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Estimating the Price of ROCs

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The UK government introduced the Renewable Obligation (RO), a system of tradable quotas, to encourage the installation of renewable electricity capacity. Each unit of generation from renewables created a renewable obligation certificate (ROC). Electricity generators must either; earn ROCs through their own production, purchase ROCs in the market or pay the buy-out price to comply with the quota set by the RO. A unique aspect of this regulation is that all entities holding ROCs receive a share of the buy-out fund (the sum of all compliance purchases using the buy-out price). This set-up ensures that the difference between the market price for ROCs and the buy-out price should equal the expected share of the buy-out fund, as regulated entities arbitrage these two compliance options. The expected share of the buy-out fund depends on whether enough renewable generation is available to meet the quota. This analysis tests whether variables associated with renewable generation or electricity demand are correlated with, and thus can help predict, the price of ROCs.

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Introduction

Widespread installation of and technological innovation in renewable electricity generation is often hindered due to prohibitive costs relative to fossil fuel generation; without long-term certainty investors are uncertain about earning a return on their investment. In order to provide investors with long-term stability, the UK government introduced the Renewable Obligation (RO) in 2002. The RO encourages large scale renewable generation by imposing a mandatory ratio of electricity that must be generated from different 'eligible' renewable sources relative to all electricity generation. Generation from eligible renewable technologies yields Renewable Obligations Certificates (ROC), which are traded in a market among firms and must be turned over to a regulatory body in order to comply with the mandatory level of renewable generation.

Fearing unreasonably high prices, the RO allows regulated firms to comply by paying the "buy-out" price for every megawatt hour (MWh) shortfall in renewable production. Any payments made are put into a "buy-out" fund which is redistributed to firms which own ROCs at the end of the compliance period. This sets up an arbitrage relationship between the price of ROCs and the buy-out price, as firms short of ROCs can either pay the buy-out price or buy a ROC and receive its share of the buy-out fund. In equilibrium, the difference between the price of a ROC and the buy-out price should equal the (expected) share of the buy-out fund. The size of the buy-out fund is determined by how far under the mandatory level of renewable generation the UK electricity sector is. As a result, the difference between the ROC price and buy-out price should be related to the expected level of renewable generation relative to all generation. This analysis will determine which renewable generation factors alter the difference between the ROC price and buy-out price. Results show that the minimum temperature, a predictor of electricity demand, is highly correlated with the ROC buy-out price difference. Other potential factors, such as wind speed and natural gas prices, are not correlated with ROC buy-out price difference. These results imply that weather derivatives may be helpful in hedging price risk in ROC compliance.

Background

Renewable energy is becoming ever more important to governments around the world. The UK government has set ambitious GHG reduction targets and their aim is to have renewable generation account for 15% of the total energy mix by 2020. Renewable energy generation is seen as vital in order for emissions reduction targets to be met. Electricity generation has been identified as a sector in which a significant level of emissions reductions can be made. In 2011, CO2 emission from power stations in the United Kingdom totalled 146 Mt, which is approximately one-third of the UK's total emissions (DECC, 2012). Numerous governments are adopting regulation specifically focused on reducing greenhouse gas emissions from electricity generation using fossil fuels. Canada, for example, has recently passed the *Reduction of Carbon Dioxide Emissions from Coal-Fired Generation of Electricity Regulation~~s~~* in an effort to reduce emission from a sector that accounts for 77% of electricity-related GHG emissions (Environment Canada, 2011) while only accounting for 13.5% of the total Canadian electricity generation fleet.

In addition to the environmental need for renewable energy, governments have a vested interest in developing renewable technologies as they offer increased energy security. Recent UK primary energy supply projections indicate that between 2010 – 2020, coal imports will make up between 9-10% of total energy supply in the UK. Oil imports will account for 4% in 2010 and increase to 26% in 2020, while gas imports will account for 13% in 2010 and rise to 32% in 2020 (Bolton, 2010). Developing renewable technologies will allow the UK to reduce their dependence on foreign supply. By reducing the dependence on foreign imports, the UK governments can also use renewable technology as a catalyst for job creation; an increased dependency on renewable rather than imports would see increased investment into technological development and innovation within the UK.

The UK government demonstrated a commitment to addressing emissions reductions when they passed *The Climate Change Act* into law in 2008. Transitioning to a low carbon economy and establishing the UK as a world leader in GHG emissions reductions are the two main aims of the act. To demonstrate this leadership, the UK government has outlined an ambitious reduction target of at least 34% by 2020 and at least 80% by 2050, against 1990 levels. While the UK's Climate Change Act set out total reductions for the country as whole, policy framework specific to electricity production came from the European Union (EU) Directive 2009/28/EC. The 2009 directive amends and repeals the original 2001 EU Directive on Electricity Production from Renewable Energy Sources (2001/77/EC), which outlined 2010 targets for the original 15 member states. The 2009 directive establishes individual national targets for member states, which collectively, will equate to a total of at least 20% renewable energy generation across Europe as a whole by the year 2020. The goal set forth for the UK government is 15% renewable generation by 2020.

Following on from the 2001 EU Directive, the UK government passed the *Renewables Obligation Order* into force on April 1st 2002. An obligation order is passed each year detailing the mandatory level of renewable generation (obligation) and setting the buy-out price for that particular year. By reviewing the RO every year, the government is able to review current conditions and update the level of obligation on an annual basis. For example, the past three Obligations Orders have seen significant changes made to the RO; in 2009 ROC banding was introduced and in 2010 the Feed-in Tariff (FiT) scheme was introduced as the main mechanism for supporting small scale electricity generators. The introduction of the FiT in 2010 is important because it has made microgeneration ineligible for RO support in England, Wales and Scotland (Ofgem, 2011).

Prior to 2009, renewable generation under the RO favoured cheaper and more mature technologies. As there were no restrictions on the amount of renewable generation from each specific source and ROCs were issued solely on a generation per MWh basis, technologies such as onshore wind were heavily favoured, while riskier and less developed technologies were largely ignored. As a result, technology banding was introduced in April 2009 in order to allow the RO to target specific renewable technologies for support. The banding is fixed until 2013 in order to provide stability for generators who invest in the more expensive and less developed forms of generation. ROCs would no longer be issued on a per MWh basis; the banding outlined in the 2009 order also sets the amount of MWh required per technology in order to generate a single ROC. Table 1 outlines the eligible technologies under the RO and their respective ROCs per MWh of generation.

The obligation period under the RO runs from April 1st until March 31st the following year. ROCs are issued to electricity generators in proportion to the amount of renewable generation and the technology used. The incentive for generators to invest in renewable technologies is the extra revenue stream that the ROCs present. Generators are able to sell their ROCs to suppliers, providing them with additional income on top of the sale of electricity at wholesale prices.

At the end of the obligation period, electricity suppliers are required to present the required level of ROCs to the regulator, OfGem, in order to show their compliance with the obligation. OfGem calculates the level of obligation on a per-period (year) basis using the following formula:

Supplier obligation (ROCs) = *total electricity supplied (MWh) * amount of RO (ROCs/MWh)*

For example, the DECC calculates[1] that in order to meet their obligations in the 2012/13 period, suppliers will require 0.158 ROCs for every MWh they supply. This means total UK renewable supply should be 15.8% of all electricity generation. If a supplier's total electricity supply is 900 MWh, their Obligation would equal 142 ROCs (900*0.158 = 142.2). If the supplier fails to provide OfGem with the requisite number of ROCs, they must pay a penalty in the form of the buy-out price for every MWh they are below the obligation. The buy-out price for the 2012/13 period is £40.71. The buy-out payments made are put into a buy-out fund which is redistributed amongst the suppliers who presented ROCs at the end of the period. The amount of money received by each supplier is directly related to the number of ROCs they presented.

The RO is a unique market mechanism, due to the arbitrage relationship that exists for suppliers between the ROC price and the buy-out price. Unlike other quota schemes targeted at emissions control, the buy-out price is not a ceiling price. For example, in the European Union's Emissions Trading Scheme (EU ETS), firms can simply choose not comply and just pay the fee for non-compliance for the amount of CO_2 emitted. In this case, the EU ETS permit price will not go above the fee for non-compliance.

In the RO, a firm could choose "not to comply" (i.e., not hold ROCs to meet their obligation) and simply pay the buy-price to comply. However, by doing so suppliers would miss out on the recycled income from the buy-out fund; a fund which redistributed £ 357,619,738 for the 2010/2011 period (DECC, 2012). In this respect, the buy-out price is no longer the ceiling price for ROCs as each ROC holder receives their share of the buy-out fund. The ceiling price for a ROC is the buy-out price and the share of the buy-out fund. Since holding a ROC and paying the buy-out price achieves compliance with the RO, suppliers will arbitrage between the two options. This implies that the ROC price should be equal to the buy-out price plus the expected share of the buy-out fund. The expected share of the buy-out fund depends on how short of the RO the suppliers will be in total. For example, if suppliers can only generate 50% of the RO, the share of the buy-out should be larger than if suppliers can generate 90% of the RO because fewer suppliers will pay the buy-out price. Figure 1 shows the ROC price and the difference between the ROC price and the buy-out price over the sample period.

Zhou (2012) argues that the recycled buy-out payment provides information to policymakers about the stringency of the RO. As long as ROC prices trade above the buy-out price, there is a shortfall in

[1] http://www.decc.gov.uk/assets/decc/11/meeting-energy-demand/renewable-energy/2884-calc-level-of-renewables-obligation-12-13.pdf

renewable generation. As ROC prices get closer to the buy-out price, it implies that the level of renewable generation is close to the RO level. While Mitchell et. al. (2006) argue that the price uncertainty of ROC prices reduce the incentives to install renewables (relative to a fixed price subsidy), Zhou (2012) shows that with the recycling of buy-out fund a large fraction of renewable investments are unaffected by the price uncertainty.

Method

As the difference between the ROC price and buy-out price should be related to the expected ratio of renewable generation to all generation, this analysis will utilize factors which influence the percentage of renewable generation to describe the difference between the ROC price and buy-out price. A time series regression is utilized to correlate the factors that drive the percentage of renewable generation with the ROC Buyout differential. The model specification is:

$$Diff_t = \alpha + \beta_1 Diff_{t-1} + \beta_2 NGP_t + \beta_3 Banding_t + \beta_4 MinTemp_t + \varepsilon_t$$

Where $Diff_t$ is the difference between the ROC price and the buyout price, *t* is time in quarters, NGP is the natural gas price, Banding is a dummy variable equal to one when the differential banding went into effect and zero otherwise, MinTemp is the minimum temperature in the UK, and ε is an error term. Other variables which might be expected to impact the percentage of renewable generation, such as the level of sunshine and the average wind speed, were also used in a regression. However, they were not statistically significant and their removal does not alter the coefficients or statistical significance of the remaining variables. Unit root tests were performed on the variables used in the analysis to ensure that spurious results are not found. Results, available by request, reveal that spurious regressions are not a concern.

The government regulator Ofgem and eROC are the main data sources for this analysis of ROC to buyout price differential as a determinant of expected renewable electricity generation. The data on current and historical buyout prices was obtained from Ofgem. As they are regulatory body overseeing the RO, they update the buyout price annually in accordance with changes in the retail price index. The press release detailing the coming year's buyout price is released by Ofgem in February. Data detailing the current and historical prices of the ROCs themselves was obtained from eROC, the online service used for selling ROCs in the market. eROC is operated by the Non-Fossil Purchasing Agency (NFPA) and runs monthly auctions for the sale of ROCs. They provide monthly data on ROC prices and the number of ROCs sold, dating back to October 2002. The data from these two sources was used to map the ROC to buyout differential for our analysis.

Data on the variables that drive renewable generation was obtained from the MET office. Weather variables that would have the highest impact on renewable generation were identified; average wind speed, deviation from the average wind speed, solar radiation, minimum temperature and rainfall. Data was taken from the Met Office's Historic Data to correspond with time period of the ROC to buyout differential data. The final variable considered to be a driver of renewable generation in this analysis was the price of natural gas. The Department of Energy & Climate Change provides data on the historical price of natural gas.

Results

Table 2 shows the regression results using both a Huber-White standard error correction in Column 1 and a Newey-West standard error correction in Column 2. The model has good explanatory power with a R^2 of 0.65. Current time period ROC differentials are positively correlated with the first lag of ROC differentials. This implies that last periods change in ROC differential will be predictive in the current periods ROC differential. Lags of two, three, and four were each regressed in conjunction with a one period lag however the higher order lags were always not statistically different than zero.

The introduction of technology banding had no statistical impact of the ROC differential at the 10% significance level with Huber-white standard errors. However, technology banding is close to statistical significance (it is significant at the 12% level). Banding is statistically significant at the 10% level with Newey-West standard errors. The negative sign would imply that the switch to banding of technologies has reduced the difference in ROC and buy-out prices, implying less demand from firms to buy-out for compliance. Natural gas prices are not statistically significant in Table 2 and all robustness checks.

The weather variable that is statistically significant is the minimum temperature, which can be thought of as a proxy for electricity use. When the temperature is lower, more heating is needed and thus more electricity demand, this is supported by figures from the DECC (2012) showing that space heating accounted for 60% of total domestic energy consumption in 2011. Given that most supply response comes from non-renewables (gas, oil, and coal), a lower minimum temperature implies that the percentage generation from renewables falls. This is due to more production, relatively, from non-renewables. The reduced ratio of renewables to total generation use leads more suppliers to be deficient in their ROC supply and, thus, more buyouts. This leads to a higher amount in the buyout fund and a greater payoff to suppliers holding ROCs. The statistically significant result for minimum temperature is found in all robustness checks.

Other variables which were tested but found to be statistically insignificant are the average wind speed, deviation from the average wind speed, solar radiation and rainfall. All of these variables are never statistically significant and their inclusion does not alter the statistical significance of minimum temperature.[2]

A number of regression diagnostic tests were undertaken to ensure the model is properly specified. The results discussed below are for the Huber-White correction but the results are equivalent when run with a Newey-West correction. First, the dependent variable is run in first differences on the model and the results are identical in sign and statistical significance to those in Table 2. The Portmanteau White Noise test fails to reject the null hypothesis of no autocorrelation in the residuals. Further, Figure 2 shows the autocorrelation of the residuals which do not violate the moving average 95% confidence interval bands. Finally, Figure 3 shows that the residuals fail to deviate from the bounds of the cumulative periodogram white noise test. These test imply that the information not accounted for in the analysis are behaving randomly.

Conclusion

Guided, initially by EU directives, the UK government has committed to the transition to a low carbon economy by passing legislation encouraging the spread of large scale renewable generation technologies. Increased renewable electricity generation is a key factor in this transition and should allow the UK to achieve not only their emissions reductions targets, but also their goal of becoming a world leader in GHG emissions reductions. To this end, the UK government have (through the RO) initiated a market instrument that is continually developing to ensure that renewable generation technologies are being implemented at the least cost to consumers.

Firms can comply with the RO by generating electricity with renewables (for which ROCs are issued), purchasing ROCs from another entity or payment of a fixed ‘buy-out’ price. This compliance flexibility presents an arbitrage relationship between the price of ROCs and the buy-out price. A unique aspect of the RO is that the buy-out fund is recycled and redistributed amongst firms who hold ROCs. In the market equilibrium, the price of a ROC should equal the buy-out price plus the expected share of the buy-out fund. The share of the buy-out fund for each ROC holder is

[2] Results of alternative specifications are available by request.

dependent on the ratio of renewable electricity generation to total electricity generation in the market.

This analysis tests which variables may influence the ratio of renewable generation to total generation, as these variables should determine the size of the buy-out fund. A regression analysis finds that the minimum temperature is correlated with the ROC buy-out price differential. Minimum temperature alters the ROC buy-out price differential due to an increase in electricity demand, which is generally met with fossil fuels given renewables intermittency. Correlation with other variables (such as wind speed, natural gas price, and rainfall) was not found. These results suggest that firms concerned with ROC price volatility should consider weather derivatives as a way to hedge this volatility.

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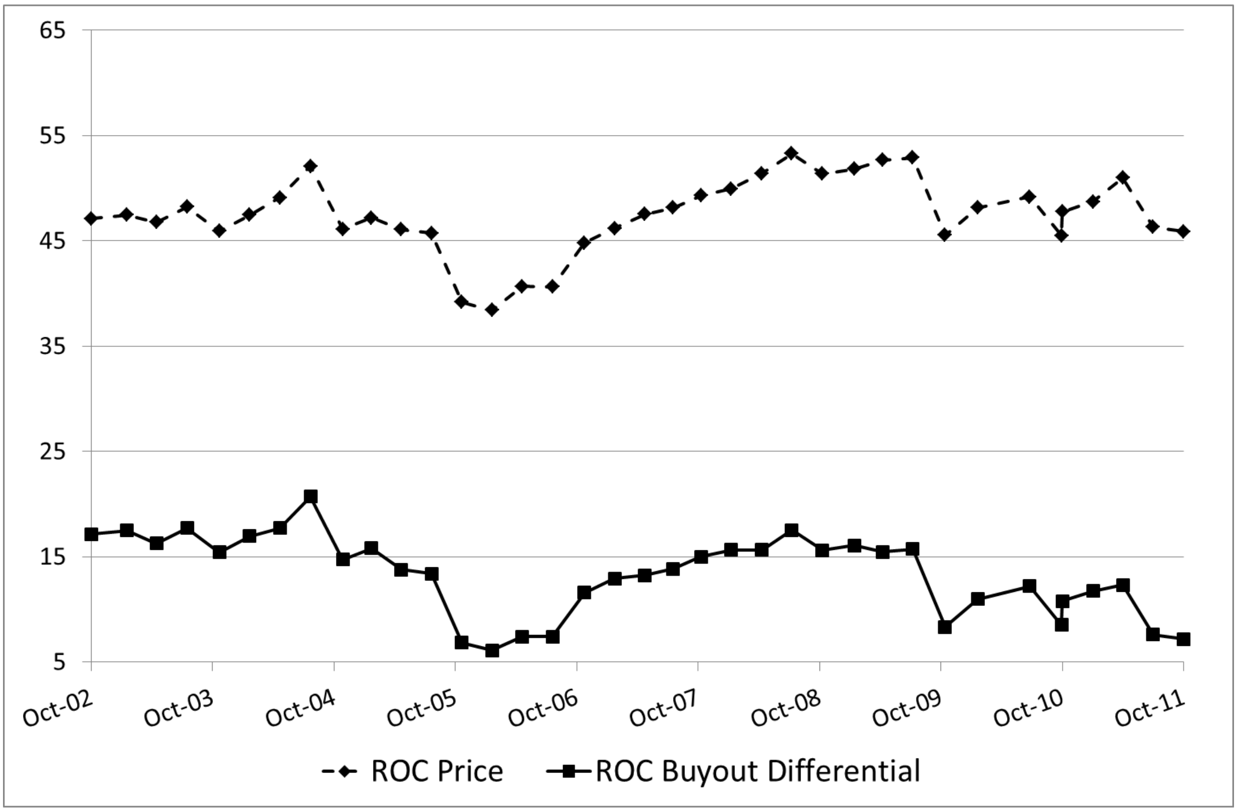
Table 1: Eligible RO Technologies and their ROC per MWh

Technology	ROCs per MWh
Hydro-Electric	1
Onshore Wind	1
Offshore wind	2
Wave	2
Tidal Stream	2
Tidal Impoundment – Tidal Barrage	2
Tidal Impoundment – Tidal Lagoon	2
Solar Photovoltaic	2
Geothermal	2
Geopressure	1
Landfill gas	0.25
Sewage gas	0.5
Energy from Waste with CHP	1
Gasification/ Pyrolysis	2
Anaerobic Digestion	2
Co-firing of Biomass	0.5
Co-firing of Energy Crops	1
Co-firing of Biomass with CHP	1
Co-firing of Energy Crop with CHP	1.5
Dedicated Biomass	1.5
Dedicated Energy Crops	2
Dedicated Biomass with CHP	2
Dedicated Energy Crops with CHP	2

Source: Dr. Ares, the Renewables Obligation, House of Commons Library, 9th August 2012

Figure 1: ROC Price and Differential between ROC Price and Buy-out Price



Notes: Authors Calculation based on E-ROC price and OFGEM's buy-out price. The buy-out price changes once a year in April.

Table 2: Regression Results

Dependent Variable: ROC Price - Buyout Price				
Model	OLS w/ Huber-White S.E.		OLS w/ Newey-West S.E.	
Variable	Coefficient	S.E.	Coefficient	S.E.
Lag ROC Buyout Differential	0.74***	0.12	0.74***	0.14
Natural Gas Price	0.45	0.76	0.45	0.62
Banding Dummy	-1.61	0.98	-1.61*	0.83
Minimum Temperature	-0.31**	0.13	-0.32**	0.13
Observations	35		35	
Portmanteau White Noise P-Value	0.42		0.42	
R-squared	0.65			

Notes: *, **, *** indicates 10%, 5%, and 1% significance, respectively, against a null of no effect. Portmanteau null hypothesis is that there is no autocorrelation among the residuals.

Figure 2: Autocorrelation of Residuals

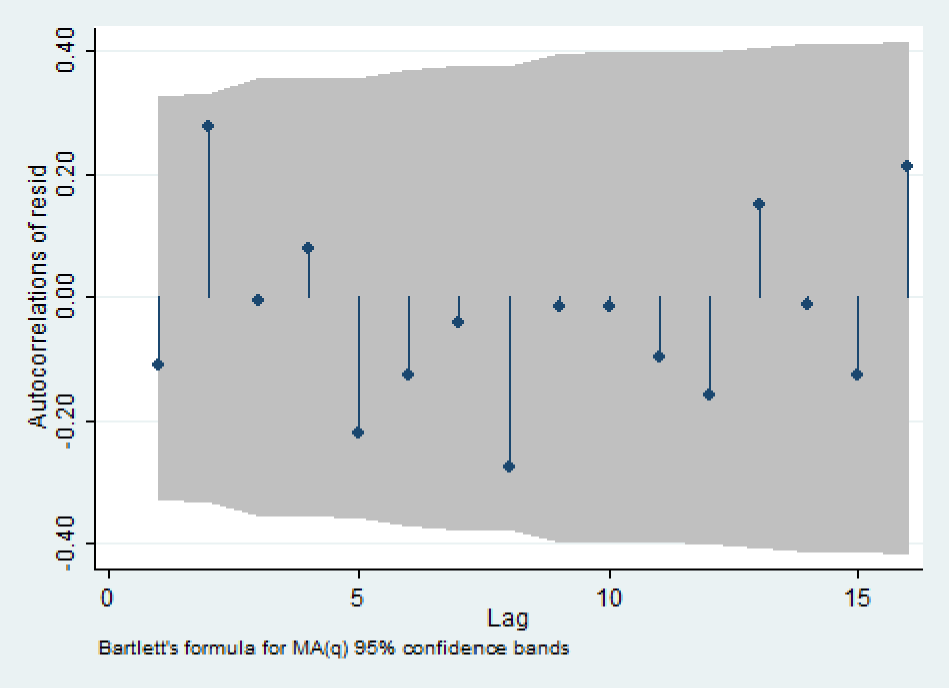


Figure 3: Cumulative Periodogram White Noise Test