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Swedish-Norwegian tradable green certificates: Scheme design flaws and perceived investment barriers

Kristin Linnerud[a,*], Morten Simonsen[b]

[a] CICERO Center for International Climate and Environmental Research – Oslo, NO–0318 Oslo, Norway
[b] Western Norway University of Applied Sciences, 6851 Sogndal, Norway

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ABSTRACT

The EU Commission recommends using market-based support schemes for renewable-electricity projects. One example is the Swedish-Norwegian tradable green certificate scheme. We examine whether design features in the Norwegian part of this scheme, specifically, the scheme's short duration and the way it is to be abruptly terminated, contribute to investors' perceptions of barriers. We apply econometric techniques on primary data collected in two surveys of Norwegian investors in hydropower, and we use real options theory to predict and interpret investors' responses. We show that: (1) immediately after the scheme was introduced, investors are eager to lock in future subsidies by investing immediately and concerned with factors that may delay the completion of their projects; (2) as the certificate deadline neared, investors have become increasingly pessimistic and concerned with economic and risk barriers. Investors in big hydropower plants with regulation reservoirs are particularly concerned with the risk of not completing their projects in time to gain the right to sell certificates. These findings are consistent with the predicted responses to the scheme design derived from real options theory. In contrast to earlier studies, we find no difference in responses to the scheme design across investor types.

1. Introduction

The Swedish-Norwegian tradable green certificate scheme is designed to achieve a given increase in annual renewable-electricity production capacity at the least cost to society and to provide incentives to producers to respond to market developments. Thus, the scheme satisfies many of the requirements in the European Commission guidance for renewable energy support schemes (Commission, 2013). It is also the first example of the use of cooperation mechanisms opened up by the EU in Directive 2009/28/EC on promoting use of energy from renewable sources (Directive, 2009).

We examine whether specific design features in the Norwegian part of the scheme contribute to or reinforce investors' perceptions of barriers, and thus may reduce the cost efficiency of the Swedish-Norwegian joint support scheme. We apply econometric techniques on primary data collected in two surveys of Norwegian investors in hydropower, and we use real options theory to predict and interpret investors' responses.

The Norwegian part of the certificate scheme is regulated by the Law on electricity certificates and a later amendment of this law (Stortinget, 2011, 2015). The scheme gives the producers of new (i.e., the added production under the scheme), renewable electricity the same support per MWh delivered on the electricity grid irrespective of which technology is used and regardless of whether the plant is located in Norway or Sweden or whether the additional production comes from a new plant or from updating and expanding an existing plant. Thus, the scheme contributes to short-term cost-efficiency. In the long run, it is of course an empirical question whether a technology-specific or a technology-neutral support scheme will be most efficient in minimising the production costs of electricity.

Moreover, the scheme is market-based. Most importantly, electricity is sold in the wholesale market for electricity. Thus, investors are exposed to changes in demand and supply conditions. This will influence decisions on which technology to choose, where to locate plants and when to produce, which is expected to contribute to a well-functioning electricity market. For example, investing in a hydropower plant with a costly regulation reservoir may be justified by the added project value that results from being flexible enough to adjust production to changes in electricity prices. In addition, with this scheme, certificates are sold in a market. Producers of new, renewable electricity have for 15 years the right to sell one certificate per MWh delivered on the electricity grid. Sellers of electricity to end consumers must buy a

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[*] Corresponding author.
E-mail addresses: kristin.linnerud@cicero.oslo.no (K. Linnerud), morten.simonsen@hvl.no (M. Simonsen).

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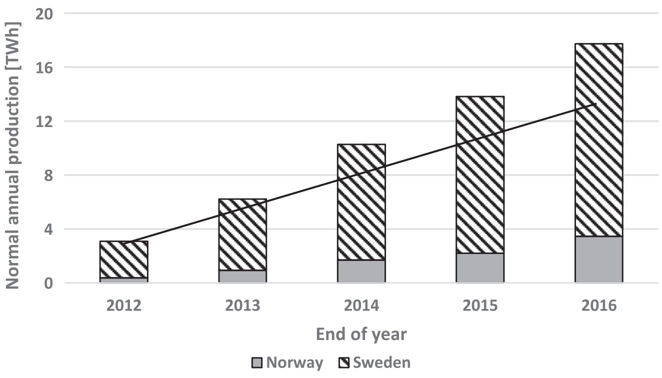

Fig. 1. Normal annual production for plants that are included in the joint green certificate target (TWh). The line illustrates a linear development towards the joint target of 28,4 TWh at the end of 2020.

fraction of a certificate, often referred to as a quota, for each MWh of electricity they sell. To balance supply of and demand for certificates, the sum of the electricity and certificate prices must at least equal the long-run marginal cost of the last producer to enter the market (Jensen and Skytte, 2002).

Finally, the scheme is quantity-driven. That is, the Swedish and Norwegian governments have determined national annual quotas. These quotas will increase through 2020 when the joint target is supposed to be met; thereafter, the quotas decline through 2035, when the last certificate is scheduled to be sold. To reach the Swedish-Norwegian target of additional 28.4 TWh annual production by the end of 2020, each country is obligated to adjust its annual quotas to accommodate changes in the forecasted demand for electricity.

In many ways, the Swedish-Norwegian tradable green certificate scheme is a success. Investments have so far increased steadily towards the target of 28.4 TWh additional annual production, and the sum of average electricity and certificate prices was only 312 NOK/MWh or 34 EUR/MWh in 2016 (Figs. 1 and 2). As of 1 January 2017, the scheme had contributed to 17.8 TWh in annual production in a normal year, divided by 10.6 TWh Swedish wind power, 2.8 TWh Swedish bio power, 3.0 TWh Norwegian hydropower, 0.8 TWh Swedish hydropower, 0.4 TWh Norwegian wind power, and 0,1 TWh Swedish solar power (NVE, 2017).

The relatively small share of Norwegian hydropower (17%) is surprising because the expected cost advantage of Norwegian hydropower was one of the reasons the first round of negotiations between Sweden and Norway failed in 2006. According to Gullberg and Bang (2015): "Sweden was concerned that the majority of the investments would be channelled into Norwegian hydropower because these projects were the least costly." In Norway, hydropower projects have prior to the certificate scheme not been subsidised. Moreover, big hydropower plants are subject to a natural resource tax in addition to the corporate tax, similar to oil and natural gas projects. Finally, some of the hydropower plants, particularly those with a total installed capacity above 10 MW, have regulation reservoirs, which gives them the added benefit of production flexibility. Thus, big hydropower plants with regulation reservoirs have historically been more profitable than other comparable renewable-electricity projects. We therefore suspect that some of the potentially most promising projects–large hydropower plants with regulation reservoirs–have not been realised under this scheme.

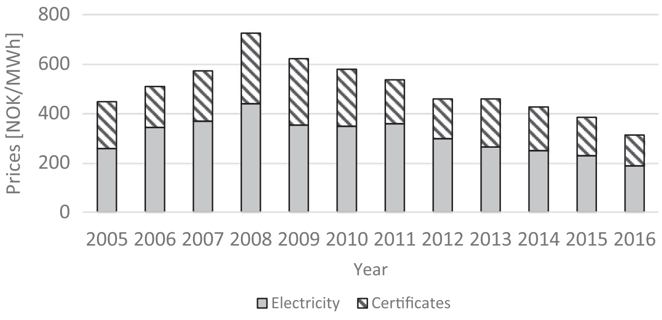

Fig. 2. The sum of electricity and certificate prices in Norwegian kroner. The electricity and certificate prices are annual averages of three-years forward contracts traded at the Nasdaq OMX Commodities (a Nordic power exchange) and by Svensk Kraftmakling (a brokerage firm), respectively.

We examine whether design features in the Norwegian part of the scheme, specifically, the scheme's short duration and the way it is to be abruptly terminated, contribute to or reinforce investors' perceptions of barriers. Sweden had already implemented a national green certificate scheme in 2003, and it was only expanded to include Norway in 2012. Thus, Norwegian investors have at most 9 years to realise a project. Moreover, at the time of the two surveys, Sweden planned to gradually phase out the scheme, whereas Norway planned to end the scheme abruptly. That is, to gain the right to sell certificates, Norwegian investors had to deliver electricity to the electricity grid by the end of 2020. In contrast, Swedish investors completing their projects in 2021–2034 would still be entitled to sell certificates, but the selling period would gradually be reduced from 15 years to 1 year. These differences in scheme design are illustrated in Fig. 3.

We refer to real options theory (Dixit and Pindyck, 1994) to predict how the Norwegian scheme design will affect investor risk over time. These predictions are formulated as two hypotheses. Based on two surveys of Norwegian hydropower investors–one done immediately after the scheme was implemented (2012) and one from three years later (2015)–we examine whether the perceived barriers against and optimism for such projects have changed as predicted by real options theory. According to real options theory, the option to postpone an investment decision has a value when future cash flows are uncertain[1] and investment costs are partly or fully irreversible (Dixit and Pindyck, 1994). In general, the value of waiting increases with project risk and size of irreversible investment cost, as do the revenues required to invest, and therefore the required rate of return.

Our paper contributes to the academic research literature assessing the performance of tradable green certificates and equivalent support schemes, specifically to the studies on how investors respond to scheme design and policy risk. For an extensive review of this literature, see Darmani et al. (2016). However, for the purpose of this paper, we delimit our focus to a selection of recent contributions to real options theory that deal directly with the scheme design features we examine. These contributions, as well as selection of theoretical and empirical studies on investor heterogeneity in the renewable-electricity market, form the basis for our analysis.

In the next section, we describe the theoretical foundation for our analysis and derive hypotheses we will examine. In the third section, we present our survey methods, including the questionnaire, the data collection procedure and the econometric techniques. In the fourth and fifth sections, we present the results of the data analysis and explore their significance. Conclusions are offered in the sixth section.

2. Theory

According to the net present value investment rule, an investor should invest now if the discounted value of future net cash flows,

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[1] The theory does not distinguish between risk and uncertainty. Both concepts refer to a situation where the possible consequences of decision or a process can be completely enumerated, and probabilities assigned to each possibility. In considering the implications of imperfect knowledge of the future, it is often useful to distinguish between risk and uncertainty. This distinction is originally due to Knight (1921) who defined situations involving risk as those where the possible consequences of a decision can be completely enumerated and probabilities can be assigned to each possibility. If this is not possible, we are dealing with uncertainty. This distinction is, however, not followed universally in the economics literature.

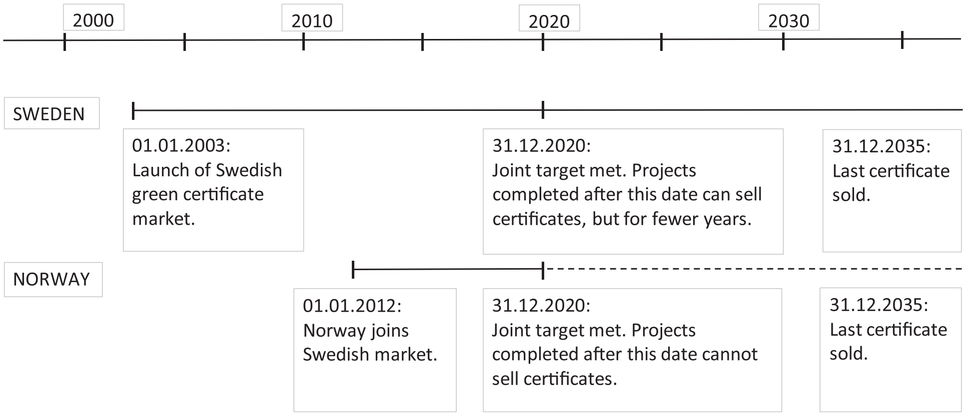

Fig. 3. Timelines for introduction and planned removal of tradable green certificates in Norway and Sweden. The timelines reflect political decisions made at the time of the two surveys.

V, is greater than or equal to the investment cost, I (Brealy et al., 2013):

$$V \geq I. \tag{1}$$

However, assuming that investment expenditures are at least partly irreversible (i.e., sunk cost) and that investments can be delayed, the investor may value the opportunity to wait for new information to arrive about uncertain market, political and technological conditions. Hence, according to the real options investment rule, the investor should invest now only if the discounted value of future net cash flows, V, exceeds the investment cost, I, by a margin sufficient to overcome the expected value of waiting, C (Dixit and Pindyck, 1994):

$$V \geq I + C = V^{*}. \tag{2}$$

Real options theory allows us to explicitly model different sources of uncertainty affecting the project's cash flows. In general, the value of waiting, C, will increase with the uncertainty in project value. Uncertain market, political and technological conditions will therefore raise the threshold project value, V^{*}, and the required rate of return, over and above what is required in the traditional net present value investment rule.

Applied to our case study, Norwegian investors with a license to construct a hydropower plant, should only invest if the sum of the electricity and certificate prices is sufficiently high to make the condition in Eq. (2) hold. If the investment is made, it is more-or-less irreversible, since the plant cannot be resold without losing considerable value. For big hydropower plants with regulation reservoirs, the extent of sunk cost will be high. Moreover, for these projects in particular, plant investment costs, the time period of construction, the quality of equipment and the know-how of the operational personnel all pose high technical risks. Thus, according to real options theory, the value of waiting would normally be higher for big and complex hydropower projects than for small-scale hydropower projects. Consequently, the required rate of return would be higher for such projects.

The prospects of introducing or removing a subsidy or tax may raise or lower the investment threshold, thereby further affecting the value of waiting. Linnerud et al. (2014) and Fleten et al. (2016) examine investments in small-scale hydropower projects prior to the introduction of green certificates in Norway. The results of their statistical analyses show that traditional utilities and other experienced investors in the energy market acted in accordance with a real options investment rule (Eq. (2)), and the prospects of possible future subsidies delayed their investment decision. On the other hand, the result did not show that local landowners and other inexperienced investors incorporated timing considerations in their investment decisions. Rather, these investors behaved as if their investment opportunity was now-or-never and invested if the project was profitable according to the net present value investment rule (Eq. (1)), ignoring the opportunity to create additional value by waiting. Dixit and Pindyck (1994) derive optimal investment rules under the prospect of removing an investment tax credit, and argue (ibid p. 309): "…if a government wishes to accelerate investment, the best thing it can do is to enact a tax credit right away, threaten to remove it soon, and swear never to restore it." Boomsma and Linnerud (2015) use tradable green certificates as an example and illustrate numerically how the prospects of removing the right to sell certificates will affect investment thresholds. Like Dixit and Pindyck (1994), they find that such threats will stimulate investments if investors can lock in the right to sell certificates by investing immediately. However, if investors believe that a future removal will affect new and old installations alike, that is, that the removal will be retroactively applied, then the value of waiting and the investment threshold will increase. They refer to these two effects as the speed-up and slow-down effect of support scheme removal, and they demonstrate that the latter effect is often substantially higher than the former.

We formulate two hypotheses based on real options theory:

(1) **The speed-up effect.** Immediately after the scheme is introduced (i.e., in our case, in the 2012 survey), Norwegian investors will be optimistic and eager to lock in future subsidies. All else equal, they will demand a lower investment threshold than Swedish investors who are only exposed to the risk of gradual removal. With a limited time to scheme termination, Norwegian investors' main concern is whether the widespread optimism will put pressure on limited resources, for example, access to funding, the electricity grid and entrepreneurial services; regulator's handling of applications; and capacity and competence within firms to manage the projects.

(2) **The slow-down effect.** As the certificate deadline nears (i.e., in the 2015 survey), Norwegian investors will become increasingly pessimistic. The speed-up effect will gradually be replaced by the much stronger slow-down effect as the probability increases that projects will not be realised by the 2020 deadline. Moreover, this probability will increase with the complexity, expected construction time and cost of the project. All else equal, Norwegian investors will demand an increasingly higher investment threshold than Swedish investors. As a consequence, Norwegian investors will be relatively more concerned with economic and risk barriers as compared to all other barriers.

The real options investment rule assumes that the neoclassical theory of the firm correctly predicts investors' preferences, characteristics and behavior (e.g. Kantarelis (2007)). This theory assumes that firms have only one objective, maximizing the economic value of the firm, and that they make rational choices based on the same information. These assumptions require, however, that firms, in our case referred to as investors, have the cognitive ability and time to value every choice against every other choice. According to the bounded rationality theory (e.g. Simon (1957) and Kahneman (2011)), people may use more simplified rules because they lack the cognitive ability or time to arrive at the optimal solution. Thus, they may instead be rational only after having greatly simplified the choices available.[2] The net present value investment rule in Eq. (1) is an example of such a rule. It treats risk in a simplified manner because it bases project appraisal on expected cash flows and lets project risks be represented by a single risk-adjusted discount rate. And, more importantly, it is based on the assumption that the investment decision must be made now or never, thereby ignoring the value of optimally timing the investment decision.

As explained above, differences in previous experience did significantly affect actual investments in Norwegian small-scale hydropower projects prior to the implementation of the Swedish-Norwegian tradable green certificate scheme. Local landowners without previous experience in the energy sector seem to have followed the simplified net present value investment rule in Eq. (1) and not the more sophisticated real options investment rule in Eq. (2) (Linnerud et al., 2014). Similarly, Linnerud and Holden (2015) document significant differences in assessments of Norwegian hydropower projects made immediately after the implementation of this support scheme. In Sweden, Bergek et al. (2013) find that investors with no traditional background in electricity production have recently made the majority of renewable-electricity investments. These emerging investors form a heterogenous group including individuals and households, cooperatives, project developers, farmers and companies diversifying from other industries. In a related case study, Mignon and Bergek (2016) examine the influence on investment decisions of formal institutions (e.g., support schemes, regulations, laws and corporate strategies) and of informal institutions (e.g., investors' and external stakeholders' social norms, values and cognitive rules). They find that different investors are affected by different institutional demands, and/or they are affected differently by the same institutional demand. In Belgium, Bauwens (2016) statistically analyse the responses from a survey among cooperative members in renewable-energy cooperatives and conclude that heterogeneous motivations drive individuals to participate, including social norms as well as economic incentives.

We formulate a third hypothesis based on the bounded rationality theory and the above-mentioned findings of investor heterogeneity in the renewable-energy sector:

(3) **The experience effect.** We expect that a new, emerging investor type in Norway–local landowners without previous experience in the energy sector–have responded differently to the risks created by the Norwegian scheme design. Specifically, we expect that inexperienced investors follow the simplified net present value investment rule in Eq. (1). Consequently, we expect these investors to be little affected by factors increasing the value of waiting, like sunk costs and uncertain conditions.

3. Methodology

In this section, we present our survey methods, including the questionnaire, the data collection procedure and the econometric techniques.

3.1. Questionnaire and variables

Based on two surveys among investors, we examine perceived barriers against and optimism for investing in Norwegian hydropower plants within the Swedish-Norwegian market for green certificates. In the questionnaire, we ask the following questions. (1) Which barriers, if any, may prevent your project from being realised by the deadline set by the certificate scheme? (2) How likely or unlikely is it that your project will be realised by the deadline set by the certificate scheme? We use a multinomial logistic regression model to examine the responses to each question, controlling for investor, project and process stage characteristics.

We designed the questionnaire in close cooperation with different types of hydropower investors, energy authorities, energy association representatives and academics in the energy field and with a professional marketing firm who carried out the two surveys for us (HiSF (2013, 2015)). We focussed specifically on selecting questions and response options that could reveal whether investors react to the green certificate scheme design as suggested by the real options approach. In the following sections, we argue for the design of our questionnaire. See Table 1 for an excerpt of the questionnaire and the response options for each question.

3.1.1. Independent variables

We included a set of general and project specific questions on investor, project and process-stage characteristics in the questionnaire (see Table 1, Independent variables). These questions reflect the empirical context of our survey, as outlined below.

3.1.1.1. Experience. Norwegian hydropower plants are typically owned by traditional vertically integrated utility companies owned by a group of municipalities. In addition, the state owns a hydropower production firm called Statkraft. However, since 2000, a political focus on small-scale, decentralised hydropower plants with installed capacities below 10 MW has resulted in new investors entering the market; these new investors are either corporations or local landowners, most without any previous experience with energy projects, who act as sole traders, partnerships or privately owned companies. For most small hydropower projects, the river is fully controlled by a group of local landowners (i.e., farmers). They can choose between two different ways of organising the ownership and operation of the power plant (NVE, 2010): (1) they can form a privately owned company or partnership, which applies for a license, makes investment decisions, obtains funding, takes on investment risks and operates the plant; or (2) they can ask a professional firm to take on these responsibilities and operate the power plant for a fixed number of years, after which the plant is sold back to the landowners at an agreed upon price. The choice of organisational model depends on the characteristics of the project (e.g., profitability, risk and size) and the group of local landowners (e.g., risk preference and access to funding). We included a question on experience to control for possible differences in preferences and characteristics between experienced and inexperienced investors. We were particularly interested in whether the responses to the 2015 questionnaire would confirm earlier findings that experienced investors behave in accordance with real options theory, while inexperienced investors do not (Linnerud et al. (2014), Linnerud and Holden (2015)).

3.1.1.2. Project characteristics. Norway produces approximately 131 TWh electricity annually, 95% of which is generated by hydropower plants (Norwegian Ministry of Petroleum and Energy, 2015). An investor may invest in new hydropower plants or in upgrading and extending existing plants. As of 1 January, the numbers of hydropower plants in various size categories were as follows: 554 micro power plants (installed capacity up to 1 MW), 587 small power plants (installed capacity between 1 and 10 MW) and 335 big power plants (installed capacity over 10 MW) (ibid). Hydropower without storage capacity provide intermittent power. They typically include run-of-river hydropower plants and small-scale power plants. Production from power plants connected to regulation reservoirs is flexible. Multi-year regulation is possible by large regulation reservoirs which can store water in years with heavy precipitation for use in years

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[2] The bounded rationality theory was first proposed by Simon (1957) and is today widely acknowledged because of the seminal work of Amos Tversky and Daniel Kahneman (see e.g. Kahneman (2011)).

Table 1
Excerpt from the 2012 and 2015 questionnaires.

Variable Dependent	**Question**	**Reponse type/categories**[a]
Type of barrier	Which barriers, if any, may prevent your project from being completed by the deadline set by the certificate scheme [select one or more responses]?	Categorical scale. Multiple responses. 1: Too low electricity- and certificate prices; 2: Too high taxes and fees; 3: Too high investment costs; 4: Too high connection fee to the grid; 5: Risk that the project will not be completed within the deadline set by the green certificate scheme; 6: Total project risk (uncertain market, political and technological conditions); 7: Delays related to purchase of services (e.g., entrepreneurial services); 8: Delays related to purchase of components (e.g., turbines); 9: Delays related to access to the electricity grid; 10: Delays caused by opposition from external parties (e.g., government, citizens, businesses, interest groups and the media); 11: Delays due to the licensing process; 12: Do not get the licence to construct the plant; 13: Delays caused by internal factors (e.g., a disagreement between the owners, lack of labor and/or expertise, leadership challenges); 14: Problems with obtaining financing (equity and/or loan); 15: Other barriers; 16: No barrier.
Degree of optimism	How likely or unlikely is it that your project will be completed by the deadline set by the certificate scheme [select only one response]?	Ordinal scale. 1: very unlikely; 2: more unlikely than likely; 3: equally likely; 4: more likely than unlikely; 5: very likely.

Variable Independent	**Question**	**Reponse type/categories**[a]
Experience	Have your organization previous experience with the development or operation of hydropower plants?	Categorical scale. Dichotomous variable. 1=yes and 0=no.
Production	What is the expected annual production volume?	Continous variable. Measurement unit is GW h.
Project type	What kind of project are you considering?	Categorical scale. 1: micro power plant, ≤1 MW (reference); 2: small power plant (1–10 MW); 3: big power plant (≥ 10 MW); 4: upgrading and extension of existing power plant.
Production flexibility	Is it possible to adjust the production volume?[b]	Categorical scale. Dichotomous variable. 1=yes and 0=no.
Investment cost	What is the expected investment cost per annual production volume?	Ordinal scale.[c] 1: 0–1 NOK/kW h; 2: 1–2 NOK/kW h; 3: 2–3 NOK/kW h; 4: 3–4 NOK/kW h; 5: 4–5 NOK/kW h; 6: 5–6 NOK/kW h; 7: ≥6 NOK/kWh.
Elspot price area	In which municipality is your planned project located?	Categorical scale. Elspot area.[d] 1: south-east (reference); 2: south-west; 3: central; 4: north; 5: west.
Process stage	At what stage from planning to implementation is your project?	Categorical scale.[e] 1: preliminary: preliminary planning / notification submitted to authorities (reference); 2: application: application for license submitted to authorities / recommendation made by relevant authority; 3: answer: received a positive and final answer from authorities; 4: contract: made an investment decision / entered into contract with entrepreneur / work in progress

[a] Each question has a response category: do not know. This is not shown in the table.
[b] This question was only included in the 2015 questionnaire.
[c] The exchange rates were 7.5 NOK=1 EUR in July 2012 and 8.9 NOK=1 EUR in January 2015. Source: Norges Bank.
[d] We define a new variable for the five bidding areas in the Norwegian Elspot market based on the municipality numbers.
[e] Seven response categories in the questionnaires are coded into 4.

of light precipitation. Storing water over the summer for use during the winter when demand for power is highest is called seasonal regulation. In addition comes weekly and daily regulation. We included questions on project type, mean annual production, production flexibility and investment costs to control for project characteristics.

3.1.1.3. Elspot price areas. The Norwegian power market was deregulated in 1991. Physical power contracts are traded in the leading power market in Europe, Nord Pool Spot, and financial power contracts as well as green certificates are traded at the world's largest power derivatives exchange, Nasdaq OMX Commodities. The Norwegian part of the Nord Pool Spot market is divided into five geographical price-bidding areas called Elspot price areas, reflecting differences in supply and demand conditions and electricity grid capacities. We included a question on location to control for possible differences in market characteristics between the Elspot price areas.

3.1.1.4. Process stage. To construct a hydropower plant in Norway, an investor must have regulatory approval. For a description of the licensing procedures, see Norwegian Ministry of Petroleum and Energy (2015). Many factors affect the time spent on license processing, for example the conflict level and complexity of the individual project. There is also a distinction in licensing procedure between power plants above 10 MW and power plants below 10 MW. As emphasised by the Norwegian Ministry of Petroleum and Energy (2015, p. 16): “The procedures for small hydropower plants are somewhat simpler than those for large projects, so that they can be processed more quickly.” The time spent on license processing for large and complex hydropower projects will vary a lot, and has been between 3 and 7 years in some recent projects.[3]

After a license is obtained, the licensee must (1) update the cost estimate to reflect any changes in license conditions and the results of any new water-flow measurements; (2) obtain tender offers for turbines, generators, penstock and construction, so that a major part of the total cost is identified; (3) secure project funding and make sales agreements for delivering the power to the electricity transmission grid and revise the investment budget accordingly; (4) acquire the regulatory authority's approval for the detailed plans for plant development; (5) decide whether to invest; (6) enter into a contract with a main entrepreneur who takes on the responsibility to construct the plant; and (7) start constructing the plant. The construction period alone will typically take 1–2 years for small hydropower projects and 2–4 years for large hydropower projects.[2]

3.1.2. Dependent variables

We included questions on the perceived barriers against and optimism for investing in Norwegian hydropower plants (see Table 1, Dependent variables). When asked about his/her perceived barriers against investing, the respondents could select one or more barriers or the response ‘no barriers’. When asked about his/her optimism for investing, the respondent could select only one response on an ordinal scale.

The complete list of responses to the barrier-question is given in Table 1. The listed barriers reflect the empirical context for our case study, as described above. It also reflects our focus on whether investor acted in accordance with real options theory when exposed to the short duration and abrupt termination of the green certificate scheme in Norway.

The first set of barriers includes factors that reduce the net cash flows generated by the project and thus the value of the project (response categories 1-4 in Table 1). These are low electricity and certificate prices and high taxes, upfront fees for connection to the electricity grid and investment costs. According to a traditional investment rule, one should invest if the net present value is zero or positive.

The second set of barriers includes factors that increase investor risk (response categories 5 and 6 in Table 1). When future cash flows generated by the project are uncertain or risky, it may be optimal to postpone even profitable projects (i.e., projects with a zero or positive net present value). Thus, the more sophisticated real options investment rule says that one should invest only when the value of immediate investment is at least as high as the value of postponing the decision to invest. Therefore, we have a response category: ‘Total project risk (uncertain market, political and technological conditions)’. In the 2015 survey, we added the response category ‘Risk that the project will not be completed within the deadline set by the green certificate scheme’. Although this kind of risk is captured in the total project risk category, we wanted to pay special attention to whether investors were reluctant to invest because of the way the Norwegian part of the support scheme is terminated.

The third set of barriers is capacity constraints that may be encountered if Norwegian investors attempt to realise a large number of hydropower projects in a relatively short period of time (response categories 7-9 in Table 1). These barriers include limited access to the electricity grid, problems entering into contracts with entrepreneurs and problems in obtaining materials and components needed for construction. According to real options theory, the short duration of this scheme (nine years) and abrupt termination of the support scheme create incentives to lock in future revenues early in the support scheme period, but the incentives to invest become much weaker as the scheme deadline approaches. Consequently, investors would be more likely to be concerned with capacity constraints early in the support scheme period but not in the latter part because of the way the Norwegian support scheme is designed.

There are also barriers related to the progress and outcomes of the licensing process (response categories 10-12 in Table 1). During the process, external stakeholders can submit complaints, suggest changes to the project or present other objections to the planned project, thus delaying the process, influencing the final outcome of the process and/or making it less attractive for investors. The process of obtaining a license is time-consuming and may prevent many projects from being realised within the short support scheme period. Similar to the capacity barriers mentioned above, we would expect investors to be particularly concerned with regulators' capacity to handle a large number of applications early in the support scheme period. Investors may expect the license process to end with a negative decision, an outcome which is independent of the scheme design. Finally, problems with obtaining adequate funding and internal factors such as capacity or knowledge constraints within a firm can also delay or prevent the project from being realised (response categories 13 and 14 in Table 1).

To keep the regression analysis simple and tractable, the response categories to the barrier question are grouped into more aggregated response categories as follows. The dichotomous variable ‘economic’ is equal to one if the respondent has chosen at least one of the response categories 1-4; the dichotomous variable ‘risk’ is equal to one if the respondent has chosen at least one of the response categories 5 and 6; the dichotomous variable ‘capacity’ is equal to one if the respondent has chosen at least one of the response categories 7-9; and, the

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[3] Information on individual license and construction processes can be found in a database administered by the Norwegian Water Resources and Energy Directorate (https://www.nve.no/konsesjonssaker/). However, the information in this database is incomplete and aggregate figures are not presented. The numbers presented in the text were obtained from Ola Lingaas, Director in the Norwegian power company SFE, in an email 13 March 2017. He had gathered the license processing time for 6 large hydropower projects that were granted a license in the period March 2012 to January 2013. The license processing time in these cases were between 3,43 to 6,76years. He anticipated that a typical construction period would be 1–2years and 2–4years for small and large hydropower projects, respectively.

dichotomous variable ‘process’ is equal to one if the respondent has chosen at least one of the response categories 10-12. The remaining individual response categories are included one by one in the regression model.

3.2. Data collection

Two similar questionnaires–one in June 2012 and one in January 2015–were sent to investors in Norway who were considering constructing a new hydropower plant or updating or extending an existing hydropower plant. A detailed description of the questionnaires, the data collection processes and the data are given in the technical reports HiSF (2013, 2015).

The 2012-questionnaire was pre-tested by the regulatory authority, the energy associations and a selected sample of energy investors. The regulatory authority and energy associations helped us produce an address list that included all potential investors in hydropower projects in Norway, ranging from small farmers to Statkraft. The list of investors was controlled against the regulator's database on submitted license applications. Only minor revisions were made in the 2015-questionnaire.

The two surveys were carried out by a professional marketing firm in close cooperation with us. The data was collected through a combination of internet and postal surveys. Respondents were asked to answer the questionnaire for all their hydropower projects that were under planning or construction.

In the 2012-survey, a total of 387 investors in our target group received the questionnaire, of which 172 investors (44%) responded. The responses covered 446 single hydropower projects with a total planned annual production of 7.3 TWh. In the 2015-survey, a total of 476 investors in our target group received the questionnaire, of which 204 investors (43%) responded. The responses covered 280 single hydropower projects with a total planned annual production of 8.2 TWh.

Comparisons of our two samples and the regulator's data on planned hydropower projects shows similar distributions of projects across project type, process stage and Elspot price area. For 2015, the distributions of the 280 projects on investor, project and process characteristics are as follows: 37% of the projects are controlled by inexperienced investors and 63% by experienced investors; 19% of the projects are micro power plants, 63% small power plants, 10% big power plants and 8% upgrading and extending existing power plants; and, 13% of the projects are in the preliminary process stage, 57% in the application stage, 19% in the answer stage and 11% in the contract stage. Note that although there are relatively few projects in the categories ‘big power plants’ and ‘upgrading and extending existing power plants', these projects accounts for 33% and 21% of total planned production capacity, respectively. Moreover, experienced investors control the biggest projects, accounting for 87% of planned production capacity. These distributions have changed somewhat from the 2012 sample. For instance, there is a relatively smaller share of small hydropower in the 2015 sample. In the regression analyses, however, we control for investor, project and process stage characteristics.

3.3. Regression model

To formally examine the influence of investor, project, and process characteristics on the outcome of the two dependent variables in Table 1, we use a multinomial logistic regression model (see Greene (2011); Long and Freese (2006)). Multinominal logistic regression models is a classification method that generalises logistic regression to problems with more than two possible discrete outcomes. In this model, we are essentially estimating a separate binary logistic regression for each pair of responses. It is the most frequently used nominal regression model.

Nominal regression techniques are often used in real options studies to describe how project value and timing of irreversible decisions are affected by uncertainty (Moel and Tufano, 2002; Schatzki, 2003; Cunningham, 2006; Dunne and Mu, 2010; Linnerud et al., 2014). The literature on barriers against investments in renewable-electricity projects contains few studies that apply econometric techniques on primary data (Creutzig et al., 2014; Martin and Rice, 2012; Ozcan, 2014; Masini and Menichetti, 2012; Linnerud and Holden, 2015).

The multinomial logistic regression model is non-linear, and consequently the simple interpretations that is possible in a linear model are no longer appropriate. In a non-linear model, the effect of each variable on the outcome depends on the level of all variables in the model. Thus, we will accompany the estimated regression models, using Eq. (3) below, with post-estimations showing the predicted probabilities of given responses for a set of values on the independent variables, using Eq. (5).

The dependent variable ‘degree of optimism’ in Table 1 could have been formally investigated using a logit or probit version of the ordinal regression model because the responses are ordered. However, these models are based on a parallel regression assumption which is not satisfied by our data. Therefore, we had to use the multinomial logistic regression model that relies on fewer assumptions.

The dependent variable ‘type of barrier’ in Table 1 can also be investigated by estimating a logistic version of a multinomial regression model. However, when we analyse the distribution of responses, we must take into consideration that one respondent can answer yes on more than one alternative. One alternative is to estimate a binary regression model for each response category. The disadvantage with this approach is that we do not consider how the responses are distributed in relation to each other. What is the probability of agreeing that A is an important barrier relative to agreeing that B is an important barrier? This question can be answered by employing a multinomial logistic regression model in which the number of responses, not the number of respondents, is the basis for the analysis of the response distribution.

The principles for the multinomial logistic regression model are the same as for a binary logistic regression model. The dependent variable is the logarithm of the odds ratio for agreeing with one statement relative to agreeing with another. The difference is that we must choose one of the categories as a base category. First, we define the odds that an outcome is equal to m relative to a base category b for a given vector of independent variables $\mathbf{x}$:

$$\Omega_{m|b}(\mathbf{x}) = \frac{\Pr(y = m|\mathbf{x})}{\Pr(y = b|\mathbf{x})}. \tag{3}$$

The odds are calculated for m=1 to $J - 1$, in which J is the number of response categories. The log of the odds is assumed to equal:

$$\ln\Omega_{m|b}(\mathbf{x}) = \boldsymbol{\beta}_{m|b}^{T}\mathbf{x} \tag{4}$$

in which $\mathbf{x}$ is a row vector augmented by one and $\boldsymbol{\beta}_{m|b}^{T}$ is the corresponding column vector of estimated parameters for an outcome equal to m relative to a base case category b. Consequently, we estimate $J - 1$ regression models. The probability that an outcome is equal to m is computed as

$$\Pr(y = m|\mathbf{x}) = \frac{\exp\left(\boldsymbol{\beta}_{m|b}^{T}\mathbf{x}\right)}{\sum_{j=1}^{J}\exp\left(\boldsymbol{\beta}_{j|b}^{T}\mathbf{x}\right)} \tag{5}$$

in which $\boldsymbol{\beta}_{b|b} = 0$ because $\ln\Omega_{b|b} = \ln 1 = 0$.

4. Data

In this section, we describe the primary data collected in our two surveys. We focus on detecting patterns in the data that may suggest whether our three hypotheses are correct or wrong.

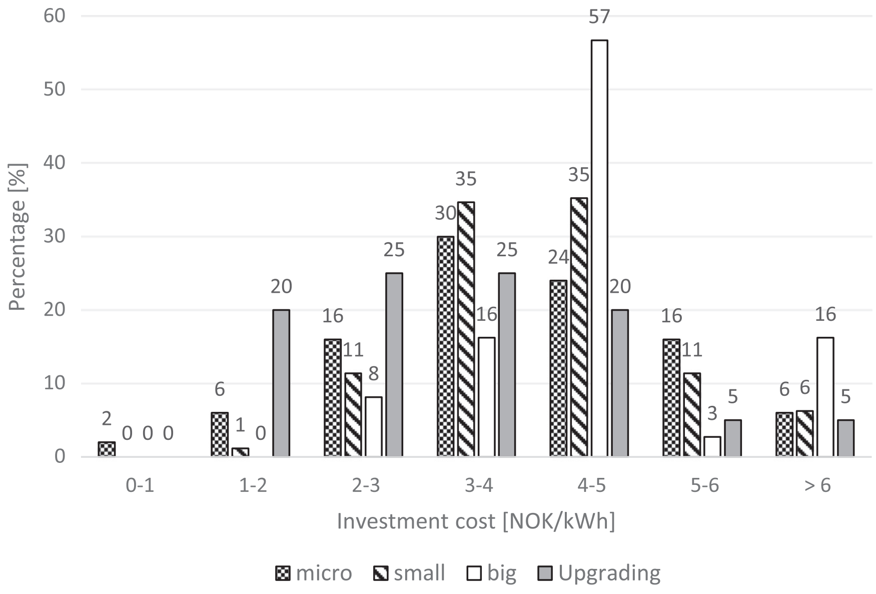

Fig. 4. Expected investment cost per project type in 2015. X-axis shows investment cost per annual production. Y-axis shows, for each project type, the distribution of costs.

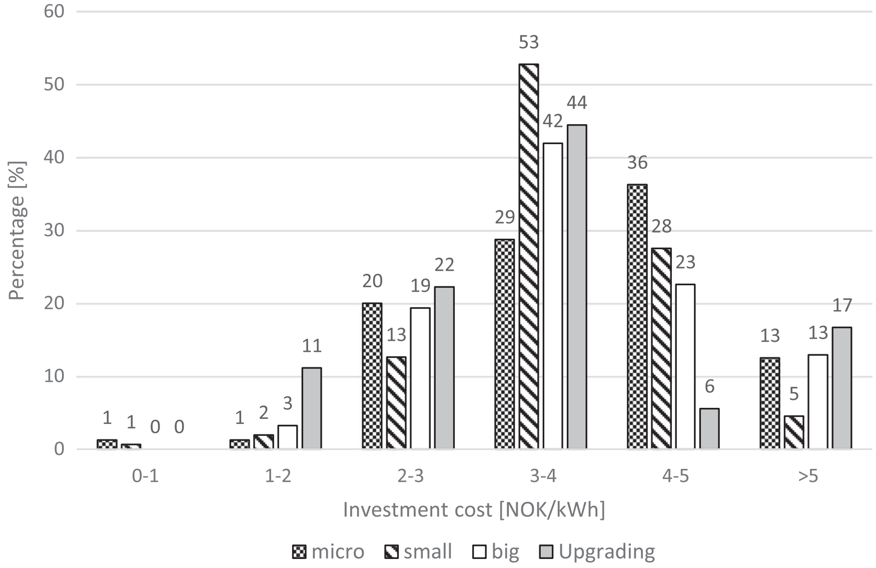

Fig. 5. Expected investment cost per project type in 2012. X-axis shows investment cost per annual production. Y-axis shows, for each project type, the distribution of costs.

We observe that, for a planned hydropower project, the expected revenues have decreased from the time of the first to the second survey. Three-years forward contracts for electricity and certificates can be used to derive expected prices three years ahead. Measured in the Norwegian currency, the sum of electricity and certificate prices on three-years forward contracts traded at the Nasdaq OMX Commodities and by Svensk Kraftmakling has decreased from 433.6 NOK/MWh in June 2012 to 418.6 NOK/MWh in January 2015, or by 9.3% when adjusting for inflation (Fig. 3).[4] The reduction in the sum of electricity and certificate prices shows that the marginal investor is satisfied with a lower revenue per kW h in 2015.

Next, according to the two surveys, the average expected investment cost per annual production has not changed. In nominal terms, it has increased from 3.69 to 3.88 NOK/kW h, but in real terms, it is unaltered (Figs. 4 and 5). However, the spread in investment costs per annual production has increased, both between individual projects of one type and across categories of projects. In the 2015-survey, upgrading of existing power plants are the least expensive and have an average expected investment cost of only 3.25 NOK/kW h, while big power plants with an installed capacity of 10 MW or more, are the most expensive with an average expected investment cost of 4.37 NOK/kW h. Of course, big power plant projects often include costs related to construction of a reservoir. Using such reservoirs, the producer can optimally plan production and thus increase expected revenues. Yet, with the decrease of prices, some of the high-cost hydropower plants may be unprofitable according to the traditional net present value rule in Eq. (1). If investors use the real options investment rule in Eq. (2), they may find it optimal to postpone even profitable projects.

Table 2 shows investors' responses to the barrier-question in Table 1. In general, investors have become more concerned with barriers that can prevent their project from being realised within the timeframe set by the certificate scheme. Only 14% of the projects do not face any barriers at all in 2015 compared with 36% in 2012, and

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[4] Inflation is estimated to of 5.1% equal to the percentage change of the consumer price index in June 2012 and January 2015. Source: Statistics Norway. The exchange rate was 7.54 NOK/EUR in January 2015 and 8.93 NOK/EUR in January 2015.

Table 2
Type of barrier. Descriptive statistics. 2012 and 2015 surveys.[a]

			Project type								Experience			
	Sum		Micro ≤1 MW		Small 1–10 MW		Big ≥10 MW		Upgrading/extension		Yes		No	
Barrier	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$
None	36^{**}	14^{*}	23^{*}	10^{*}	39^{**}	14^{*}	50^{***}	14^{*}	30^{**}	29^{*}	42^{**}	15^{*}	26^{*}	14^{*}
Electricity price	16^{*}	52^{***}	19^{*}	56^{***}	14^{*}	52^{***}	10^{*}	55^{***}	29^{*}	45^{**}	14^{*}	54^{***}	22^{*}	57^{***}
Certificate price	12^{*}	52^{***}	16^{*}	56^{***}	11^{*}	52^{***}	7	55^{***}	19^{*}	45^{**}	9	54^{***}	21^{*}	57^{***}
Taxes/fees	8	21^{*}	8	15^{*}	8	19^{*}	7	34^{**}	14^{*}	30^{**}	5	24^{*}	17^{*}	16^{*}
Investment costs	26^{*}	50^{***}	42^{**}	48^{**}	22^{*}	53^{***}	23^{*}	52^{***}	33^{**}	30^{**}	20^{*}	55^{***}	41^{**}	48^{**}
Upfront connection fee electricity grid	–	22^{*}	–	23^{*}	–	23^{*}	–	24^{*}	–	5	–	24^{*}	–	21^{*}
Access to services	2	1	0	2	2	2	10	0	10	0	3	1	2	2
Access to components	2	1	0	2	1	1	3	0	10	0	2	1	1	1
Access to transmission electricity grid	15^{*}	16^{*}	16^{*}	13^{*}	15^{*}	18^{*}	7	17^{*}	19^{*}	0	18^{*}	16^{*}	8	19^{*}
External stakeholders	15^{*}	17^{*}	22^{*}	23^{*}	13^{*}	13^{*}	13^{*}	14^{*}	29^{*}	45^{**}	10^{*}	21^{*}	30^{**}	13^{*}
Process	17^{*}	19^{*}	13^{*}	15^{*}	18^{*}	15^{*}	10^{*}	34^{**}	19^{*}	35^{**}	18^{*}	20^{*}	14^{*}	1
May not be granted a lisence	–	20^{*}	–	19^{*}	–	18^{*}	–	24^{*}	–	40^{**}	–	27^{*}	–	19^{*}
Overall risk	7	17^{*}	16^{*}	12^{*}	16^{*}	19^{*}	3	24^{*}	19^{*}	10^{*}	6	20^{*}	12	15^{*}
Deadline scheme risk	–	21^{*}	–	12^{*}	–	19^{*}	–	45^{**}	–	20^{*}	–	25^{*}	–	18^{*}
Funding	3	10^{*}	6	10^{*}	2	11^{*}	0	7	5	5	1	9	7	16^{*}
Internal aspects	3	8	5	10^{*}	3	10^{*}	0	0	5	0	2	10^{*}	7	7
Other aspects	7	11^{*}	6	27^{*}	6	8	7	7	14^{*}	0	8	9	5	18^{*}
Number of respondents N[b]	446	277	80	53	312	174	33	29	21	21	306	173	128	101
Don't know/no response	10	6	3	1	4	4	3	0	0	1	3	9	7	10
Production GW h[b]	7256	8141	206	140	3424	3638	2799	2652	827	1171	5759	7105	1261	1024

[a] The responses are expressed as percentages of the number of responses in each column excluding the number of responses 'don't know' and no responses. For example, in 2015, 141 respondents choose electricity/certificate as one barrier. The percentage is calculated as 141/(277-4)=52%. To better illustrate which barriers the respondents are most concerned with, we have marked with *, **, *** and **** barriers in which the number of projects (N) are in the corresponding intervals: 10–30%, 30–50%, 50–70% and 70–100% of the total for that type of project.

[b] These numbers include respondents who have chosen the response '6: don't know'. Still, the respondents may not have answered all questions in the project specific part of the survey, thus the sum of respondents N and the sum of production GWh for each project type and for each experience level will not always be equal to the total number of projects and production volume in the survey.

the exposure to all barriers has increased. Investors have become particularly concerned with economic barriers and risk. In 2015, half of the projects are exposed to low electricity and certificate prices and/or high investment costs; and, around one fifth of the projects are exposed to overall project risk and the risk represented by the abrupt termination of the scheme at the end of 2020.

These findings are all in accordance with our speed-up and slow-down hypotheses. In particular, we note that in 2015, as much as 45% of big hydropower projects are concerned with the risk presented by abrupt termination of the certificate scheme in 2020 compared with only 12% and 19% of the micro and small hydropower projects, respectively. However, in conflict with our third hypothesis, inexperienced investors have become equally concerned with risk exposure as experienced investors. Finally, we observe that the responses for upgrading and extending existing plants have changed less over time than the responses for other project types, and as much as 29% of these projects are in 2015 not exposed to any barrier. This finding may be partly explained by the low costs of such projects.

Table 3 shows investors' responses to the optimism-question in Table 1. These responses follow the same pattern as the responses to the barrier-question. In general, investors have become more pessimistic with respect to the chances of their project being realised within the timeframe set by the certificate scheme. For example, for an average hydropower project, the percentage that think it is very likely that their project will be realised has been reduced from 40% in 2012 to 25% in 2015. Again, the responses for upgrading and extending existing plants have changed less over time than the responses for other project types, and as much as 37% of these projects are in the response category 'very likely' in 2015.

5. Results and discussion

In the previous section, we detected relations between dependent and independent variables in our survey data that were consistent with the speed-up effect and slow-down effect hypotheses, but in conflict with the experience effect hypothesis. These patterns can be examined more formally using a multinomial logistic regression model. This model allows us to investigate the partial impact on investors' responses of one investor, project and process characteristic at a time, while controlling for other characteristics. Furthermore, we can test whether these relations are statistically significant or are merely due to a sampling error.

5.1. Regression analysis. Type of barrier

In the questionnaire, we asked: "Which barriers, if any, may prevent your project from being realised by the deadline set by the certificate scheme?" We examine the relative importance of the aggregate response categories by using Eq. (3) to estimate a multinomial logistic regression model in which the response category 'no barriers' is the base outcome or reference. Other references are an inexperienced investor (for the independent variable 'experience'), a micro power plant with installed capacity ≤1 MW (for the independent variable 'project type'), no production flexibility (for the independent variable 'production flexibility', 'south-east' (for the independent variable 'Elspot price area') and 'preliminary' (for the independent variable 'process stage'). For the 2015 survey, Table 4 gives the estimated regression model and Table 5 gives the predicted probabilities for projects with particular sets of characteristics assuming mean values for the independent

Table 3
Degree of optimism. Descriptive statistics. 2012 and 2015 surveys.

			Project type								Experience			
	Sum[a]		Micro ≤1 MW		Small 1–10 MW		Big ≥10 MW		Upgrading/extension		Yes		No	
Optimism	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$	$\%_{12}$	$\%_{15}$
1: Very unlikely	8	6	6	16^{*}	9	4	3	7	5	0	11^{*}	4	1	10^{*}
2: More unlikely than likely[a]	12^{*}	10^{*}	10^{*}	20^{*}	14^{*}	5	0	14^{*}	5	21^{*}	14^{*}	11^{*}	8	9
3: Equally likely[a]	14^{*}	29^{*}	29^{*}	34^{**}	10^{*}	29^{*}	15^{*}	21^{*}	19^{*}	21^{*}	11^{*}	30^{**}	23^{*}	27^{*}
4: More likely than unlikely[a]	26^{*}	30^{**}	26^{*}	20^{*}	24^{*}	34^{**}	45^{**}	31^{**}	29^{*}	21^{*}	24^{*}	28^{*}	31^{**}	32^{**}
5: Very likely[a]	40^{**}	25^{*}	28^{*}	10^{*}	42^{**}	28^{*}	36^{**}	28^{*}	43^{**}	37^{**}	40^{**}	27^{*}	38^{**}	22^{*}
Number of responses N[b]	446	280	79	53	311	174	33	29	21	21	311	173	134	101
6: Don't know	4	16	1	3	2	11	0	0	0	2	1	5	3	11
Production GW h[b]	7251	8172	205	140	3412	3639	2799	2652	827	1711	5806	7105	1443	1024
6: Don't know GW h	11	471	2	9	8	124	0	0	0	338	2	358	9	113

[a] The responses are expressed as percentages of the number of responses in each column excluding the number of responses ‘6: don't know’. For example, in 2012, 36 respondents choose the category ‘1: very unlikely’. The percentage is calculated as 36/(446-4)=8%. To better illustrate which degree of optimism the respondents most often choose, we have marked with * and ** percentages in the corresponding intervals: 10–30% and 30–50%.

[b] These numbers include the responses ‘6: don't know’. Still, the respondents may not have answered all questions in the project specific part of the survey, thus the sum of responses *N* and the sum of production GW h for each project type and for each experience level will not always be equal to the total number of projects and production volume in the survey.

variables not explicitly mentioned. Equivalent tables for the 2012 survey are given in the appendix.

The estimated coefficients in Tables 4 can be interpreted as follows. Consider the regression model ‘Funding’. The coefficient for the independent variable ‘investment cost’ is +0.957. If the investment cost increases from one category to the next, the natural logarithm to the odds ratio of funding barriers relative to no barriers will increase by 0.957. Since the coefficient is positive, the probability of responding that there are funding barriers is significantly higher than the probability of responding that there are no barriers for a project with a high investment cost than for a project with a low investment cost. The constant is −4.858. This includes the effect for the reference respondent–who is an inexperienced investor, considering a project with an installed capacity below 1 MW without production flexibility, located in Elspot area south-east and where the project has only just started. Since the constant is negative, this respondent is more likely to consider funding barriers as more important than no barriers. Based on an investigation of the sign and significance of coefficients in Table 4 and on the predicted probabilities in Table 5 (and the corresponding Tables A1 and A2 in the Appendix), we draw the following conclusions:

In 2015, investors in a project with average characteristics would be highly concerned with barriers; only 4% would rule out barriers altogether. Furthermore, these investors would be particularly concerned with economic barriers (50%), risk barriers (23%) and process barriers (22%) while they would not be concerned with capacity barriers (1%). Three years earlier, investors were more optimistic; as much as 27% would rule out barriers altogether. Furthermore, they were much more concerned with capacity barriers (12%), like for instance problems getting access to the electricity grid.

In 2015, the responses to the barrier-question were not significantly affected by whether the respondent had previous *experience* from the energy sector or not, all else being equal. However, experience did matter three years earlier; assessing identical projects, local landowners were in 2012 significantly less concerned with capacity barriers and significantly more concerned with economic, process, risk, funding and internal barriers than experienced investors were.[5] In 2012, the predicted probability of being exposed to economic barriers was 23% for experienced vs. 41% for inexperienced investors; while the predicted probability of being exposed to capacity barriers was 17% for experienced vs. 5% for inexperienced investors. Recall that these predicted probabilities are calculated using Eq. (5), setting all other independent variables but ‘experience’ equal to mean values. Thus, we are comparing identical projects with, for instance, the same investment cost in the same Elspot area and at the same process stage.

In 2015, the responses to the barrier-question were significantly affected by *production flexibility*. Respondents considering a project without production flexibility were more likely to choose the response ‘no barriers’ relative to a capacity barrier than were respondents considering projects with such flexibility. The predicted probability of choosing the response ‘no barriers’, all else being equal, decreases from 20% when the project does not include production flexibility to only 6% when it does.[6]

In 2015, the responses to the barrier-question were significantly affected by the expected *investment cost*; the higher the investment cost, the more likely the respondent was to choose responses in the barrier categories ‘economic’, ‘risk’ and ‘funding’ relative to choose the response ‘no barriers’. For instance, for projects with an expected investment cost in the range 1.1–2.0 NOK, the predicted probability of being exposed to economic barriers was 38%; while for projects with an expected investment cost in the range 5.1–6.0 NOK, the corresponding percentage was 54%. The increased risk as the deadline of the scheme nears, may explain why investors are more concerned with economic barriers like investment costs.

Both in 2015 and 2012, the perceived exposure to most barriers is reduced throughout the *process stages*. However, a significant change in responses to the barrier-question happens at a later process-stage in 2015 compared with 2012. In 2012, respondents are significantly more exposed to economic, capacity, risk, internal and other barriers relative to no barriers when they enter the application stage as compared with the preliminary stage. In 2015, respondents have to enter the answer stage to achieve a significant drop in the relative importance of ‘process barriers’ to ‘no barriers’ and to enter the contract stage to achieve a significant drop in the relative importance of ‘economic’, ‘capacity’, ‘risk’ and ‘other barriers’ to ‘no barriers’.

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[5] More specifically, in Table A.1 (2012) in the Appendix, the coefficients for ‘experience’ are with one exception statistically significantly different from 0. This is not the case in Table 4 (2015).

[6] The question on production flexibility was unfortunately not included in the 2012 survey, and consequently the estimated 2012-impacts of location and investment costs (which are both correlated to production flexibility) should be interpreted with care. For instance, most projects in Elspot area south-east (reference) are less expensive run-of-the-river projects without production flexibility.

Table 4
Type of barrier. Multinomial logistic regression model. 2015 survey.

Response categories (Base outcome: No barriers[a])	Economic[a]		Capacity[a]		Process[a]		Risk[a]	
	β[b]	p	β[b]	p	β[b]	p	β[b]	p
Experience (D=1)	+0.399	0.544	+0.173	0.808	+0.775	0.259	+0.935	0.180
Production (GW h)	−0.009	0.209	−0.009	0.467	−0.003	0.667	−0.012	0.106
Project type: small power plant (D=1)[c]	−1.194	0.117	−1.294	0.123	−1.204	0.133	−0.867	0.296
Project type: big power plant (D=1)[c]	−0.489	0.703	−0.146	0.920	−0.851	0.525	+0.408	0.762
Project type: upgrading (D=1)[c]	−2.016	0.055	−17.277	0.991	−1.725	0.111	−1.664	0.146
Production flexibility (D=1)	+0.751	0.179	+1.524*	0.023	+0.560	0.334	+0.742	0.208
Investment cost (ordinal scale)	+0.639*	0.018	+0.162	0.604	+0.517	0.064	+0.581*	0.042
Elspot price area: south-west (D=1)[d]	+0.284	0.799	+16.116	0.989	+1.151	0.340	−0.287	0.806
Elspot price area: central (D=1)[d]	−0.842	0.401	+14.739	0.990	−0.075	0.947	−1.417	0.182
Elspot price area: north (D=1)[d]	−0.534	0.601	+15.687	0.989	+0.173	0.880	−0.948	0.377
Elspot price area: west (D=1)[d]	+0.084	0.929	+15.537	0.989	+0.883	0.401	−0.360	0.717
Process stage: application(D=1)[e]	+0.798	0.362	+1.119	0.322	+0.735	0.407	+1.125	0.234
Process stage: answer(D=1)[e]	−0.010	0.992	+0.838	0.498	−2.268*	0.047	−0.085	0.936
Process stage: contract (D=1)[e]	−3.992**	0.000	−2.732*	0.039	−5.404**	0.000	−4.855**	0.001
Constant	−0.746	0.646	−17.175	0.988	−1.170	0.500	−1.568	0.374
N	462		462		462		462	
LR $\chi^2(98)$[f]	233.48	0.000	233.48	0.000	233.48	0.000	233.48	0.000
McFadden's R^2[g]	0.1402		0.1402		0.1402		0.1402	

Response categories (Base outcome: No barriers[a])	Funding[a]		Internal factors[a]		Other[a]	
	β[b]	p	β[b]	p	β[b]	p
Experience (D=1)	+0.112	0.887	+1.055	0.230	−0.027	0.975
Production (GW h)	−0.005	0.630	−0.095	0.112	−0.003	0.762
Project type: small power plant (D=1)[c]	−0.993	0.300	−1.271	0.208	−1.515	0.083
Project type: big power plant (D=1)[c]	−1.348	0.450	−12.518	0.990	−1.116	0.510
Project type: upgrading (D=1)[c]	−17.556	0.994	−17.677	0.993	−17.974	0.993
Production flexibility (D=1)	+1.004	0.156	+0.684	0.384	+0.792	0.280
Investment cost (ordinal scale)	+0.957**	0.005	+0.296	0.424	+0.185	0.617
Elspot price area: south-west (D=1)[d]	+0.612	0.670	−0.882	0.524	−0.500	0.730
Elspot price area: central (D=1)[d]	−0.220	0.868	−2.972*	0.050	−1.004	0.421
Elspot price area: north (D=1)[d]	−0.529	0.701	−0.635	0.617	−15.347	0.987
Elspot price area: west (D=1)[d]	+0.820	0.521	−0.812	0.514	−0.010	0.993
Process stage: application(D=1)[e]	+0.688	0.556	+0.750	0.537	−0.114	0.917
Process stage: answer(D=1)[e]	−0.150	0.908	+0.141	0.915	−0.844	0.501
Process stage: contract (D=1)[e]	−29.415	1.000	−29.216	1.000	−3.056*	0.021
Constant	−4.858*	0.034	+0.156	0.943	+0.499	0.803
N	462		462		462	
LR $\chi^2(98)$[f]	233.48	0.000	233.48	0.000	233.48	0.000
McFadden's R^2[g]	0.1402		0.1402		0.1402	

[a] The reference or base outcome is no barriers.
[b] Coefficients marked with * and ** are significantly different from zero at the 5% and 1% significance levels, respectively.
[c] The reference project type is micro power plants with installed capacity below 1 MW.
[d] The reference Elspot price area is Elspot area 1 in the south-east.
[e] The reference process stage is the preliminary process stage including preliminary planning and notification to the authorities.
[f] $LR\chi^2(12)$ test the null hypothesis that all coefficients except the intercept are zero.
[g] McFadden's R^2 compares a model with just the intercept to a model with all parameters.

Table 5 (2015) provides additional support for the differences in responses across project types that we detected in our descriptive data analysis in Section 3. First, we find that investors who, in 2015, planned big power plants with installed capacity above 10 MW were more likely to be exposed to risk, including the risk of not completing the project within the deadline set by the green certificate scheme, than investors in other type of projects were. For instance, at the preliminary process stage, a planned big power plant project with production flexibility and expected investment costs and production volumes typical for this type of project, has a predicted probability of being exposed to risk in 22% of the cases, compared with 11–15% for the smaller projects listed in Table 5.

Second, we find that investors who, in 2015, planned upgrading and extension of existing hydropower plants were more likely to rule out the existence of barriers, than investors in other type of projects were. For instance, at the preliminary process stage, a planned upgrading and extension project has a predicted probability of not being exposed barriers in 21–32% of the cases, compared with only 4% for an average project. And, from 2012 to 2015, an average project has become much more exposed to economic barriers, while upgrading and extension projects have not (see Tables 4 and 4, 5).

5.2. Regression analysis. Degree of optimism

In the questionnaire, we asked: “How likely or unlikely is it that your project will be realised by the deadline set by the certificate scheme?” We examine the relative importance of all the response categories by using Eq. (4) to estimate a multinomial logistic regression model in which the response categories ‘more unlikely than likely’ and ‘very unlikely’ are merged (because there are few responses in the last

Table 5
Type of barrier. Individual predicted probabilities.[a] 2015 Survey.

Response categories[b]	Economic	Capacity	Process	Risk	No barriers
At means					
	0.50	0.01	0.22	0.23	0.04
Process stage					
Preliminary	0.42	0.00	0.34	0.17	0.04
Application	0.42	0.01	0.31	0.23	0.02
Answer	0.62	0.01	0.05	0.23	0.06
Contract	0.16	0.01	0.03	0.03	0.78
Investment costs					
1.1–2 NOK/kW h	0.38	0.02	0.24	0.21	0.15
3.1–4 NOK/kW h	0.47	0.01	0.23	0.23	0.05
5.1–6 NOK/kW h	0.54	0.00	0.21	0.23	0.02
Production flexibility					
Yes	0.47	0.00	0.24	0.22	0.06
No	0.43	0.00	0.26	0.20	0.20
Process stage: Preliminary					
Micro p.p., 3.1–4.0 NOK/kW h, prod. flex., 2.58 GW h[c]	0.37	0.01	0.32	0.12	0.03
Micro p.p., 3.1–4.0 NOK/kW h, no prod. flex., 2.58 GW h[c]	0.34	0.00	0.36	0.11	0.05
Small p.p., 3.1–4.0 NOK/kW h, prod. flex., 9.28 GW h[c]	0.35	0.01	0.31	0.15	0.09
Small p.p., 3.1–4.0 NOK/kW h, no prod. flex., 9.28 GW h[c]	0.30	0.00	0.33	0.13	0.16
Small p.p., 4.1–5.0 NOK/kW h, prod. flex., 9.28 GW h[c]	0.38	0.00	0.30	0.16	0.05
Small p.p., 4.1–5.0 NOK/kW h, no prod. flex., 9.28 GW h[c]	0.34	0.00	0.33	0.14	0.10
Big p.p., 4.1–5.0 NOK/kW h, prod. flex., 84.82 GW h[c]	0.38	0.01	0.32	0.22	0.05
Big p.p., 4.1–5.0 NOK/kW h, no prod. flex., 84.82 GW h[c]	0.34	0.00	0.35	0.20	0.09
Upgrading, 2.1–3.0 NOK/kW h, prod. flex., 41.28 GW h[c]	0.22	0.00	0.37	0.10	0.32
Upgrading, 3.1–4.0 NOK/kW h, prod. flex., 41.28 GW h[c]	0.28	0.00	0.40	0.11	0.21
Process stage: Contract					
Micro p.p., 3.1–4.0 NOK/kW h, prod. flex., 2.58 GW h[c]	0.19	0.01	0.04	0.03	0.72
Micro p.p., 3.1–4.0 NOK/kW h, no prod. flex., 2.58 GW h[c]	0.10	0.00	0.03	0.01	0.85
Small p.p., 3.1–4.0 NOK/kW h, prod. flex., 9.28 GW h[c]	0.07	0.00	0.01	0.01	0.90
Small p.p., 3.1–4.0 NOK/kW h, no prod. flex., 9.28 GW h[c]	0.03	0.00	0.01	0.01	0.95
Small p.p., 4.1–5.0 NOK/kW h, prod. flex., 9.28 GW h[c]	0.12	0.01	0.02	0.02	0.83
Small p.p., 4.1–5.0 NOK/kW h, no prod. flex., 9.28 GW h[c]	0.06	0.00	0.01	0.01	0.91
Big p.p., 4.1–5.0 NOK/kW h, prod. flex., 84.82 GW h[c]	0.12	0.01	0.02	0.03	0.81
Big p.p., 4.1–5.0 NOK/kW h, no prod. flex., 84.82 GW h[c]	0.06	0.00	0.02	0.02	0.90
Upgrading, 2.1–3.0 NOK/kW h, prod. flex., 41.28 GW h[c]	0.01	0.00	0.01	0.00	0.98
Upgrading, 3.1–4.0 NOK/kW h, prod. flex., 41.28 GW h[c]	0.02	0.00	0.01	0.00	0.96

[a] The predicted probabilities are calculated setting all variables but those explicitely mentioned in the table equal to mean values.

[b] Predictions for only the most frequently chosen response categories in 2012 and 2015 are presented.

[c] The annual production volume is set equal to the average level in our 2012 sample for each project type; that is, 2.58 GW h for micro power plants, 9.28 GW h for small power plants, 84.82 GW h for big power plants and 41.28 for upgrading existing power plants.

category) and used as the base outcome or reference. Other reference categories are the same as for the barrier-regression. For the 2015 survey, Table 6 gives the estimated regression model and Table 7 gives the predicted probabilities for projects with particular sets of characteristics assuming mean values for the independent variables not explicitly mentioned. Tables A3 and A4 in the appendix give the same information for the 2012 survey. An examination of these tables leads to conclusions similar to the ones we made for the barrier-question:

Norwegian hydropower investors have on average become more pessimistic since the support scheme was launched in 2012. For a project with average characteristics, the predicted probability of responding very likely decreased from 49% in 2012 to 32% in 2015 while the predicted probability of responding very unlikely or more unlikely than likely increased from 4% in 2012 to 14% in 2015.

The responses in 2012 to the optimism-question vary significantly with investors' previous *experience*, while they do not in 2015. Back in 2012, experienced investors were on average six time more likely to choose the response category ‘very unlikely/ more unlikely than likely’ than inexperienced investors were.

The responses in 2015 to the optimism-question vary significantly with expected *investment costs*. Investors are significantly less optimistic when it comes to realising their project if investment costs are high. Moreover, in 2015, the *location* of the project does significantly affect the degree of investor optimism, all else equal. We cannot, based on our data, explain the reasons for this result because location did not significantly affect the responses in 2015 to the barrier-question.

Naturally, optimism increases as a project moves forward through the *process stages*. However, just like for the barrier-question, significant changes in responses to the optimism-question happens at a later process-stage in 2015 compared with 2012. In 2012, respondents are significantly more optimistic when they enter the application stage as compared with the preliminary stage. In 2015, respondents have to enter the contract stage to have a significant increase in the response ‘very likely’ relative to ‘very unlikely/more unlikely than likely’ (the reference).

5.3. Discussion

The results of our regression analyses are consistent with the first two of our three hypotheses presented in Section 2.

5.3.1. . The speed-up effect

Immediately after the scheme is introduced (i.e., in our case, in the 2012 survey), Norwegian investors in hydropower projects are opti-

Table 6
Degree of optimism. Multinomial logistic regression model. 2015 survey.

Response categories (Base outcome: VUL/MUL[a])	EL[a]		ML[a]		VL[a]	
	β^b	p	β^b	p	β^b	p
Experience (D=1)	−0.106	0.862	−0.606	0.330	−0.258	0.717
Production (GW h)	+0.006	0.497	+0.014	0.065	+0.014	0.076
Project type: small power plant (D=1)[c]	+0.658	0.294	+1.181	0.088	+2.254**	0.014
Project type: big power plant (D=1)[c]	−1.003	0.338	−0.264	0.801	+0.723	0.580
Project type: upgrading (D=1)[c]	−1.201	0.262	−0.249	0.818	+1.021	0.397
Production flexibility (D=1)	−0.277	0.602	−0.655	0.230	+0.001	0.999
Investment cost (ordinal scale)	−0.527*	0.018	−0.725**	0.002	−0.882**	0.001
Elspot price area: south-west (D=1)[d]	+1.788*	0.053	+2.210*	0.026	+1.041	0.332
Elspot price area: central (D=1)[d]	+0.732	0.416	+1.237	0.199	+1.010	0.307
Elspot price area: north (D=1)[d]	+1.946*	0.047	+2.479*	0.017	+1.085	0.324
Elspot price area: west (D=1)[d]	+0.874	0.299	+1.389	0.120	−0.305	0.751
Process stage: application (D=1)[e]	+0.910	0.185	+1.415	0.079	+1.770	0.077
Process stage: answer (D=1)[e]	+1.507	0.090	+2.454*	0.013	+2.424*	0.040
Process stage: contract (D=1)[e]	−13.130	0.987	+1.026	0.552	+5.755**	0.000
Constant	+1.465	0.287	+1.087	0.462	0.358	0.831
N	218		218		218	
LR $\chi^2(39)$[f]	128.80	0.000	128.80	0.000	128.80	0.000
McFadden's R^2[g]	0.2199		0.2199		0.2199	

[a] The abbreviations VUL, MUL, EL, ML and VL refer to 'very unlikely', 'more unlikely than likely', 'equally likely', 'more likely than likely' and 'very likely', respectively. The reference or base outcome is VUL/MUL.

[b] Coefficients marked with * and ** are significantly different from zero at the 5% and 1% significance levels, respectively.

[c] The reference project type is micro power plants with installed capacity below 1 MW.

[d] The reference Elspot price area is Elspot area 1 in the south-east.

[e] The reference process stage is the preliminary process stage including preliminary planning and notification to the authorities.

[f] $LR\chi^2(12)$ test the null hypothesis that all coefficients except the intercept are zero.

[g] McFadden's R^2 compares a model with just the intercept to a model with all parameters.

mistic, less concerned with economic barriers and more concerned with capacity barriers that may delay the completion of their projects. The short duration and abrupt termination of the Norwegian part of the scheme make Norwegian investors value the opportunity to lock in future subsidies by investing immediately. Consequently, Norwegian investors do not value the opportunity to wait in Eq. (2) and will demand a lower rate of return than Swedish investors who are only exposed to the risk of gradual scheme removal. In 2012, Norwegian investors expected to realise many hydropower projects and were concerned about the pressure placed on limited resources. Our results show that access to the electricity grid and delays in regulator's handling of applications are viewed as particularly important barriers. This also explains the substantial increase in optimism when the application has been submitted to the regulator. These findings are all consistent with the speed-up hypothesis derived from real options theory.

5.3.2. . The slow-down effect

As the certificate deadline neared (i.e., in the 2015 survey), Norwegian investors have become increasingly pessimistic and concerned with economic and risk barriers. Moreover, investors have become increasingly sceptical of whether early-stage projects will be completed in time to realise the gains from the certificate scheme. The abrupt termination design of the Norwegian part of the scheme represents an increasing risk to investors as they approach the end of the period in which investors gain the right to sell certificates. New, large hydropower plants with regulation reservoirs are particularly exposed to such barriers. A possible explanation for this exposure is that big and complex projects have a long planning and construction period, and the risk that the project will not be completed and entitled to sell certificates within the 2020 deadline was high with only 6 years remaining of the support period. Note that the exposure to risk for big power plants at the preliminary stage was substantially lower in June 2012 (2%). These findings are all consistent with the slow-down hypothesis derived from real options theory.

Investors' change in sentiment from 2012 to 2015 can be explained by the prospect of a subsidy termination first lowering and then raising the required rate of return. Moreover, as predicted by the real options theory, the last effect appears to be substantial, particularly for capital-intensive projects with a long construction period. Missing the 2020 deadline would mean a substantial reduction in expected revenues (close to 40% reduction based on 2015 forward contract prices, see Fig. 2) for Norwegian investors, and as the certificate deadline nears, they will therefore increase the required rate of return on their hydropower projects substantially. If the Swedish investors had been exposed to the same risk, we would have expected the sum of electricity and certificate prices to rise to reflect this, all else equal. But, they were not exposed to this risk. The asymmetry between the Norwegian and Swedish scheme designs therefore results in different risk exposures and to Norwegian investors becoming less willing to invest at prices the Swedish investors find acceptable.

For upgrading and extension projects, we find, however, no support for the slow-down effect hypothesis. This is surprising because many of these projects are complex, have a long construction period and require a substantial and irreversible investment. A possible explanation is that investors in such projects have little flexibility to optimally time their investment decision or to choose not to invest. For instance, the regulation reservoir needs maintenance to satisfy safety requirements or to handle an increasing amount of precipitation and runoff. Or, the turbine is 50 years old and needs replacement. In such cases, the producer may incur a loss if maintenance and upgrading of the plant is not undertaken. Furthermore, the producer may not have a choice whether-or-not to maintain and update the plant, but must undertake this project within a reasonable amount of time. Thus, high costs, low prices and the risk that the project will not be funded by certificates may be less important barriers for these projects than for projects including a new plant. Moreover, in 2015, the updating and extending projects have become relatively less expensive than other kinds of Norwegian hydropower projects, thus making them relatively less exposed to economic barriers like falling prices, and to the risk

Table 7
Degree of optimism. Individual predicted probabilities.[a] 2015 survey.

Response categories[b]	VUL/MUL	EL	ML	VL
At means				
	0.14	0.08	0.45	0.33
Experience				
Experienced	0.16	0.09	0.42	0.34
Inexperienced	0.11	0.07	0.53	0.30
Process stage				
Preliminary	0.30	0.40	0.23	0.07
Application	0.11	0.37	0.35	0.16
Answer	0.05	0.32	0.48	0.15
Contract	0.01	0.00	0.03	0.96
Investment costs				
1.1–2 NOK/kW h	0.01	0.04	0.42	0.53
3.1–4 NOK/kW h	0.04	0.06	0.47	0.43
5.1–6 NOK/kW h	0.18	0.08	0.44	0.30
Process stage: Preliminary				
Micro p.p., 2.58 GW h[c]	0.43	0.43	0.12	0.02
Small p.p., 9.28 GW h[c]	0.23	0.46	0.22	0.08
Big p.p., 84.82 GW h[c]	0.41	0.24	0.26	0.09
Upgrading, 41.28 GW h[c]	0.53	0.20	0.19	0.09
Process stage: Application				
Micro p.p., 2.58 GW h[c]	0.21	0.52	0.23	0.04
Small p.p., 9.28 GW h[c]	0.08	0.41	0.33	0.18
Big p.p., 84.82 GW h[c]	0.16	0.23	0.41	0.21
Upgrading, 41.28 GW h[c]	0.23	0.21	0.33	0.22
Process stage: Answer				
Micro p.p., 2.58 GW h[c]	0.16	0.47	0.32	0.04
Small p.p., 9.28 GW h[c]	0.05	0.35	0.44	0.16
Big p.p., 84.82 GW h[c]	0.10	0.18	0.53	0.18
Upgrading, 41.28 GW h[c]	0.18	0.19	0.41	0.22
Process stage: Contract				
Micro p.p., 2.58 GW h[c]	0.08	0.00	0.06	0.86
Small p.p., 9.28 GW h[c]	0.01	0.00	0.03	0.97
Big p.p., 84.82 GW h[c]	0.13	0.00	0.03	0.96
Upgrading, 41.28 GW h[c]	0.02	0.00	0.02	0.96
Elspot price area				
South-east	0.30	0.06	0.21	0.43
South-west	0.08	0.09	0.50	0.32
North	0.07	0.09	0.56	0.29

[a] The predicted probabilities are calculated setting all variables but those explicitely mentioned in the table equal to mean values.

[b] The abbreviations VUL, MUL, EL, ML and VL refer to 'very unlikely', 'more unlikely than likely', 'equally likely', 'more likely than likely' and 'very likely', respectively.

[c] The annual production volume is set equal to the average level in our 2012 sample for each project type; that is, 2.58 GW h for micro power plants, 9.28 GW h for small power plants, 84.82 GW h for big power plants and 41.28 for upgrading existing power plants.

represented by the scheme termination (see Fig. 4). Another possible explanation for small changes in responses for upgrading and extension projects is that they have already secured social acceptance (Wolsink, 2007). Thus, the process of obtaining licenses will probably be easier, hence more optimism.

5.3.3. . The experience effect

Contrary to our expectations, the responses to our questionnaire in 2015 are not affected by investor's previous experience in the energy sector. That is, there are no longer differences in preferences and characteristics between these two groups that make them systematically assess the same project in different ways. There are two possible explanations for this finding. First, inexperienced investors have changed and become more similar to experienced investors. For example, local landowners and other inexperienced investors may have gained more knowledge on the risks and barriers that may prevent their projects from being realised. That is, their cognitive abilities, knowledge and access to information have improved, and they are more able to value every choice against every other choice and arrive at more optimal solutions. Consequently, their decisions are less rationally bounded. Second, the group of inexperienced investors has become smaller, and the ones that left were those with different preferences and other characteristics as compared to experienced investors. In other words, self-selection has occurred. Based on our data, we are unable to judge whether one explanation is more important than the other.

6. Conclusions and policy implications

Policy uncertainty can provide a powerful deterrent to immediate investment. In August 2014, the International Energy Agency (2014) stated: 'The expansion of renewable energy will slow over the next five years unless policy uncertainty is diminished'. In their Guidance for Renewables Support Schemes, the EU Commission (2013) advises that: "unannounced or retroactive changes to support schemes should be avoided as they undermine investor confidence and prevent future investment."

Policymakers and regulators can create uncertainty with respect to future cash flows that a renewable-electricity project could generate and thus provide incentives to postpone even profitable projects according to the traditional net present value investment rule. According to real options theory, investors will value the opportunity to wait when exposed to uncertainty, and as a consequence, the investment threshold will increase. The sources of uncertainty can be political discussions on whether, when and how to support renewable-electricity projects or whether, when and how to remove such support. Similar uncertainties can be created by the design of the support scheme itself.

The requirement that Norwegian renewable-electricity projects must deliver electricity on the electricity grid by 31 December 2020 to obtain the right to sell green certificates for 15 years is an example of design-introduced uncertainty. Initially, prospective investors will speed up the pace of investments to lock in future subsidy revenues. However, as the deadline nears, investors face the risk that construction projects that were started before the deadline may not be completed until after the deadline, thereby erasing a substantial part of future revenues. The problem is accentuated by the short duration of the Norwegian scheme (9 years) and by the fact that the development and construction of hydropower projects require a long lead time, especially projects with regulation reservoirs. Implicitly, the way the certificate scheme is terminated in Norway includes retroactive elements because there is no guarantee that a project started under the support scheme will be completed in time to receive the support.

Our statistical analysis of two surveys of Norwegian investors in hydropower conducted in 2012 and 2015 shows that investors' assessments of barriers and project prospects have developed as predicted by real options theory. This leads us to conclude that the short duration and abrupt termination of the Norwegian part of the scheme may explain why some of the potentially best projects–large hydropower plants with regulation reservoirs–have not been realised under the scheme. Consequently, our study illustrates how policy intervention can sometimes increase market failure by contributing to additional risk and transaction costs. Moreover, our data suggest that a new, emerging group of investors, local landowners without previous experience in the energy sector, has either left the sector during this period and/or learned how to cope with the risks and barriers under the scheme. Based on these results we make two policy recommendations.

First, risk is not inherently bad. Market risk (i.e., fluctuating electricity and certificate prices) reflects uncertainties related to supply and demand. Exposed to such risk, investors will make investment and operational decisions that contribute to a better functioning market. Policy risk (i.e., changes in taxes, subsidies and other policy instruments) reflects the ability of policymakers to flexibly adapt to a changing environment. With a flexible policy, policymakers can respond to improved information on the science of climate change, the cost and benefits of renewable electricity technologies, political decisions and trends in other countries, the impact of an increased share of intermittent, renewable energy sources on the power market, and the need to ensure continued political support. One way to address the problem of uncertainty is to ask: Who is best positioned to cope with these risks, the investor or the government? Renewable electricity investors' needs for long-term stability need to be weighed against the benefits of policy flexibility and a well-functioning market.

Second, we argue that investors should be shielded against some policy risk, namely decisions that are retroactively applied and affect new and old installations alike. This includes retroactive aspects built into the design of renewable-electricity support schemes. We suggest that the cost efficiency of the Swedish-Norwegian tradable green certificate scheme and similar schemes can be improved by choosing the Swedish design, which has a gradual reduction in the number of years investors can sell certificates. Admittedly, a gradual phasing out of support after 2020 will make Norway overshoot its 2020 renewable energy target set by EU, and it will require some not entirely straightforward adjustments in the requirements to buy certificates. Still, these challenges should be overcome to improve the overall cost-efficiency of the joint scheme.

Our analysis examined how one aspect–scheme design–may have reduced the short-term cost-efficiency of the Swedish-Norwegian tradable green certificate scheme. Admittedly, there are other important aspects. For example, differences in taxes and regulation across technologies and between the two countries mean that the playing field is not necessarily level; consequently, a technology-neutral support scheme cannot by itself ensure that the least costly solutions are used first. A gradual awareness of such differences may or may not have contributed to increased pessimism among Norwegian hydropower producers. More research is needed to examine these issues.

Although our analysis shows that there is no longer a systematic difference in project assessments across investor groups, it does not explain why. Empirical investigation of why such differences across investor types exist and disappear would be interesting given the distributed nature of many renewable electricity technologies. Solar and wind power, for example, can be installed by small land and homeowners as well as by large corporations. More research in this field could help policymakers better understand the forces shaping the future market for electricity and form better policies.

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Appendix A

Table A.1
Type of barrier. Multinomial logistic regression model. 2012 survey.

Response categories (Base outcome: No barriers[a])	Economic[a]		Capacity[a]		Process[a]		Risk[a]	
	β[b]	p	β[b]	p	β[b]	p	β[b]	p
Experience (D=1)	−1.301**	0.000	0.568*	0.021	−0.989**	0.004	−1.123*	0.033
Production (GW h)	−0.018*	0.048	−0.005	0.626	−0.005	0.546	−0.009	0.558
Project type: small power plant (D=1)[c]	−0.127	0.755	0.005	0.993	0.140	0.741	−0.539	0.356
Project type: big power plant (D=1)[c]	0.708	0.428	−0.463	0.667	−0.391	0.686	−0.629	0.735
Project type: upgrading (D=1)[c]	0.717	0.333	−0.523	0.611	0.531	0.507	0.552	0.587
Investment cost (ordinal scale)	−0.249	0.133	−0.730**	0.000	−0.308	0.072	−0.510*	0.050
Elspot price area: south-west (D=1)[d]	−1.619**	0.004	−0.571	0.395	−1.023	0.066	−2.382**	0.001
Elspot price area: central (D=1)[d]	−1.697**	0.002	−0.837	0.230	−1.471*	0.011	−3.266**	0.000
Elspot price area: north (D=1)[d]	−1.940**	0.000	−0.957	0.152	−1.802**	0.001	−3.395**	0.000
Elspot price area: west (D=1)[d]	−1.260*	0.015	−0.408	0.525	−1.223*	0.023	−3.163**	0.000
Process stage: application (D=1)[e]	−1.519***	0.000	−1.335**	0.003	−1.833**	0.000	−1.754**	0.008
Process stage: answer (D=1)[e]	0.125	0.802	−2.142*	0.014	−0.254	0.615	1.312	0.055
Process stage: contract (D=1)[e]	−2.209**	0.000	−1.105	0.093	−2.856**	0.000	−1.635	0.074
Constant	4.526**	0.000	3.657**	0.002	4.225**	0.000	4.875**	0.000
N	517		517		517		517	
LR χ^2(12)[f]	236.03**	0.000	236.03**	0.000	236.03**	0.000	236.03**	0.000
McFadden's R^2[g]	0.1302		0.1302		0.1302		0.1302	

Response categories (Base outcome: No barriers[a])	Funding[a]		Internal factors[a]		Other[a]	
	β[b]	p	β[b]	p	β[b]	p
Experience (D=1)	−2.893**	0.001	−1.509*	0.045	−0.579	0.332
Production (GW h)	−0.048	0.439	−0.007	0.863	0.009	0.427
Project type: small power plant (D=1)[c]	0.021	0.982	0.670	0.477	0.037	0.958
Project type: big power plant (D=1)[c]	−10.825	0.991	−13.149	0.990	−1.816	0.369
Project type: upgrading (D=1)[c]	1.731	0.243	1.675	0.268	0.328	0.807
Investment cost (ordinal scale)	−0.453	0.210	−0.801*	0.030	−0.416	0.158
Elspot price area: south-west (D=1)[d]	−1.559	0.180	−3.570**	0.003	−1.591*	0.044
Elspot price area: central (D=1)[d]	−1.552	0.165	−2.855**	0.005	−2.005*	0.022
Elspot price area: north (D=1)[d]	−2.196	0.116	−16.495	0.979	−1.916*	0.018

(continued on next page)

Table A.1 *(continued)*

Response categories (Base outcome: No barriers[a])	Funding[a]		Internal factors[a]		Other[a]	
	β[b]	p	β[b]	p	β[b]	p
Elspot price area: west (D=1)[d]	−1.013	0.363	−2.534**	0.006	−2.486**	0.005
Process stage: application (D=1)[e]	−1.393	0.117	−2.181**	0.005	−2.069**	0.001
Process stage: answer (D=1)[e]	0.322	0.744	−0.439	0.662	0.091	0.901
Process stage: contract (D=1)[e]	−2.494	0.082	−16.687	0.986	−16.379	0.985
Constant	3.454	0.067	5.410**	0.002	3.268*	0.035
N	517		517		517	
LR $\chi^2(12)$[f]	236.03**	0.000	236.03**	0.000	236.03**	0.000
McFadden's R^2[g]	0.1302		0.1302		0.1302	

[a] The reference or base outcome is no barriers.

[b] Coefficients marked with * and ** are significantly different from zero at the 5% and 1% significance levels, respectively.

[c] The reference project type is micro power plants with installed capacity below 1 MW.

[d] The reference Elspot price area is Elspot area 1 in the south-east.

[e] The reference process stage is the preliminary process stage including preliminary planning and notification to the authorities.

[f] $LR\chi^2(12)$ test the null hypothesis that all coefficients except the intercept are zero.

[g] McFadden's R^2 compares a model with just the intercept to a model with all parameters.

Table A.2

Type of barrier. Individual predicted probabilities.[a] 2012 Survey.

Response categories[b]	Economic	Capacity	Process	Risk	No barriers
At means					
	0.29	0.12	0.26	0.04	0.27
Experience					
Experienced	0.23	0.17	0.24	0.03	0.32
Inexperienced	0.41	0.05	0.30	0.05	0.16
Process stage					
Preliminary	0.29	0.15	0.34	0.04	0.11
Application	0.23	0.14	0.19	0.02	0.39
Contract	0.15	0.22	0.09	0.03	0.50
Process stage: Prelemenary					
Experienced, micro power plant, 2.58 GW h[c]	0.27	0.22	0.27	0.05	0.12
Inexperienced, micro power plant, 2.58 GW h[c]	0.42	0.05	0.31	0.06	0.05
Experienced, small power plant, 9.28 GW h[c]	0.22	0.23	0.32	0.03	0.13
Inexperienced, small power plant, 9.28 GW h[c]	0.37	0.06	0.38	0.04	0.06
Experienced, big power plant, 84.82 GW h[c]	0.25	0.19	0.24	0.02	0.25
Experienced, upgrading, 41.28 GW h[c]	0.26	0.10	0.35	0.05	0.11
Process stage: Application					
Experienced, micro power plant, 2.58 GW h[c]	0.20	0.19	0.14	0.03	0.41
Inexperienced, micro power plant, 2.58 GW h[c]	0.39	0.06	0.21	0.04	0.22
Experienced, small power plant, 9.28 GW h[c]	0.16	0.20	0.17	0.02	0.43
Inexperienced, small power plant, 9.28 GW h[c]	0.34	0.06	0.25	0.03	0.24
Experienced, big power plant, 84.82 GW h[c]	0.14	0.13	0.10	0.01	0.61
Experienced, upgrading, 41.28 GW h[c]	0.20	0.10	0.20	0.03	0.41
Process stage: Contract					
Experienced, micro power plant, 2.58 GW h[c]	0.12	0.29	0.06	0.04	0.49
Inexperienced, micro power plant, 2.58 GW h[c]	0.31	0.12	0.12	0.08	0.35
Experienced, small power plant, 9.28 GW h[c]	0.10	0.30	0.07	0.02	0.51
Inexperienced, small power plant, 9.28[c] GW h	0.27	0.13	0.15	0.05	0.38
Experienced, big power plant, 84.82 GW h[c]	0.08	0.18	0.04	0.01	0.69
Experienced, upgrading, 41.28 GW h[c]	0.14	0.16	0.10	0.05	0.55
Elspot price area					
South-east	0.36	0.07	0.26	0.17	0.09
South-west	0.23	0.12	0.30	0.05	0.28
Central	0.26	0.11	0.24	0.03	0.34
North	0.24	0.11	0.20	0.03	0.40
West	0.32	0.13	0.24	0.02	0.27

[a] The predicted probabilities are calculated setting all variables but those explicitely mentioned in the table equal to mean values.

[b] Predictions for only the most frequently chosen response categories in 2012 and 2015 are presented.

[c] The annual production volume is set equal to the average level in our 2012 sample for each project type; that is, 2.58 GW h for micro power plants, 9.28 GW h for small power plants, 84.82 GW h for big power plants and 41.28 for upgrading existing power plants.

Table A.3
Degree of optimism. Multinomial logistic regression model. 2012 survey.

Response categories (Base outcome: VUL/MUL[a])	EL[a]		ML[a]		VL[a]	
	β[b]	p	β[b]	p	β[b]	p
Experience (D=1)	-1.895^{**}	0.000	-1.743^{**}	0.000	-1.460^{**}	0.002
Production (GW h)	−0.130	0.382	−0.006	0.610	−0.008	0.482
Project type: small power plant (D=1)[c]	−0.685	0.187	−0.330	0.510	−0.250	0.620
Project type: big power plant (D=1)[c]	2.690	0.151	3.107	0.076	2.966	0.093
Project type: upgrading (D=1)[c]	16.127	0.990	16.534	0.990	15.856	0.990
Investment cost (ordinal scale)	0.139	0.558	−0.176	0.936	0.298	0.177
Elspot price area: south-west (D=1)[d]	−0.409	0.600	−0.873	0.241	0.110	0.886
Elspot price area: central (D=1)[d]	−0.833	0.283	−1.263	0.086	−0.747	0.332
Elspot price area: north (D=1)[d]	−0.320	0.700	−0.550	0.464	0.488	0.525
Elspot price area: west (D=1)[d]	−1.446	0.066	−1.138	0.103	−0.790	0.177
Process stage: application (D=1)[e]	0.186	0.702	1.993^{**}	0.000	3.118^{**}	0.000
Process stage: answer (D=1)[e]	-1.172^{*}	0.036	0.233	0.635	1.138^{*}	0.032
Process stage: contract (D=1)[e]	13.690	0.990	14.182	0.989	18.472	0.986
Constant	1.746	0.175	1.674	0.168	−1.150	0.378
N[e]	399		399		399	
LR $\chi^2(12)$[f]	213.34	0.000	213.34	0.000	213.34	0.000
McFadden's R^2[g]	0.2042		0.2042		0.2042	

[a] The abbreviations VUL, MUL, EL, ML and VL refer to 'very unlikely', 'more unlikely than likely', 'equally likely', 'more likely than likely' and 'very likely', respectively.
[b] Coefficients marked with * and ** are significantly different from zero at the 5% and 1% significance levels, respectively.
[c] The reference project type is micro power plants with installed capacity below 1 MW.
[d] The reference Elspot price area is Elspot area 1 in the south-east.
[e] The reference process stage is the preliminary process stage including preliminary planning and notification to the authorities.
[f] $LR\chi^2(12)$ test the null hypothesis that all coefficients except the intercept are zero.
[g] McFadden's R^2 compares a model with just the intercept to a model with all parameters.

Table A.4
Degree of optimism. Individual predicted probabilities.[a] 2012 survey.

Response categories[b]	VUL/MUL	EL	ML	VL
At means				
	0.04	0.14	0.33	0.49
Experience				
Experienced	0.06	0.12	0.31	0.51
Inexperienced	0.01	0.17	0.37	0.45
Process stage				
Preliminary	0.25	0.36	0.26	0.13
Application	0.05	0.08	0.34	0.53
Contract	0.00	0.02	0.03	0.95
Process stage: Prelimenary				
Experienced, micro power plant, 2.58 GW h[c]	0.44	0.32	0.16	0.09
Inexperienced, micro power plant, 2.58 GW h[c]	0.11	0.55	0.24	0.10
Experienced, small power plant, 9.28 GW h[c]	0.58	0.19	0.14	0.09
Inexperienced, small power plant, 9.28 GW h[c]	0.19	0.42	0.27	0.12
Experienced, big power plant, 84.82 GW h[c]	0.09	0.32	0.43	0.17
Experienced, upgrading, 41.28 GW h[c]	0.00	0.45	0.44	0.11
Process stage: Application				
Experienced, micro power plant, 2.58 GW h[c]	0.11	0.10	0.29	0.50
Inexperienced, micro power plant, 2.58 GW h[c]	0.02	0.14	0.37	0.47
Experienced, small power plant, 9.28 GW h[c]	0.15	0.06	0.28	0.51
Inexperienced, small power plant, 9.28 GW h[c]	0.04	0.09	0.37	0.50
Experienced, big power plant, 84.82 GW h[c]	0.01	0.05	0.42	0.51
Experienced, upgrading, 41.28 GW h[c]	0.00	0.08	0.51	0.40
Process stage: Contract				
Experienced, micro power plant, 2.58 GW h[c]	0.00	0.03	0.02	0.95
Inexperienced, micro power plant, 2.58 GW h[c]	0.00	0.04	0.03	0.93
Experienced, small power plant, 9.28 GW h[c]	0.00	0.02	0.02	0.96
Inexperienced, small power plant, 9.28 GW h[c]	0.00	0.03	0.03	0.94
Experienced, big power plant, 84.82 GW h[c]	0.00	0.01	0.03	0.95
Experienced, upgrading, 41.28 GW h[c]	0.00	0.03	0.05	0.92

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Table A.4 *(continued)*

Response categories[b]	VUL/MUL	EL	ML	VL
Elspot price area				
East	0.02	0.16	0.45	0.36
South	0.03	0.15	0.26	0.56
Central	0.05	0.18	0.33	0.44
North	0.02	0.12	0.26	0.59
West	0.06	0.10	0.39	0.44

[a] The predicted probabilities are calculated setting all variables but those explicitely mentioned in the table equal to mean values.

[b] The abbreviations VUL, MUL, EL, ML and VL refer to 'very unlikely', 'more unlikely than likely', 'equally likely', 'more likely than likely' and 'very likely', respectively.

[c] The annual production volume is set equal to the average level in our 2012 sample for each project type; that is, 2.58 GW h for micro power plants, 9.28 GW h for small power plants, 84.82 GW h for big power plants and 41.28 for upgrading existing power plants.

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