249
D ₃	0,002	0,358	0,002	0,191	-0,001	-0,162
D ₄	-0,003	-0,689	-0,002	-0,228	0,000	-0,056
D ₅	-0,004	-0,825	-0,009	-1,030	-0,008	-0,928
D ₆	-0,003	-0,622	-0,009	-1,063	-0,009	-1,015
D ₇	-0,002	-0,389	0,000	-0,015	-0,004	-0,448
D ₈	-0,004	-0,889	-0,003	-0,354	-0,005	-0,525
D ₉	0,001	0,297	0,005	0,558	0,002	0,251
D ₁₀	-0,007	-1,296	-0,005	-0,624	-0,007	-0,764
D ₁₁	-0,002	-0,333	0,002	0,271	0,002	0,187
D ₁₂	-0,001	-0,159	-0,006	-0,654	-0,005	-0,584

*Table 3. Event Study Regression Approach Results: we regress abnormal returns on market correlation ($\Delta\rho$) and overall risk ($\Delta\sigma$) variations and on company-specific dummy variables (D_i) for 3 different event periods: a) one-day period, b) three-day period and b) five-day period. For each regression we also report the significant level of the test, F-value, and the corrected R². *** statistically different from zero at the 99% level, ** statistically different from zero at the 95% level, * statistically different from zero at the 90% level.*

In order to test the robustness of the results related to the choice of the event period, we also repeated the analysis considering variables from a three-day event period and from a five-day event period. The results are also shown in table 3 and are coherent with those obtained from a one-day event period. The only difference is that the statistical significance of the t-tests, the F-test and the corrected R² decreases with the length of the event period, as expected. The results confirm the correct identification of the event dates in which new regulatory information is released to the market.

¹² The regression results satisfy the normality, the heteroskedasticity, and the functional diagnostic test.

We repeated this analysis considering only the events that are found to be statistical different from zero at 90% in the first phase (Table 2) in at least one variable among abnormal returns, beta variation, overall risk variation and market correlation variation¹³. The results strictly confirm those of table 3, with a slightly higher significance level of the T-tests for the market correlation variation, δ .

We further examine company specific characteristics testing a simplified version of equation [7] for individual companies, for an equally weighted portfolio and for a value weighted portfolio. In particular, the model to be tested is:

$$AR_j = \alpha + \gamma\Delta\sigma_j + \delta\Delta\rho_j + e_j \quad j=1, \dots, 22 \text{ observations}$$

Variable	Intercept	$\Delta\sigma$	$\Delta\rho$	F-value	R ²
EEL	0,001	-0,099***	-0,100**	30,20***	76,1%
EME	0,002	-0,128***	-0,119**	30,41***	76,2%
LON	-0,001	-0,107***	-0,211***	18,28***	65,8%
MEB	-0,002	-0,113***	-0,086*	14,67***	60,7%
MWB	-0,002	-0,125***	-0,079*	15,83***	62,5%
NTE	0,000	-0,296***	0,019	17,99***	65,4%
NRW	-0,003	-0,108***	-0,173**	24,25***	71,9%
SBD	-0,004	-0,114**	-0,173**	17,44***	64,7%
SEL	0,000	-0,115***	-0,245***	50,87***	84,3%
SWA	-0,005	-0,116***	-0,107*	19,77***	67,5%
SWN	-0,003	-0,101***	-0,176***	38,45***	80,2%
YKE	0,000	-0,120***	-0,122***	34,81***	78,6%
Equally Weighted Portfolio	-0,002	-0,106***	-0,147***	26,20***	72,4%
Value Weighted Portfolio	-0,002	-0,107***	-0,142***	25,25***	72,7%

*Table 4. Company Specific Results: we regress abnormal returns on market correlation ($\Delta\rho$) and overall risk ($\Delta\sigma$) variations for a) individual companies, b) an equally weighted portfolio and c) a value weighted portfolio considering a one-day period. For each regression we also report the significant level of the test, F-value, and the corrected R². *** statistically different from zero at the 99% level, ** statistically different from zero at the 95% level, * statistically different from zero at the 90% level.*

Table 4 reports the company specific results. Also at the company level we find a strong negative correlation between abnormal returns, overall risk and market correlation variations. The only coefficient different from our prediction is the market correlation variation $\Delta\rho_j$ of Northern Electricity, NTE, which is positive but without statistical significance. The likeness of the model

¹³ The six events eliminated are the number 4,5,8,13,16 and 17.

outcomes for each REC and their portfolios is not surprising since these companies are very similar for dimension and business activity. In fact, they all operate in the sector of electricity distribution in different areas of UK.

5. Concluding remarks

Following the developments of regulation, an interesting debate has emerged about the regulatory impact on company value and risk. Even though different works have found a negative relationship between abnormal returns and CAPM beta variations, no study has analyzed whether systematic risk variations are due to overall risk variations or to market correlation variations.

This paper aims at overcoming the lack of literature on this issue by considering an analytical model. This model leads to the following results: i) there is a negative relationship between abnormal returns and overall risk variations and ii) there is a negative relationship between abnormal returns and market correlation variations. In other words, regulatory events affect both overall risk and market correlation in the same direction. In particular, we can obtain the latter theoretical result by considering the option on regulated company price changes owned by the regulator. We believe that market correlation represents a proxy of that option and, therefore, one could use it to measure the “competitive pressure” regulators apply to the above regulated companies.

To test this theoretical model, we use a methodology where CAPM betas are allowed to vary over time. Through this method we can estimate the impact of regulatory events on the company’s abnormal returns, beta, overall risk and market correlation variations. Our company sample consisted in the twelve Regional Electricity Companies (RECs) operating in the English electricity distribution industry. First of all, we use the event study hypothesis testing approach to find the regulatory impact of the selected 22 regulatory events. In order to strengthen our empirical findings, we use the regression approach to analyze the relationships between abnormal returns, overall risk and market correlation variations. We successfully tested our model in the RECs industry and also at the company level, obtaining very significant negative relationships between abnormal returns, and both overall risk and market correlation variations. When regulation becomes stricter, abnormal returns are negative, and betas increase due to both overall risk and market correlation increases, and vice versa.

The results of our event analysis carry important policy implications. The effect of a regulatory event can be properly identified only in the related event window. In this context, we find that it significantly affects systematic risk. However, if we consider longer periods, events of different nature, respect to which the regulatory action is not influent, may occur. For this reason, the regulator should not ignore beforehand our empirical and theoretical findings, even in a long-term perspective.

Future developments of this work could test our model on different data sets. For example, one possible study is whether the relationships verified in the English electricity distribution also hold in other regulated industries, such as telecommunications, gas and water supply. Even though we developed this model by considering a price cap regulation scenario, one could also generalize it by analyzing the case of rate of return regulation. Furthermore, this study points out a useful tool to test the regulator's strength: the correlation between the regulated company and the market could help measure regulatory effectiveness, and could consequently be employed to test the capture hypothesis.

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Appendix A

The expected returns μ in a certain period can be defined as follows:

$$[8] \quad \mu = \frac{\int_0^{\infty} p(c) \cdot [R - c] \cdot dc}{V_0}$$

Where c is the company total cost, $p(c)$ is the cost distribution probability, R is the revenue allowed by the price cap system, and V_0 is the initial capital invested by shareholders in the company. It corresponds to the initial market value of the company before any revenue changes. $R - c$ represents the company's profit.

Expected returns variance σ^2 represents a shareholder's overall risk proxy:

$$[9] \quad \sigma^2 = \int_0^{\infty} p(c) \cdot \left[\frac{R - c}{V_0} - 1 - \mu \right]^2 \cdot dc$$

We are going to differentiate the two latter expressions with respect to R in order to see how regulation affects expected returns and variance:

$$[10] \quad \frac{\partial \mu}{\partial R} = \frac{\int_0^{\infty} p(c) \cdot dc}{V_0} = \frac{1}{V_0}$$

$$[11] \quad \frac{\partial \sigma^2}{\partial R} = 0$$

The initial capital employed V_0 is not affected by changes in revenues. The meaning of derivative [10] is straightforward: the higher the revenues, the higher the expected returns. From the second derivative we understand that revenue variations do not change volatility and risk. It is important to note that this model does not consider either limited liability or any possible bankruptcies. Thus, increases in the allowed revenue R have an impact only on expected profits but not on risk.

When taking limited liability into consideration, the expected returns and variance expressions become:

$$[12] \quad \mu = \frac{\int_0^{V_0+R} p(c) \cdot [R - c] \cdot dc - V_0 \int_{V_0+R}^{\infty} p(c) \cdot dc}{V_0}$$

$$[13] \quad \sigma^2 = \int_0^{V_0+R} p(c) \cdot \left[\frac{R-c}{V_0} - \mu \right]^2 \cdot dc + [-1-\mu]^2 \int_{V_0+R}^{\infty} p(c) \cdot dc$$

Shareholders will completely lose their initial investments if losses (R-c) become higher than the firm's initial activity value V_0 . Figure 1 shows the relationship between shareholder profit and company cost.

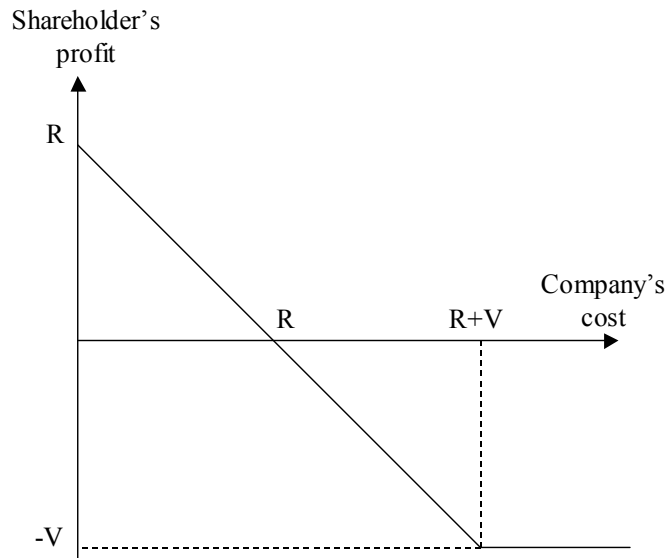


Figure 1. Relationship Between Shareholder's Profit and Limited Liability Company Cost. R stands for the company revenues, and V for the company activity value.

By calculating the new expected returns and variance differentials with respect to R , it is possible to obtain the following expressions:

$$[14] \quad \frac{\varphi\mu}{\varphi R} = \frac{\int_0^{V_0+R} p(c) \cdot dc}{V_0}$$

$$[15] \quad \frac{\varphi\sigma^2}{\varphi R} = \frac{2(1+\mu) \int_{V_0+R}^{\infty} p(c) \cdot dc}{V_0}$$

Then we introduce probability of default p_f , defined as the probability that the company will lose its entire initial capital V_0 :

$$[16] \quad p_f = \int_{V_0+R}^{\infty} p(c) \cdot dc$$

Considering that $\int_0^{V_0+R} p(c) \cdot dc = 1 - p_f$, the above derivatives become:

$$[17] \quad \frac{\varphi\mu}{\varphi R} = \frac{1 - p_f}{V_0} \quad \text{and} \quad \frac{\varphi\sigma^2}{\varphi R} = \frac{2p_f}{V_0} (1 + \mu)$$

Since p_f is non-negative by definition, the variance derivative with respect to revenues R is non-negative as well. This result is counterintuitive since one would expect that if revenues increase then not only will the probability of default go down, but firm risk will decrease, too. However, this analysis considers neither financial distress nor bankruptcy costs. Under these assumptions, the default scenario decreases the variance of expected returns. Consequently, the lower the probability of default, the higher the expected returns variance. The extreme scenario would occur when probability of default is equal to one: this is a “free-risk” scenario, since the expected returns are certainly equal to -100% .

By considering financial distress and bankruptcy costs, then the shareholder’s expected returns are:

$$[18] \quad \mu = \frac{\int_0^{iV_0+R} p(c) \cdot (R - c) \cdot dc + \int_{iV_0+R}^{R+V_0-C_f-C_b} (R - c - C_f) p(c) \cdot dc - V_0 \int_{R+V_0-C_f-C_b}^{\infty} p(c) \cdot dc}{V_0}$$

Here iV_0 is the percentage of company value representing the loss limit over which the company would face financial distress. Such financial distress implies that the company incurs in an incremental cost equal to C_f .

If losses increase, the company faces bankruptcy and incurs in another incremental cost equal to C_b : in this case, shareholders lose everything, see figure 2.

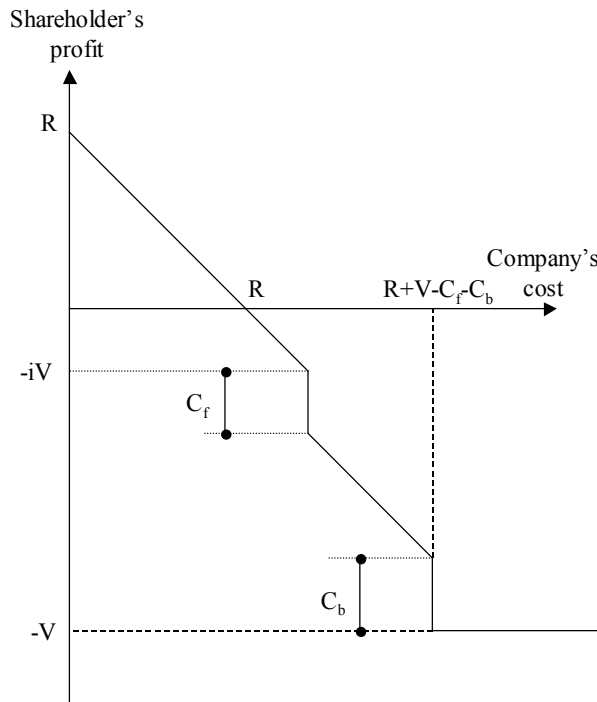


Figure 2. Relationship Between Shareholder's Profit and Limited Liability Company Cost, Taking Into Consideration Financial Distress And Bankruptcy Costs. R stands for company revenues, V for the company activity value, C_f for financial distress costs and C_b for bankruptcy costs.

Under these realistic assumptions the derivatives are complicated functions. However, a positive correlation between expected returns and revenues is likely to occur. In this case, research would consider a simulation to study the revenues-variance relationship.

Here is an example: the company cost function is normally distributed with average 5,000 and variance 2,000. The company initial activity value is 5,000 (V_0), the financial distress loss limit, written as a percentage of company activity value, is 15% ($i=15\%$). Both the financial distress and bankruptcy costs are 15% of the company initial activity value ($C_f=C_b=15\%V_0$).

Figure 3 portrays the results of our simulation. It is interesting to note that increases in revenues induce decreases in variance. The same figure shows also the bankruptcy probability: when it tends to zero, returns variance is at a level around 15,3%. The latter result is not surprising since this scenario is equivalent to that considering neither limited liability nor bankruptcy probability.

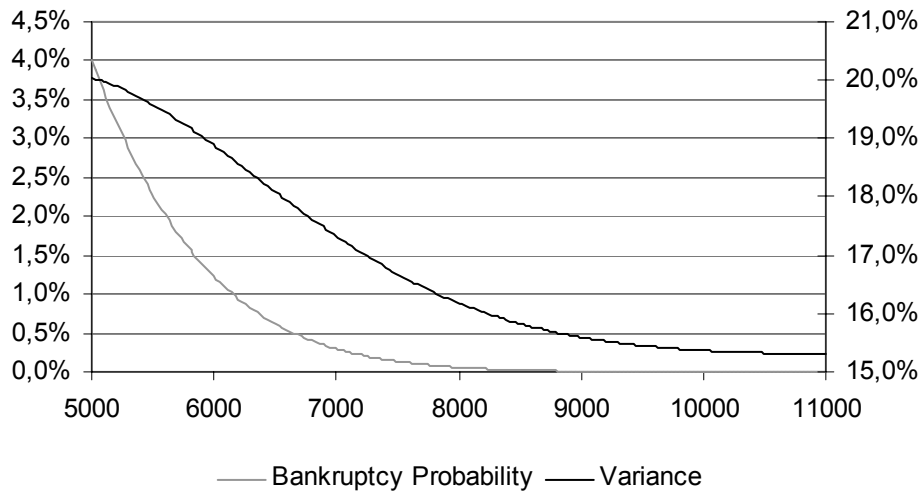


Figure 3. Relationship Between Company Revenues (x axis), Probability of bankruptcy (on the left side) And Return Variance (on the right side) Taking Into Consideration Financial Distress And Bankruptcy Cost.

Appendix B: The list of regulatory events considered in the empirical analysis and the hypotheses to be tested.

Event Date	Event Description	Hypotheses to be tested			
		Abnormal returns	Beta Variations	Overall Risk Variations	Market Correlation Variations
1-Apr-92	Vesting day for Northern Ireland Electricity	-	+	+	+
7-Jul-92	OFFER releases "Future control of NGC prices"	+	-	-	-
2-Sep-92	The Director of Electricity calls for a reduction in the nuclear levy	-	+	+	+
8-Oct-92	A consultation paper about the methodologies of regulation is released	+	-	-	-
10-Dec-92	Offer allows RECs to move into gas-powered generation	+	-	-	-
29-Jan-93	A report from the Trade and Industry Select Committee calls for a reduction in the RECs' return on capital	-	+	+	+
9-Jul-93	The revised X factors for the supply business of RECs are fixed	+	-	-	-
4-Aug-93	RECs accept the price control review	+	-	-	-
26-Oct-93	A consultation paper on the cost of capital assets valuation and identification of operating cost drivers is released	+	-	-	-
14-Feb-94	The director of electricity decides not to refer generators to Monopoly and Merger Commission (MCC)	-	+	+	+
22-Jun-94	Indiscretions about a letter Offer has sent to RECs call for a 10-20% price cut	-	+	+	+
28-Jun-94	New indiscretions call for a lenient price review	+	-	-	-
8-Aug-94	New indiscretions anticipate price changes between -10% and -15%, then RPI-2 until 2000	-	+	+	+
11-Aug-94	Presentation of the proposal of distribution price control	+	-	-	-
29-Sep-94	Revised factors for supply and distribution business of SWA and SWN are announced	-	+	+	+
28-Oct-94	Scottish Hydro Electric announces it will not accept revised price controls	-	+	+	+
15-Nov-94	OFFER refers Scottish Hydro proposed price control to MMC	-	+	+	+
22-Feb-95	The Director of Electricity warns that he will review the distribution price	-	+	+	+
23-Feb-95	Reports say that the director of electricity may change the 1994 price cap	-	+	+	+
7-Mar-95	The director of electricity confirms that new price controls will be effective before the expected time of five years: a price cap of RPI-4 is taken into account	-	+	+	+
24-Mar-95	The director of electricity announces a price controls review	-	+	+	+
6-Jul-95	Offer publishes revisions. X increased from 2% to 3% per year	+	-	-	-

Appendix C: A List Of the Twelve Regulated Regional Electricity Companies (RECs)

Regional Electricity Companies (RECs)
Eastern Electricity - EEL
East Midlands Electricity - EME
London Electricity - LON
Midlands Electricity - MEB
Manweb - MWB
Northern Electricity - NTE
Norweb - NRW
Seeboard - SBD
Southern Electricity - SEL
South Wales Electricity Swalec- SWA
Southwestern Electricity SWEB - SWN
Yorkshire Electricity - YKE

Appendix D: technical note on the Kalman Filter estimation

As seen above, the returning generation process implied by the CAPM is:

$$R_t = R_{ft} + \beta_t(R_{mt} - R_{ft}) + e_t$$

Let Y_t be the dependent variable and X_t the independent variable at time t , the last equation can be written in the following regression form, known as observation equation:

$$Y_t = \beta_t X_t + e_t$$

The regression coefficient, beta, is time-varying with the following stochastic process:

$$\beta_t = \beta_{t-1} + w_t$$

Where w_t is the innovation term, serially uncorrelated, normally distributed with zero average and constant variance. The last equation, describing the time-varying behaviour of the parameter β is called the state equation.

It is possible to show (Harvey, 1989) that the following equation represents a minimum-variance estimator of β_t :

$$\beta_t = \frac{\sum_{j=1}^t \phi_j X_j Y_j}{\sum_{j=1}^t \phi_j X_j^2}$$

Where

$$\phi_{j+1} = \phi_j + K \sum_{h=1}^j \phi_h X_h^2$$

K represents the ratio between two variances: the variance of the innovation term of the state equation, w_t , and the variance of the innovation term of the observation equation, e_t . These two parameters and the initial value ϕ_1 are estimated after maximization of the likelihood function (Harvey, 1989).

If β is not time-varying, stationary, K is equal to zero and all ϕ s are equal to 1. In this case the beta estimator is that of the well-known regression approach. If $K > 0$, the Kalman Filter weights more the observation (X_t, Y_t) with higher ϕ_t .