The impact of interest rate uncertainty on renewable energy investments: Compared with conventional energy investments

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Abstract. In contrast to other types of energy investments, governments often use long-term power purchase agreements (PPAs), subsidy policies, etc., to lock in returns on renewable energy investments. To some extent, these initiatives ensure that renewable energy investment has a fixed future cash flow. The public's demand for an increase in the proportion of renewable energy also forces the government to maintain an annual investment in renewable energy. However, it remains uncertain whether people's willingness to invest would not be severely affected, and whether renewable energy investment volumes are uniquely robust in the face of financial uncertainty. In this paper, linear regression method is used to analyse the impact of short-term interest rate uncertainty on renewable/conventional energy investment, and covariance analysis is used to test whether these impacts are significantly different. The data indicate that short-term interest rate uncertainty has a significant negative impact. Investment in both types of energy shrinks rapidly in the face of high interest rate uncertainty. No obvious stability is found on renewable energy investment volume in the face of short-term interest rate uncertainty.

Keywords: Interest Rate Uncertainty; Renewable Energy Investment; Covariance Analysis

1. Introduction

As global CO_2 emissions surge, climate change continues to intensity [1]. There is a broad consensus on the need to build a low-carbon society. Among them, an increase in the proportion of RE is an important goal [2]. However, economic and technological constraints have greatly hindered the promotion of RE [3]. Today, governments often use policy instruments such as RE subsidies, long-term power purchase agreements, and diversified financing sources (e.g., green bonds) to increase the total investment.

However, even if the demand for growth in RE is constant, the volume of investment in it is not increasing every year. Many considerations for investment by governments or other invests, subject to factors such as volatile market conditions, exists. This paper attempts to measure the impediments to RE expansion under highly uncertain market conditions. The relationship between short-term interest rate uncertainty and total RE investment was analysed by regression. In addition, using ANOVA, it focuses on whether RE investment is uniquely immune to short-term interest rate uncertainty by comparing the impact on RE and conventional energy investment.

The main contribution of this paper is to demonstrate that short-term interest rate uncertainty has a similar negative effect on total energy investments of any type, i.e., energy investments are sensitive to

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interest rate uncertainty. And no significant differences were found between RE investments and conventional energy investments, even in the presence of many policy aids.

A brief descriptive review of the relevant literature is given in part II. The research methodology and data are shown in part III. Part IV gives the exposure of energy investment to short-term interest rate uncertainty and attempts to explain. Part V gives policy recommendations.

2. Theoretical Background

Literature studies related to this topic fall into two categories: the quantification of interest rate uncertainty, and the exposure of RE investments to market uncertainty.

The process of quantifying uncertainty in interest rates has been approached in a number of ways, among which the following are common: the disagreement among forecasters, the average variance of individual forecast errors, and the variance of the surveys' aggregate probability distribution. Disagreement among forecasters is a common proxy for uncertainty [4][5]. However, as Polzin et al. [6] argues, this incorrectly assumes that "the average dispersion of intra-personal predictive probabilities held by individual experts (i.e., the average uncertainty in the market)" can be directly replaced by "the degree of disagreement between people's predictions (i.e., the average disagreement between people)". Lahari and Sheng et al. [7] argue that disagreement in point estimates between forecasts is not equal to forecast uncertainty. Therefore, following Istrefi and Mouabbi [8], this paper attempts to adopt the combined quantitative approach used in their study.

High interest rate uncertainty has been shown to be harmful to the overall market environment [8]. This may come from the investor panic it brings as well as liquidity depletion. Wang et al. [9] also argued that green finance is vulnerable, especially in the face of financial uncertainty. Godwin and Oktay's [10] study also proved that there is a significant positive correlation between interest rate uncertainty on the volatility of investment. High interest rate uncertainty may distort the market mechanism for raising long-term capital. Thus, the negative impact of interest rate uncertainty on energy, a long-term investment, is to be expected.

3. Methods and Data

The negative impact of interest rate uncertainty on investment is easy to understand. However, the consistency of its impact on energy investment and on RE investment needs to be further explored. This paper first analyses the impact of short-term interest rate uncertainty on renewable and other conventional energy sources by linear regression:

$$y_i = \alpha + \beta x_i + \epsilon \tag{1}$$

where

y_i: the total investment of year i

x_i: the interest rate uncertainty of year i

and the least squares method is used to find α and β in equation (1). Afterwards, analysis of variance is applied to test whether two regression lines are significantly different (after adjusting for the effects of size).

This paper adopts a comprehensive quantification of interest rate uncertainty as mentioned in Istrefi and Mouabbi [8]. That is, uncertainty is considered to consist of the disagreements between forecasters and the perceived variability of future aggregate shocks. denoted as:

$$U_t^x(h) = D_t^x(h) + V_t^x(h) \tag{2}$$

where

$U_t^x(h)$: the h-period ahead subjective uncertainty in the variable uncertainty x_t

$D_t^x(h)$: the disagreements between forecasters, calculated from data given by Consensus Economics

$V_t^x(h)$: the perceived variability of future aggregate shocks, estimated using a standard stochastic volatility model.

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This paper is based on the short-term yield uncertainty indicators it gives for the US, Japan, UK, Germany, France, Italy, Spain, Sweden and Canada over the period 2000-2015. It is used as a dependent variable to perform the regression analysis, i.e., the x_i data in equation (1).

In addition, the database of the International Renewable Energy Agency (IRENE) gives information on all project investments in renewable/non-renewable energy sources in each country from 2000 onwards, including: year of investment, whether renewable, country of project assistance, date of the project (roughly), and size of the project in US dollar terms. Data on annual RE investments and conventional energy investments in the corresponding countries are categorized and calculated as dependent variables, i.e., the y_i data in equation (1).

4. Empirical analysis and discussion

4.1. Data processing

Plot Figure 1 based on the data:

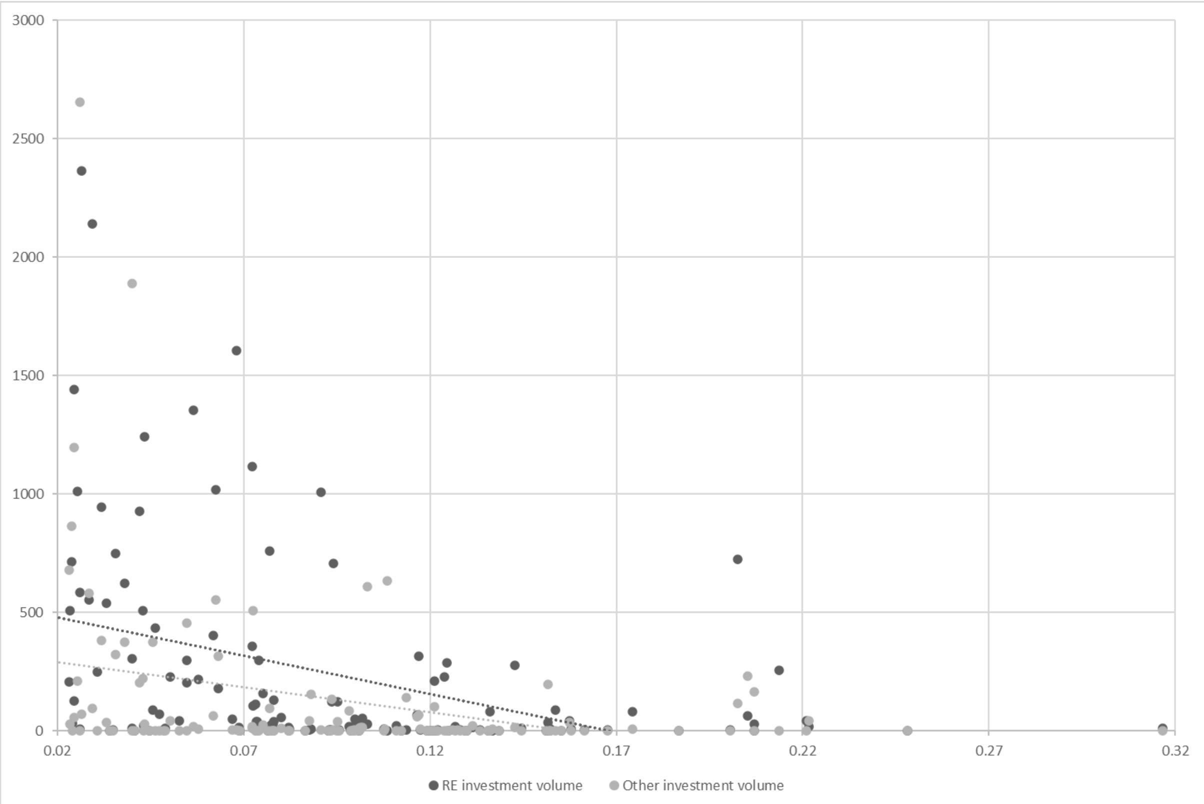

Figure 1. Interest Rate Uncertainty – RE / Other Energy Investment Volume.

Tables 1-4 provide the regression statistics:

Table 1. ANOVA table of Interest Rate Uncertainty – RE Investment Volume regression.

	DF	SS	MS	F
Regression	1	4485816.46	4485816.46	28.09
Residual	142	22675155.57	159684.19	
Total	143	27160972.03		

Table 2. Coefficients of Interest Rate Uncertainty – RE Investment Volume regression.

	Coefficients	Standard Error	p-value
Intercept	543.52	66.96	2.07E-13
IR Uncertainty	-3238.54	611.02	4.32E-07

Table 3. ANOVA table of Interest Rate Uncertainty – Other Energy Investment Volume regression.

	DF	SS	MS	F
Regression	1	1911818.75	1911818.75	17.36
Residual	142	15636964.20	110119.47	
Total	143	17548782.95		

Table 4. Coefficients of Interest Rate Uncertainty – Other Energy Investment Volume regression.

	Coefficients	Standard Error	p-value
Intercept	331.78	55.61	1.84E-08
IR Uncertainty	-2117.22	507.41	5.34E-05

In both cases, the coefficients on the interest rate uncertainty are negative and the corresponding P-values are less than 0.001, i.e., there is very strong evidence that short-term interest rate uncertainty has a negative impact on the volume of investment in both, as expected. Then, analyse whether interest rate uncertainty has a smaller effect on RE. To exclude the effect of the size factor, the data are first normalized and plotted in Figure 2.

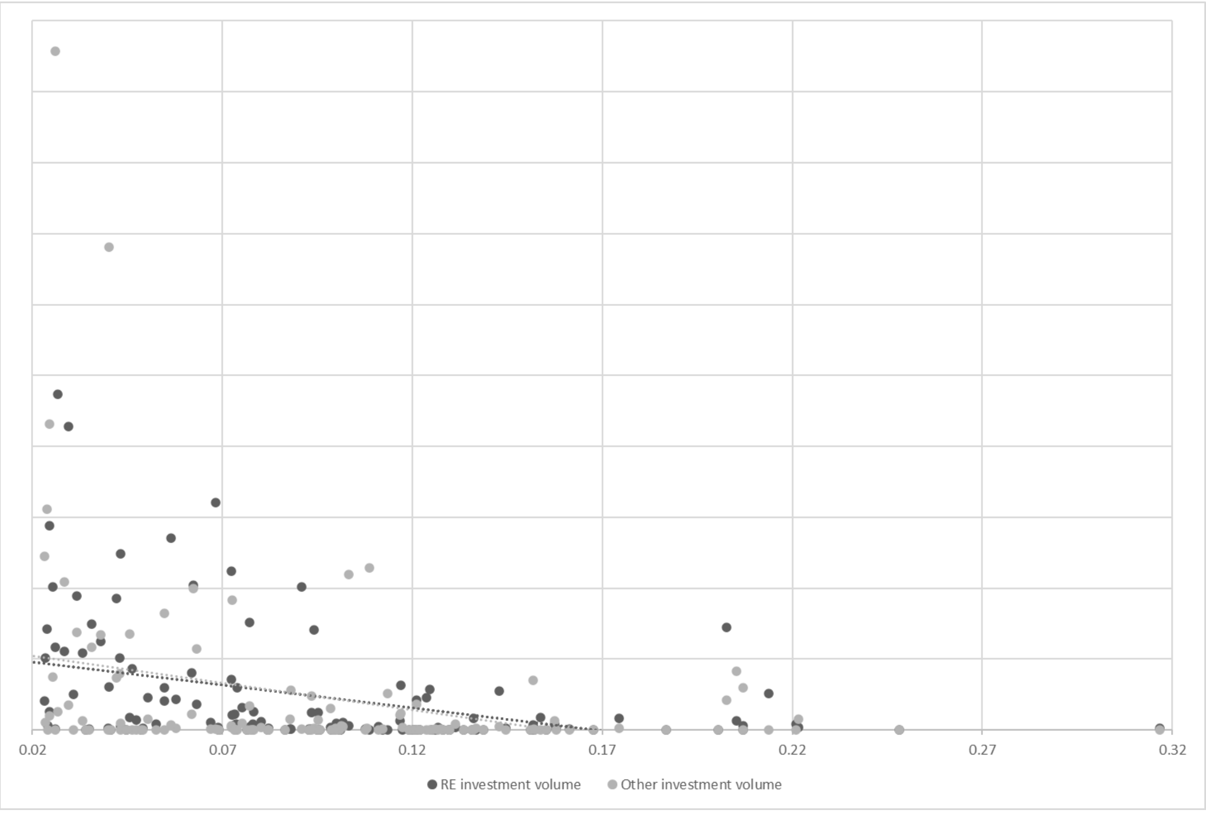

Figure 2. Scale-Standardized Interest Rate Uncertainty – RE / Other Energy Investment Volume.

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After normalizing for size, ANOVA can be used. The data are split into two groups based on energy type. RE investment is Group I and other energy investment is Group II. The covariance analysis was carried out, and the results are shown in Table 5.

Table 5. Tests for between-subjects effects

Source	Class I SS	DF	MS	F	p
Revised model	10692101.139	3	3564033.713	13.783	0.000
Intercept	15985266.878	1	15985266.878	61.819	0.000
X	10622437.018	1	10622437.018	41.080	0.000
Group	0.002	1	0.002	0.000	1.000
Group * X	69664.119	1	69664.119	0.269	0.604
Error	73437029.200	284	258581.089		
Total	100114397.216	288			

R-square = 0.127 (adjusted R-square = 0.118)

As shown in Table 5, the effect of groups on X has a p-value of 0.604 > 50%, which means there is no evidence against that two groups have different effects.

The test concluded that the impact of interest rate uncertainty on the amount of investment in RE and other energy sources is not significantly different. That is, in the face of high interest rate uncertainty, investment in RE does not have a significant advantage over investment in other energy sources.

4.2. Discussion

According to the regression analysis, it is predictable that high interest rate uncertainty has a negative impact on energy-based investments. As the study carried out by Wang et al. [9], uncertainty in finance has a significant negative impact on green investments. Firstly, in the face of increased uncertainty, investors need to consider the possibility of a potential increase in financing costs when making decisions. Banks and financial institutions may also opt for higher lending rates and stricter financing conditions under this condition. The attractiveness of the project will also be reduced in the case of high interest rates. The resulting increase in overall project risk is something that investors do not want to see.

Moreover, high interest rate uncertainty even has a huge impact on the overall market environment [8], and in the face of possible extremes, deteriorating market conditions force firms to increase their liquidity and thus reduce the amount of their investments. Cuts in capital exports can bring about a contraction in overall investment, and energy investments are not immune to this.

In terms of investor psychology, the acceptance of high uncertainty information by investors often leads to procrastination and wait-and-see in order to wait for further information and greater clarity of the environment in which to make decisions [11]. The delay it causes may dampen investment intentions in the short term.

Unexpectedly, however, while some articles argue that signing long-term power purchase agreements reduces a certain degree of risk for RE investments by locking in a portion of the return [12], increasing the immunity to short-term interest rate uncertainty. The government subsidies and incentives that have been put in place so far have also increased their solidity to some extent nature [6]. These actions on RE still fail to significantly differentiate itself from conventional energy investments in the data analysis. This paper attempts the following explanation:

Kabel and Bassim state that storage of energy is more difficult due to current technological limitations [3]. Therefore, variable RE sources (e.g., fluctuating supply of solar and wind energy) can only be supplied when there is sufficient sunshine or wind, which is one of the reasons why RE sources are unable to fully replace conventional energy sources. To meet a stable energy supply, governments prefer to make necessary conventional energy investments rather than RE investments under complex market conditions of high interest rate uncertainty. Thus, the non-essential nature of RE makes investment more vulnerable to interest rate uncertainty.

High interest rate uncertainty reflects political uncertainty in the short run to some extent. Farooq and Ahmed argue that the presidential elections in the United States have become a source of serious uncertainty, leading to significant movements in dividend payout ratios at the national level [13]. Cyclical elections bring about policy instability and investors are unable to anticipate the policy winds of the government in the future. At this point, RE investments that rely on government subsidies are unattractive. Investors may favour short-term investments and reject RE investments that span several election cycles.

Mathews et al. suggests that private market and investment participation is of high importance in RE investments [14]. Bergek et al. analyses the categories of RE investors in Sweden and concludes that a large part of RE investments are made up of emerging investors, with Independent Energy Providers and self-employed individuals investing in around 50 percent of RE plants [15]. This group of investors may be more concerned with the availability of resources and the ability to raise finance, whereas long-term power purchase agreements and government subsidies do not guarantee investors' interests on the finance side in the face of high interest rate uncertainty. This decision-making factor may account for a higher proportion of the stability of RE investments.

5. Conclusion

This paper uses short-term interest rate uncertainty and standardized renewable/other energy investment data to demonstrate that interest rate uncertainty has a negative impact on the volume of investment in both. RE investment, however, does not show a particular tolerance to short-term interest rate uncertainty, given a number of possible factors. As in the case of conventional energy sources, investment shrinks rapidly under the influence of high uncertainty.

In a market environment of high uncertainty, governments and investors should anticipate a possible contraction of energy investments and RE investments will receive similar impacts. Polzin F., et al. argues that policy tools available to governments include economic and financial incentives, such as feed-in tariffs (FITs), especially for less mature technologies [6]. These policy measures can directly affect the risk and reward structure of RE projects, perhaps reducing the contraction of RE investments in extreme cases. Similarly, economic policies to ensure the stability of financing under conditions of high uncertainty in order to secure the interests of investors might also reduce the impact of uncertainty on RE investment.

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