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# The impact of behavioural factors in the renewable energy investment decision making process: Conceptual framework and empirical findings

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ABSTRACT

Investments in renewable energy (RE) technologies are regarded with increasing interest as an effective means to stimulate growth and accelerate the recovery from the recent financial crisis. Yet, despite their appeal, and the numerous policies implemented to promote these technologies, the diffusion of RE projects remains somehow below expectations. This limited penetration is also due to a lack of appropriate financing and to a certain reluctance to invest in these technologies. In order to shed light on this phenomenon, in this paper we examine the decision making process underlying investments in RE technologies. We propose and test a conceptual model that examines the structural and behavioural factors affecting the investors decisions as well as the relationship between RE investments and portfolio performance. Applying econometric techniques on primary data collected from a sample of European investors, we study how the investors' a-priori beliefs, their preferences over policy instruments and their attitude toward technological risk affect the likelihood of investing in RE projects. We also demonstrate that portfolio performance increases with an increase of the RE share in the portfolio. Implications for scholars, investors, technology managers and policy makers are derived and discussed.



## 1. Introduction

In the World Energy Outlook 2009 (IEA, 2009a), the International Energy Agency launches an extremely clear and compelling message: current energy policies cannot be maintained if we want to avoid catastrophic consequences for the climate. An "energy technology revolution" is called for, in order to meet the challenging objective of halving $CO_2$ emissions by 2050 compared with 2005 levels (IEA, 2008a). "The task is urgent; we must ensure that investment decisions taken now do not leave us with inefficient, high-emitting technologies in the long term" (IEA, 2009b, page 1). It seems that a new era is about to start, where renewable energy technologies are no longer considered a "Cinderella option" (Grubb, 1990) but are increasingly seen as "survival technologies" (Leggett, 2009).

To increase the share of renewables in the global energy mix, significant innovations are needed not only in the technical field, but also in the social and institutional context (Krewitt et al., 2007). Improved policy frameworks for renewable energies are required, which correct externalities and ensure a more level playing field. Furthermore, cooperation between public and private actors needs to be strengthened. Both groups play a key role. Policy makers should create incentives to ensure that the necessary investments are undertaken (IEA, 2007). In turn, the private sector can play a crucial role in raising the required financial resources to facilitate the transition towards a low-carbon economy.

Energy analysts estimate that huge additional investments are needed to realize this transition to a low carbon economy. Needless to say, this is particularly challenging in the current economic context, as investors are reluctant to do so unless dedicated policies are implemented to stimulate renewable energy investments. Recently, a group of 181 investment institutions which collectively represent assets for 13 trillion US dollars has stated that clear and appropriate long-term policy signals are essential to help investors integrate climate change considerations into decision-making processes and reallocate capital to low-carbon technologies (UNEP FI, 2009). Indeed, it seems that the main barrier to investments in greenhouse gas mitigation technologies is not the lack of capital, but rather the lack of appropriate policy packages to attract it (Usher, 2008a). As a matter of fact, many policies implemented so far have attained only partial results, because they have been unable to leverage the true drivers of the investment decision process.

An emerging body of literature has started investigating how policies should be designed to mobilize investments in the renewable energy sector. Several studies at the EU level have

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provided a measure for policy effectiveness (EC SEC, 2008; OPTRES, 2007; PROGRESS, 2008). Yet, although distinguished, these studies provide only limited insights into the investors' perspective.

The lack of emphasis on investors' preferences is an important shortcoming in the extant research, which is acknowledged in the management and the finance literature (Bürer and Wüstenhagen, 2009; Russo, 2003; Shleifer, 2000). This paper intends to fill this knowledge gap by shedding new light on the process through which investors allocate capital to renewable energy projects. To this end, we develop and empirically test a model that takes explicitly into account behavioural factors to analyse investors' decisions. The model examines how a priori beliefs vis-à-vis renewable energy technologies, policy preferences and technological risk attitudes influence the agents' willingness to invest in renewables, and how this, in turn, affects the investment performance. The model is empirically tested using primary data collected from a sample of European investors. Europe is an appropriate context for our empirical analysis, both for its leading role on climate change and energy policies and because it is the world region that attracted the largest share of new renewable energy investments in 2008 (UNEP and NEF, 2009).

The paper makes several contributions. First, by providing a better understanding of the investors' decision making process, the study will help policy makers design more effective policy instruments to support the market deployment of renewable energy technologies. Second, by extending the empirical analysis to a wide range of institutional investors, the paper makes a methodological contribution too. So far, the few studies in this field have focused on a restricted group of investors, namely venture capitalists. By expanding the scope of the analysis to a broader set of financial actors, this work will contribute to extend the validity of previous findings to a broader and more general context.

The remainder of the paper is structured as follows: the next section reviews the most relevant literature and the theoretical foundations of our work. Section 3 presents a conceptual model linking investors' beliefs, investment decisions and performance. Section 4 describes the research design and the empirical methods employed to test the model. Section 5 illustrates the main findings. Finally, Section 6 highlights the main conclusions and discusses implications for theory and practice.

## 2. Literature review and theoretical background

### 2.1. Renewable energy investments and financial performance

Investments in renewable energy technologies have increased steadily over the last years. Analysts estimate that from 2002 until the end of 2009, the green energy market has attracted more than USD 650 billion cumulatively (NEF, 2009a; UNEP and NEF, 2009). The years 2006 and 2007 have experienced double-digit growth, whilst 2008 and 2009 have been affected by the consequences of the global financial crisis, which has impacted the clean energy market both directly (through a liquidity squeeze) and indirectly (via a general fall in global energy demand associated with lower oil and gas prices). Even though the economic downturn has hit the renewable energy market quite severely, experts believe that in the long term the clean energy sector should recover better and faster than others. Many governments have launched green fiscal measures that have contributed to moderate the fall of investments in this industry. Furthermore, the IEA recently called for a "Clean Energy New Deal" to exploit the financial and economic crisis as an opportunity to induce a permanent shift in investments to low-carbon technologies (IEA, 2009c).

Some experts recognize that low carbon technologies can offer tremendous opportunities to overcome the current crisis thanks to the numerous environmental, economic and societal benefits they incorporate (IEA, 2009c; Ragwitz et al., 2009; Deutsche Bank, 2008). Fulton (Deutsche Bank, 2008) identifies a "safety net effect" for clean energy investments determined by government regulations, which ensure a built-in advantage over most other sectors in the long term.

As scientific evidence on human-induced climate change becomes more robust and consensus over the urgency and the necessity of taking action is reached, practitioners and policy makers are provided with a number of dedicated tools for financial analysis and decision making. Comparative studies on the performance of renewable energy investments versus traditional assets are also becoming common. These studies show that, in recent years, investments in renewable energy technologies have lead to superior performance compared to more traditional investments (Deutsche Bank, 2009; NEF, 2009b).

Providing an explanation for this phenomenon, by clarifying the underlying relations between renewable energy investments and financial performance would represent a useful theoretical contribution and it would also help policy makers design more effective policies to attract further investments in this area. Unfortunately, management scholars have somewhat overlooked this topic so far. Given the lack of studies specifically addressing the link between renewable energy investments and financial performance, some useful insights can be obtained from studies in related fields, such as those examining the relationship between environmental performance and financial performance. Scholars seem to suggest that there is a positive relationship between the companies' involvement in environmental and social activities and their financial performance (Cohen et al., 1995; Dowell et al., 2000; Hart and Ahuja, 1996; Porter and van der Linde, 1995; Reinhardt, 1999; Russo and Fouts, 1997). However as King and Lenox (2001) point out, correlative studies offer only a partial picture to corporate managers and policy makers, because they do not indicate the direction of causality. These authors therefore call for additional research in this area, to explore how underlying firm characteristics affect the relationship between environmental performance and financial performance. This view is shared by Weber et al. (2005) who state that while the positive correlation between environmental performance and financial performance is widely accepted, the strength of the correlation and its genesis are still often unclear.

Although the relationship between renewable energy investments and financial performance remains underexamined and somehow uncertain, there is increasing evidence that policy targets and the accompanying policy instruments deployed at the national, regional and global level have a strong influence on the investors' decision to allocate capital to renewable energy projects.

### 2.2. Policy preferences and effectiveness

Policy targets and measures have been set by several countries worldwide to support the deployment of renewable energy technologies. According to REN21 (2010) more than 80 countries have already established renewable energy policies. Policies can play a crucial role in reducing the risk associated to an investment decision, by providing a stable framework and decreasing market uncertainty.

As pointed out by Ecofys (2008) "commitment, stability, reliability and predictability are all elements that increase confidence of market actors, reduce regulatory risks, and hence significantly reduce the cost of capital". However, the relationship between policies and investment flows in a dynamic environment is not straightforward. Sometimes even ambitious policy targets are not able to catalyse investments. Even worse, the policy framework is sometimes perceived as a potential risk factor per se. In fact, policies and supporting measures can also change, thereby affecting the profitability of investments. Examples are changes in – or even ending of – the policy support schemes or changes in the market structure. As most markets for clean technologies are regulated under policy schemes, this risk is of particular importance for renewable energy technologies (Ecofys, 2008).

An increasingly relevant body of literature is investigating the role of public regulators, by looking at how policies should be designed to stimulate the growth of renewable energy innovations. Scholars have extensively disputed over the effectiveness of different policy support systems in achieving policy objectives. For instance, Menanteau et al. (2003) have highlighted the positive role of feed-in tariffs in leading to an increase of the renewable energy share by lowering the risk associated with the investment decision. Other studies provide support to the hypothesis that feed-in tariffs are a more effective policy scheme, compared to market-based approaches (Butler and Neuhoff, 2004; Sawin, 2004). In contrast, other analyses indicate that the hidden costs of feed-in tariffs may offset their benefits by determining liabilities in the long term (Liebreich, 2009).

As these alternative perspectives suggest, there is increasing evidence that policy effectiveness should be measured along a wider set of attributes, which incorporate not only the type of support scheme but also other important characteristics such as the design of the administrative framework, and the level and duration of the support provided to renewable energy projects. For example, the IEA (2008b) has found that feed-in tariffs and tradable green certificates can be equally effective in promoting the renewable energy market depending on the technology and on some country-specific conditions. It is rather the adherence to key policy design principles and the coherence of policy measures which determine the effectiveness and efficiency of renewable energy policies. This analysis confirms previous findings (Held et al., 2006), which have already highlighted the important role of long term policy frameworks that enable the successful deployment of renewable energy technologies by providing clear signals to the market.

While these studies have focused mostly on the policy level, other empirical works have started incorporating the investor's perspective into the picture, so as to understand the attitude of financial actors vis-à-vis the various policy instruments available. In particular, Bürer and Wüstenhagen (2009) have surveyed a sample of 60 venture capital and private equity funds to analyse investors' preferences for different types of support schemes. Along the same lines, Lüthi and Wüstenhagen (2009) have examined the influence of a set of policy attributes on the investment decisions of a sample of European PV project developers.

These studies have the clear merit of shedding further light on the relationship between policies and investment decisions by incorporating the investors' perspective into the picture. Yet, by overlooking the role that behavioural factors play in this process, they represent only a first step towards a better understanding of the relationship between policy instruments and investment decisions. The present paper intends to complement and extend this literature, by examining how cognitive elements and behavioural factors and attitude towards technological risk influence an actor's willingness to invest in renewable energy projects. We believe this is an important contribution to the literature, because incorporating these factors can provide a much more accurate description of the relationship between policies and investments and, in the end, to the design of better and more effective policy instruments.

### 2.3. Behavioural factors affecting investment decisions

The idea that agents are not fully rational and that behavioural factors may strongly affect human decisions is not new. Since the pioneering work of Simon (1957) it has gained increasing recognition in a number of disciplines, including economics (Van Zandt, 1999), and operations management (Loch and Yaozhong, 2005; Bendoly, 2006; Gino and Pisano, 2008). Yet, it has been seldom applied to study investments in renewable energy technologies.

Behavioural finance traces its roots back to the seminal work by Amos Tversky and the Nobel Laureate Daniel Kahneman in the 1970s. The two authors challenged the perfect rationality principle by applying a cognitive psychology perspective to analyse the most common misperceptions in many decision-making processes. They argued that people tend to rely on a series of heuristics when making judgements under uncertainty, and this can lead sometimes to severe and systematic errors in assessing the probability of events (Tversky and Kahneman, 1974).

As opposed to efficient market theory, behavioural finance argues that individuals are not fully rational (Akerlof and Yellen, 1987; Barberis and Thaler, 2003; Miller, 1977). It also argues that they do not deviate from rationality randomly, but rather that most agents do so in similar ways.

Behavioural finance approaches have been applied to underline a series of market "anomalies", including the limited effects of arbitrage (Froot and Dabora, 1999; Rosenthal and Young, 1990; Shleifer and Vishny, 1997), volatility of prices (Shiller, 1981), overreaction and underreaction phenomena (Barberis et al., 1998; Daniel et al., 1998; DeBondt and Thaler, 1985), the equity premium puzzle (Barberis et al., 1999; Bernantzi and Thaler, 1995; Jegadeesh and Titman, 1993; Mehra and Prescott, 1985), underperformance of mutual fund managers and pension fund managers relative to passive investment strategies (Malkiel, 1995), market's reaction to non-information (Cutler et al., 1991; Roll, 1984), amongst others.

As stated by Shleifer (2000, p.181) "the perception of risk is one of the most intriguing open areas in behavioural finance". He adds that "the emphasis on investors is entirely foreign to traditional finance, which has achieved its success by assuming precisely that investors do not matter except for the determination of the equilibrium discount rate…". The author highlights the need to develop a conceptual model to fully capture the way investors assess risk, their rules of thumb and how they forecast expected scenarios. In turn, Thaler (1999) points out that adding a human element to financial market analysis can lead to a better understanding of the mechanisms underlying market behaviour.

The venture capital literature (Gompers and Lerner, 2001; March, 1994; Zacharakis and Shepherd, 2001) has acknowledged the need to better clarify the role of cognitive factors in entrepreneurial decision making processes, as well as these agents' understanding of risk and return. Yet, further empirical and theoretical work still needs to be done, particularly to study entrepreneurial firms in the domain of sustainable technologies (Jacobsson and Johnson, 2000; Russo, 2003).

We aim to apply this behavioural perspective to the domain of renewable energy investments. To this end, we develop and test a conceptual model that examines the behavioural factors affecting the investors' decisions, as well as the relationship between renewable energy investments and portfolio performance. The model is described in detail in the next section.

## 3. Conceptual model

The analysis of the above literature and a series of exploratory interviews with industry experts have provided the groundwork for the development of the conceptual model in Fig. 1. The model, which includes two stages, examines whether behavioural factors have a measurable influence on the decision to invest in renewable energy projects, and whether, in turn, the share of renewable energy in the portfolio that results from these decisions is reflected into the portfolio performance.

The first stage examines the factors influencing an investor's willingness to invest in renewable energy technologies. Controlling for the investor's experience and the type of firm undertaking the investment, we expect that an agent willing to invest in renewable energy technologies is affected by three general categories of behavioural factors: a priori beliefs, policy preferences and attitude towards technological risk. A priori beliefs are the result of the investors' personal history, educational backgrounds, and personal previous experience with renewable energy investments. As the success of a renewable energy project (and the resulting appeal of such a project for an investor) depends on the technological feasibility of the project and on the market's ability to value the project, we argue that investors have a priori beliefs with respect to both aspects. Accordingly, we expect that investors are influenced by two types of a priori beliefs. They reflect the investors' trust in the technologies considered for the investment, as well as their trust in the efficiency of the market mechanisms. We argue that both types of a priori beliefs have a positive impact on the investors' willingness to allocate capital to renewable energy projects, and we propose the following hypotheses:

**Hypothesis 1a.** The higher is the level of confidence in market efficiency the larger is the renewable energy share in the investment portfolio.

**Hypothesis 1b.** The higher is the level of confidence in the technological effectiveness of renewable energy systems, the larger is the renewable energy share in the investment portfolio.

In the current energy market, policies play a paramount role in determining the success of a renewable energy project. Thus, we expect that an agent's willingness to invest in a renewable energy project will be also strongly influenced by his preferences over different policy schemes. The analysis of the literature and some interviews with relevant stakeholders have suggested that the effectiveness of renewable energy policies depends on a large set of policy attributes, which include a combination of the right policy signals, incentive levels, program administration and predictability. By the same token, various elements of policy play a role in determining the decision to invest in renewable energy projects. Based on this review and the advice of industry experts, we have initially taken into account five different policy attributes: the type of support scheme, the level of support, the duration of the support, the length of the administrative process and the degree of social acceptance. After a preliminary screening of these attributes and after analysing the results of the conjoint analysis that revealed how investors assigned extremely low utility values to the last two attributes (see Section 4.4), we have

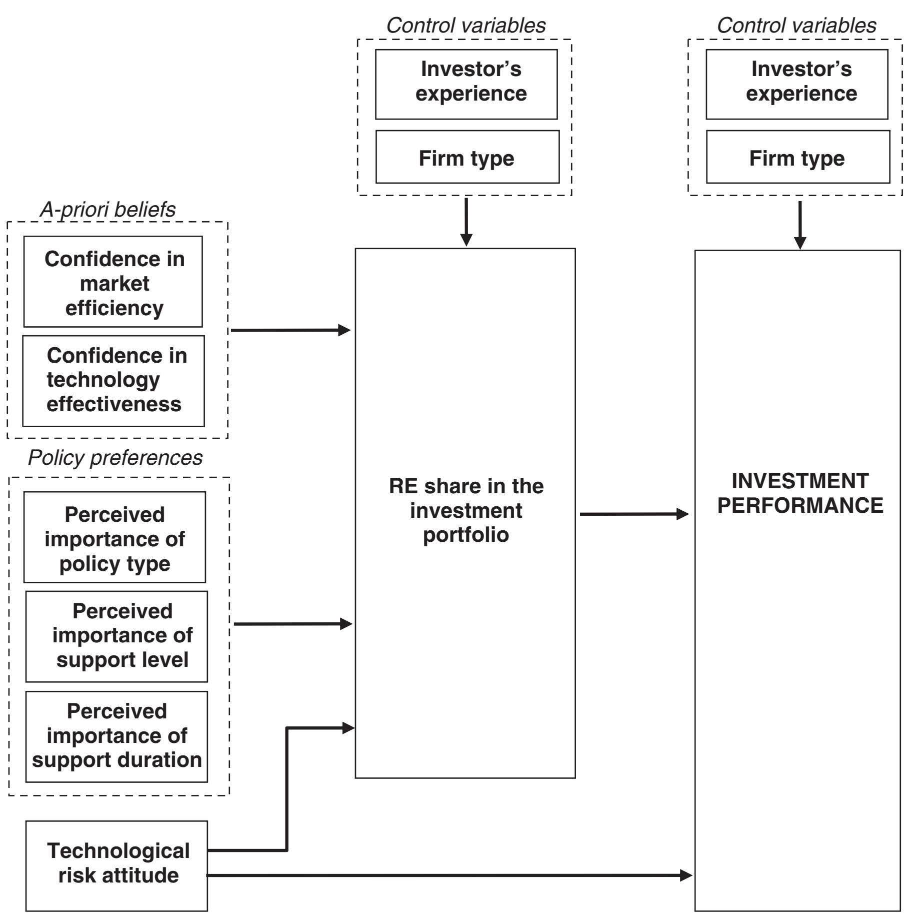


**Fig. 1.** Conceptual model.

retained only three policy attributes as main elements influencing the investment decisions: the type of policy scheme, the level of support and the duration of the support. We expect the perceived importance of policy attributes to strongly influence the willingness to invest in renewable energy projects. We propose therefore the following hypotheses:

**Hypothesis 2a.** The renewable energy share in the investment portfolio is strongly dependent upon the perceived importance of the type of policy scheme.

**Hypothesis 2b.** The renewable energy share in the investment portfolio is strongly dependent upon the perceived importance of the level of support.

**Hypothesis 2c.** The renewable energy share in the investment portfolio is strongly dependent upon the perceived importance of the duration of support.

Finally, as renewable energy technologies are sometimes perceived as unproven technologies with greater technological uncertainty but, also, with the possibility to grant higher potential returns in the future, we argue that an investor's attitude vis-à-vis technological risk has also a strong influence on his willingness to invest. We expect investors adverse to technological risk to be less likely to invest in renewables compared to more risk oriented actors. We propose therefore the following hypothesis:

**Hypothesis 3.** A higher propensity to invest in radically new technologies is associated with a higher renewable energy share in the investment portfolio.

The second stage of the model considers the factors influencing the investment performance. Controlling for the investor's experience and the type of firm undertaking the investment, we expect that the performance of the investment is dependent upon two variables: the renewable energy share in the portfolio and the investors' attitude towards technological risk.

As renewable energy technologies have a higher degree of technological and market risks, but also the potential of guaranteeing higher future returns, providing these risks are properly managed, we expect the investment performance to be positively correlated with the renewable energy share in the portfolio. We propose therefore the following hypotheses:

**Hypothesis 4.** The higher is the share of renewables in the portfolio, the higher is the investment performance.

**Hypothesis 5.** The propensity to invest in radically new technologies has a strong impact on the investment performance.

For sake of completeness the existence of a reverse feedback relationship between investment performance and RE share in the portfolio should also be examined. One would expect that, over time, rational investors who obtained above-average returns by including renewable in their portfolios, will also tend to increase the RE share in their portfolios in the next investment round. Therefore, it would be interesting to test the relationship between investment performance at time $t$ and the RE share in the investment portfolio at time $t+1$. However, addressing this question requires a dedicated experimental design which is outside the scope of this paper.

## 4. Methods

### 4.1. Research design

The stylized model outlined in Fig. 1 was tested by analysing a sample of cross-sectional data collected by the authors via a web-based survey. The research design included a combination of qualitative and quantitative methods (Black, 1999; Snow and Thomas, 1994) and was articulated into three phases. In the first phase, documentary analysis and interviews with experts were carried out to test and refine the conceptual model and to assure content validity for the various constructs in the model. Special attention was dedicated to the behavioural finance literature in order to operationalize and validate the cognitive variables in the model (Menichetti, 2008). In the second phase of the research, a web-based survey questionnaire was developed, pre-tested, and administered to a sample of European investors. In the third phase, the data were analysed by means of adaptive conjoint analysis (Luce and Tukey, 1964; Green and Srinivasan, 1978; Johnson, 2001; Louviere and Woodworth, 1983) and multivariate regressions.

As discussed more in detail below, the purpose of the questionnaire was both to develop valid psychometric measurements based on Likert scales and to elicit policy preferences through adaptive conjoint analysis. This method was preferred to qualitative ranking for determining investors' preferences for methodological reasons. By inferring the utility of each attribute from the respondents' trade-off decisions, adaptive conjoint analysis does not require the researcher to ask direct questions on the desirability of the chosen attribute levels. In this respect, conjoint analysis offers the advantage to mimic the decision making process in real life situations (Orme, 2009). Although the use of conjoint analysis is not radically new in management and entepreneurial research (see for example: Birley et al., 1999; Dufhues et al., 2004; Landström, 1998; Muzyka et al., 1996; Riquelme and Rickards, 1992), to the authors' knowledge this paper represents one of the earliest attempts to apply this technique to assess investors' preferences over renewable energy policy characteristics (a similar experiment was conducted by Lüthi and Wüstenhagen, 2009).

### 4.2. The survey instrument

The questionnaire covered four main areas and included 35 specific questions. The first section aimed at determining the diffusion of renewable energy investments. Respondents were asked to indicate the share of their investment portfolios allocated to renewables and the specific technologies included in their portfolios. It is worth highlighting that the term "portfolio" was used quite broadly. In our research we targeted a diversified group of investors, who had different profiles and were involved at different stages of the technology value chain. Therefore, given the different nature of the investments these agents undertake, it was not possible to provide a common definition for the term portfolio. In order to avoid possible misunderstandings and to maximize the generalizability of our results, in the questionnaire respondents were explicitly invited to consider the most representative investment undertaken by their company and to refer to this investment.

The purpose of the second section was to assess the investors' knowledge and awareness of the technological and market potential of renewable energy sources, their a priori beliefs about the role of market and policy in supporting the growth of renewables, as well as their attitude toward technological innovation.

The third section was dedicated to elicit preferences for renewable energy policies. Respondents were asked to compare a number of alternative policy options to support an onshore wind project, which differed in the type of policy scheme implemented, level of support, duration of the support, length of the administrative process and degree of social acceptance.

The fourth section of the questionnaire was dedicated to performance assessment: respondents were solicited to provide a self-assessment of the perceived past performance and of the expected future performance of their investments compared to their direct competitors. These were defined as other investors operating in the same market. Finally, the questionnaire also included a series of demographic questions covering the company profile, the investors' experience with renewable energy investments, as well as their age, their educational background and their position in the organizations.

### 4.3. Sample selection and sample characteristics

As a first step of the data collection process, a database of target respondents was developed in the preliminary phases of the research project. Contact details of companies and their senior representatives were gathered from multiple sources including the websites of the European Venture Capital Association and its national affiliates, The Business Place website and other specialised directories. Additional sources of information used included the lists of participants to some of the most reputed international conferences on sustainable energy finance, such as the Wind Energy Conference for Equity Investors, the Renewable Energy Finance Forum, the New Energy Finance Summit. Overall, a list of about 300 contacts in various European countries was collected. Investor profiles include venture capitalists, private equity funds, asset managers, investment funds, commercial banks and energy companies.

The administration of the survey took place between June and September 2009. Before launching the survey, a pre-test with a limited number of investors from the sample and other relevant stakeholders was conducted in order to validate the measurement and refine the research instrument. The investors selected for the full scale survey received individual invitations via email. Reminders were also sent at regular intervals. Furthermore, a link to the survey was posted on the UNEP Sustainable Energy Finance Initiative website. In order to limit the impact of self-assessment and maximize the accuracy of responses, we followed Huber and Power's (1985) guidelines: we guaranteed that the information collected would remain completely confidential; we agreed to distribute a personalized feedback document and we promised to share the final results of the study with respondents.

We received 136 responses. However, 43 responses had to be discarded because they were either plainly unreliable or greatly incomplete. As a result, 93 questionnaires were ultimately retained for the analysis, corresponding to an effective return rate of 31%, which is in line with studies of this nature.

**Table 1**
Descriptive statistics for the research sample.

| | Research sample | |
|---|---|---|
| | ***N*** | **%** |
| **Exposure to the RE investing domain** | | |
| Yes | 62 | 67 |
| No | 31 | 33 |
| **Investment by technology** | | |
| Solar photovoltaic | 36 | 57 |
| Wind onshore | 29 | 47 |
| Biomass | 21 | 33 |
| Solar thermal | 15 | 24 |
| CSP | 14 | 23 |
| Hydropower | 13 | 21 |
| Wind offshore | 12 | 19 |
| Geothermal | 11 | 17 |
| Biofuels | 4 | 7 |
| Tidal/Wave | 3 | 5 |
| **Share of renewables in the investment portfolio** | | |
| Less than 5% | 12 | 19 |
| From 5% to 9% | 6 | 10 |
| From 10% to 49% | 16 | 26 |
| From 50% to 99% | 11 | 18 |
| I only invest in renewables | 17 | 27 |
| **Experience in the RE investing domain** | | |
| No experience | 10 | 16 |
| Less than 5 years | 29 | 47 |
| From 5 to 10 years | 17 | 27 |
| More than 10 years | 6 | 10 |
| **Company profiles** | | |
| Venture capital, private equity or hybrid | 34 | 37 |
| Banks, hedge funds, pension funds and insurance companies | 10 | 11 |
| Project developers and utilities | 5 | 6 |
| Infrastructure Funds | 4 | 4 |
| Private companies | 8 | 8 |
| Engineering/other | 5 | 6 |
| No response | 26 | 28 |
| **Age of respondents** | | |
| Under 30 years | 10 | 11 |
| From 31 to 40 years | 35 | 37 |
| From 41 to 50 years | 11 | 12 |
| More than 50 years | 6 | 7 |
| No response | 31 | 33 |
| **Educational background** | | |
| Economics and business administration | 24 | 25 |
| Finance | 16 | 18 |
| Legal | 2 | 2 |
| Engineering | 24 | 25 |
| Multidisciplinary | 27 | 29 |

Table 1, which displays descriptive statistics, suggests that the sample is fairly well diversified, with respect to the degree of renewable energy penetration in the investment portfolios, the types of technologies included in the portfolios, as well as the profile of investors. The data indicate that about two thirds of the respondents currently invest in renewables. Renewables represent at least 10% of the portfolio for over 70% of respondents, while 27% of respondents invest only in renewables. Solar photovoltaics and wind onshore are the two most represented technologies, being in the investment portfolios of 57% and 47% of the respondents, respectively. Biomass, solar thermal and concentrated solar power follow, while tidal and wave are the least represented technologies (accounting for only 5% of the portfolio). With respect to the investors' profiles, the sample is also well diversified. Although more than half of respondents who have answered the question declare to work for a venture capitalist (VC) and private equity (PE) funds or hybrid combinations of both, other investors are well represented too. Private companies and investment funds constitute 8% of the sample. Banks, insurance companies, pension funds and hedge funds total 10% of the sample, project developers and utilities cover 6% of the sample, and infrastructure funds account for 4%. The average investor's experience in the renewable energy sector is not particularly high. Only 27% of respondents have more than 5 years of experience with renewables, and only 10% have more than 10 years experience. The majority (47%) declared having less than 5 years of experience, and the remainder has not experience at all. This is not surprising, if we consider that the renewable energy market has started experiencing a considerable growth only quite recently and still represents a limited fraction of the global energy market (Usher, 2008b). It also worth noting that, although respondents seem to have rather limited experience with the renewable energy industry, on average they have considerable overall working experience. By looking at their age groups, it can be noted that 84% of those who have answered this question are at least 30 years old or older, 27% are older than 40 years old and 10% are older than 50 years. This suggests that investors have acquired relevant experience in other sectors before switching to the renewable energy business. Finally, in terms of education almost one third of respondents have a multidisciplinary background; 25% have studied engineering and 25% economics and business administration.

### 4.4. Operationalization of variables

The variables in the conceptual model were operationalized using a combination of quantitative indicators and psychometric scales, as appropriate. A priori beliefs were operationalized by means of multi-item psychometric scales. Respondents were first asked to express their degree of agreement with some statements reflecting six common beliefs about renewables, using a 5-point likert scale. These questions were developed using a cognitive psychology approach, employing alternative formulations of the same problem to assess the influence of variations in framing on choice selection (Tversky and Kahneman, 1981). The items were then factor analysed using orthogonal rotation. After eliminating two items with high levels of cross loadings, the procedure yielded a two-factor solution representing, respectively, the degree of confidence in renewable energy technological adequacy and the degree of confidence in market efficiency. The two variables were finally operationalized by aggregating the items tapping into each construct.

The degree of *confidence in RE technology effectiveness* was assessed by means of the following two items: (a) energy supply from new renewable electricity sources (e.g. wind and solar) will grow by more than 10% per year worldwide over the next 20 years; (b) solar energy is a low-density resource, requiring a lot of land: therefore it will never achieve a significant share of the world's energy mix (reversed). The degree of *confidence in market efficiency* was assessed by means of the following two items: (c) market forces alone will never lead to a significant exploitation of renewables (reversed); (d) government intervention does more harm than good, let governments stay out of the way.

The attitude for technological risk was assessed by means of a two-step procedure. Respondents were first asked to allocate a hypothetical investment budget of USD 10 million to three different solar technologies with increasing degrees of technological uncertainty: crystalline silicon cells, thin film cells and third-generation solar cells based on nanostructures. *Technological risk attitude* was then measured as the ratio of the amount allocated to the radically innovative technologies (nanostructures) to the amount allocated to the less innovative technologies (crystalline silicon and thin films).

The three policy variables (importance of the *type of policy*, importance of the *level of support* and importance of the *duration of the support*) were measured using the results of the conjoint analysis. In the survey, respondents were asked to choose among different attributes and levels of a hypothetical policy framework to support an onshore wind project in Europe. In order to reduce the possible influence of unobserved factors and to allow for a fair comparison among attributes, some characteristics of the project, such as the availability of wind and the project size, were set by the researchers and fully disclosed. Five different policy attributes (type of policy, level and duration of the support, length of the administrative process and degree of social acceptance) were presented, each of which with different attribute levels. The combination of attributes and attribute levels lead to a total number of 14 individual options that respondents had to compare (see Table 2).

The respondents' choices were then analysed using a dedicated software for conjoint analysis (Sawtooth SSI Web 6.6), which produced estimates for both the individual utilities of each choice, and the average importance of the attributes. These average importance scores were finally used to operationalize the three policy variables retained in the regression model.

**Table 2**
Attributes and attribute levels of renewable energy policies selected under the present research.

| Attributes | Levels |
|---|---|
| 1. Type of renewable energy policy | 1. Tax incentives/investment grants<br>2. Tender schemes<br>3. Feed-in tariffs<br>4. Tradable Green Certificates/ Renewable Portfolio Standard |
| 2. Level of the incentive (the premium paid per kWh produced and sold) | 1. 100 €/MWh incentive<br>2. 75 €/MWh incentive<br>3. 50 €/MWh incentive<br>4. 25 €/MWh incentive |
| 3. Duration of the support (number of years for which the incentive is paid) | 1. Incentive unchanged for less than 10 years<br>2. Incentive unchanged from 10 to 20 years<br>3. Incentive unchanged for more than 20 years |
| 4. Duration of the administrative process | 1. Less than 6 months<br>2. From 6 to 12 months<br>3. More than 12 months |
| 5. Social acceptance | 1. Low (anti-wind activism, negative press, anti-wind demonstrations)<br>2. High (pro-wind activism of NGOs, favourable press, pro-wind citizens' coalitions) |

The model also included two main control variables, namely investor's experience and firm's type, which were measured as follows. *Investor's experience* was measured as the number of years of experience that each respondent had in the renewable energy sector. To control for *firm's type*, we created three dummy variables: dummy_VC included venture capitalists and private equity firms; dummy_funds included pension funds, hedge funds and banks; finally, dummy_others included all other investors not belonging to the former two broad categories.

The *share of RE in the investment portfolio* was measured as the percentage of renewable energy technologies in the investment portfolio. Finally, the *performance of the investment* was measured through a 3-point likert scale that assessed the extent to which the portfolio's performance was considered by the respondent above, equal to, or below the competitor's performance. It is worth highlighting that, although the questionnaire included questions regarding both the past and the future expected performance, only past performance was retained in the model as dependent variable. Given the confidential nature of the information collected, all our dependent variables could not be obtained from public sources and had to be self-assessed. As a result, we could not exclude a priori the presences of common method variance (CMV). However, we tested for CMV using Harman's single factor test (Podsakoff et al., 2003). Results (available upon request) showed no evidence of this problem in our data. Descriptive statistics for the above variables and Pearson's correlations are displayed in Table 3.

### 4.5. Econometric analysis

The stylized model in Fig. 1 was tested by estimating the linear models below

$$Y_{1,i} = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \beta_3 x_{3i} + \beta_4 x_{4i} + \beta_5 x_{5i} + \beta_6 x_{6i} + \sum_j \beta_j control_{ij} + \varepsilon_i \tag{1}$$

$$Y_{2,i} = \gamma_0 + \gamma_1 Y_{1,i} + \gamma_2 x_{3i} + \sum_j \gamma_j control_{ij} + \eta_i \quad (2)$$

where $Y_1$ is the RE share in the investment portfolio, $Y_2$ the investment performance, $x_1$ the confidence in market efficiency, $x_2$ the confidence in technology effectiveness $x_3$ the technological risk attitude, $x_4$ the perceived importance of policy type, $x_5$ the perceived importance of support level, $x_6$ the perceived importance of support duration, Control$_j$ the investor's experience, dummy VC, dummy funds, dummy 'other investors'.

The two equations were fist estimated as independent regressions by means of ordinary least squares (OLS). However, as the dependent variable of Eq. (1) ($Y_1$) is one of the explanatory variables in Eq. (2), OLS estimators could be biased and inconsistent. The model was therefore re-estimated using three different methods: 2-stage least square (2SLS), 3-stage least square (3SLS) and seemingly unrelated regression (SUR) as well. SAS Proc Model was used to estimate both the OLS and the system equation models.

The results of a Hausman specification test suggested that the data structure was not affected by endogeneity and that system estimation methods were not necessarily preferred over OLS. For completeness purposes the results of all the four estimation methods are reported in Table 4. It is also interesting to note that the estimates are consistent across different methods, which is a testament to the robustness of the model.

For consistency purposes, and to take into account the econometric characteristics of our dependent variable, we re-estimated the performance equation using a multinomial logit model (as the analysis revealed no endogeneity problems, it was possible to estimate Eqs. (1) and (2) separately). The estimates of the logit model were consistent with the original OLS estimates and are not reported in the interest of space.

## 5. Results

First and foremost, it is worth signalling that the empirical study depicts a business context dominated by highly rational and well informed investors, who tend to minimise the risk of their choices by founding their decisions on factual, technical information. A descriptive analysis of the survey results reveal that the investors in our sample have clear preferences for mature and well established renewable energy technologies. They also look for stable policy frameworks axed on high levels of financial support as a prerequisite for investment decisions.

Against this background, our analysis has brought some interesting findings to light. In particular, it has identified a series of causal relationships between behavioural attitudes and the share of renewables in the investment portfolio, as well as between behavioural attitudes and the investment performance.

**Table 3**
Descriptive statistics and Pearson correlations.

| | Min | Max | Mean | Std | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Confidence in market efficiency | 1.00 | 5.00 | 3.45 | 0.79 | | | | | | | | |
| 2. Confidence in technology effectiveness | 2.00 | 5.00 | 3.56 | 0.72 | −0.03 | | | | | | | |
| 3. Technological risk attitude | 0.00 | 9.00 | 0.48 | 1.02 | 0.03 | 0.06 | | | | | | |
| 4. Perceived importance of policy type | 0.71 | 5.17 | 1.68 | 0.78 | 0.17 | 0.08 | 0.03 | | | | | |
| 5. Perceived importance of support level | 0.64 | 8.86 | 2.02 | 1.19 | 0.21 | −0.02 | −0.08 | 0.85 | | | | |
| 6. Perceived importance of support duration | 0.48 | 6.91 | 1.67 | 0.95 | 0.20 | −0.06 | −0.05 | 0.88 | 0.94 | | | |
| 7. Investor's experience | 1.00 | 4.00 | 2.29 | 0.62 | 0.22 | 0.12 | −0.17 | 0.06 | −0.01 | 0.08 | | |
| 8. RE share in the investment portfolio | 0.00 | 5.00 | 2.11 | 1.94 | 0.37 | 0.13 | −0.15 | 0.14 | 0.04 | 0.15 | 0.34 | |
| 9. Perceived investment performance | 1.00 | 3.00 | 2.24 | 0.41 | 0.21 | −0.11 | −0.32 | 0.01 | 0.10 | 0.13 | 0.08 | 0.26 |

**Table 4**
Results of the multivariate regressions (all coefficients are standardized).

| | OLS | | | 2SLS | | | SUR | | | 3SLS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Estimate* | *Std Err* | *p* | *Estimate* | *Std Err* | *p* | *Estimate* | *Std Err* | *p* | *Estimate* | *Std Err* | *P* |
| *RE share in the investment portfolio* | | | | | | | | | | | | |
| Confidence in market efficiency | 0.34 | 0.25 | 0.18 | 0.34 | 0.25 | 0.18 | 0.32 | 0.25 | 0.19 | 0.29 | 0.25 | 0.25 |
| Confidence in technology effectiveness | 0.81 | 0.22 | 0.00 | 0.81 | 0.22 | 0.00 | 0.83 | 0.22 | 0.00 | 0.86 | 0.22 | 0.00 |
| Technological risk attitude | −0.37 | 0.09 | 0.00 | −0.37 | 0.09 | <0.001 | −0.37 | 0.09 | <0.001 | −0.36 | 0.09 | <0.001 |
| Perceived importance of policy type | 0.41 | 0.37 | 0.28 | 0.41 | 0.37 | 0.28 | 0.38 | 0.38 | 0.31 | 0.32 | 0.38 | 0.41 |
| Perceived importance of support level | −1.29 | 0.50 | 0.01 | −1.29 | 0.50 | 0.01 | −1.27 | 0.50 | 0.01 | −1.20 | 0.50 | 0.02 |
| Perceived importance of support duration | 1.32 | 0.62 | 0.04 | 1.32 | 0.62 | 0.04 | 1.33 | 0.62 | 0.04 | 1.31 | 0.62 | 0.04 |
| Investor's experience | 0.50 | 0.28 | 0.08 | 0.50 | 0.28 | 0.08 | 0.50 | 0.28 | 0.08 | 0.50 | 0.28 | 0.08 |
| Dummy Funds | −0.89 | 0.94 | 0.35 | −0.89 | 0.94 | 0.35 | −0.90 | 0.93 | 0.34 | −0.95 | 0.92 | 0.31 |
| Dummy VC | 0.21 | 0.59 | 0.72 | 0.21 | 0.59 | 0.72 | 0.19 | 0.59 | 0.75 | 0.15 | 0.59 | 0.80 |
| Dummy other investors | −0.42 | 0.58 | 0.48 | −0.42 | 0.58 | 0.48 | −0.44 | 0.58 | 0.46 | −0.48 | 0.59 | 0.41 |
| $R^2$ | 0.35 | | | 0.35 | | | 0.35 | | | 0.27 | | |
| *Investment performance* | | | | | | | | | | | | |
| RE share in the investment portfolio | 0.05 | 0.02 | 0.04 | 0.08 | 0.06 | 0.16 | 0.06 | 0.02 | 0.02 | 0.09 | 0.06 | 0.12 |
| Technological risk attitude | −0.12 | 0.03 | 0.00 | −0.11 | 0.03 | 0.00 | −0.12 | 0.03 | 0.00 | −0.11 | 0.03 | 0.00 |
| Investor's experience | 0.01 | 0.10 | 0.89 | −0.02 | 0.11 | 0.88 | 0.00 | 0.10 | 0.97 | −0.03 | 0.11 | 0.81 |
| Dummy Funds | −1.12 | 0.16 | 0.00 | −1.09 | 0.17 | <0.001 | −1.11 | 0.16 | <0.001 | −1.08 | 0.17 | <0.001 |
| Dummy VC | −0.93 | 0.16 | 0.00 | −0.95 | 0.16 | <0.001 | −0.94 | 0.16 | <0.001 | −0.96 | 0.16 | <0.001 |
| Dummy other investors | −0.86 | 0.13 | 0.00 | −0.84 | 0.14 | <0.001 | −0.85 | 0.13 | <0.001 | −0.84 | 0.14 | <0.001 |
| $R^2$ | 0.23 | | | 0.21 | | | 0.23 | | | 0.14 | | |

Table 4 displays the results of the multivariate regressions for the renewable energy share model and the investment performance model (for sake of simplicity in the following we refer to the OLS results only). Both models are significant ($F=4.14$ with $p<0.01$ and $F=3.83$, $p<0.01$, respectively) and have an acceptable explanatory power ($R^2=0.35$ and $R^2=0.23$ respectively). It can be noted from the table that a priori beliefs have a positive influence on the investors' willingness to back renewable energy projects. However, the degree of confidence in technology effectiveness has a stronger impact than the confidence in the market efficiency ($\beta=0.81$ with $p<0.01$ versus $\beta=0.34$ with $p=0.18$).

This might be interpreted as an indication that the proven reliability of a technology is a conditio sine qua non for investing, whereas investors believe that possible market inefficiencies can be corrected through the adoption of appropriate policy instruments. In other terms, investors seem to have a strong preference for those technologies which have already overcome both the technology and cash flow ''valleys of death'' (Grubb, 2004; Murphy and Edwards, 2003). This finding is in line with the results of a survey carried out by Fritz-Morgenthal et al. (2009) where the majority of the sample stated that investors are expected to focus less on innovation and more on established technologies in the next 2–3 years, as a response to the financial crisis.

Quite surprisingly, and in sharp contrast with the hypothesized effect, a higher propensity for technological risk (i.e. a tendency to invest in radically new technologies which are still far from commercial viability) is negatively associated with the renewable energy share in the portfolio. This can be due to the fact that most of the portfolios are skewed towards relatively well known renewable energy technologies. Investors who have an appetite for technological risk and invest in radically new technologies need to hedge against this risk by including a higher share of conventional technologies in their portfolios compared to those who invest in less innovative technologies. Thus, the total renewable energy share in their portfolios will be lower than investors with a moderate appetite for technological risk. As our dependent variable does not distinguish among types of renewable energy investments, this effect cannot be singled out. Another explanation could be that investors willing to invest in radically new technologies still do not find enough credible and well documented investment opportunities.

Policy preferences have different impacts on the share of renewables in the investment portfolio. The analysis of their specific effects offers interesting insights. The influence of the type of policy scheme is statistically not significant ($p=0.28$). A more in-depth analysis of the conjoint measurement results has highlighted that the surveyed investors have a clear and strong preference for feed-in tariffs over other policy instruments. This limits the variance of the policy type variable and its consequent effect on investment choices. This is tantamount to saying that, regardless of the technological choices they make, the investors in our sample believe that feed-in tariffs are by far the most effective policy instruments to attract investments in renewable energy technologies.

A high perceived importance of the level of support is negatively associated with the share of renewable energy in the investment portfolio ($\beta=-1.29$ with $p=0.01$), suggesting that investors implicitly believe that the level of support currently allocated to renewable energy technologies is still inadequate. Conversely, and in sharp contrast with the above result, a high perceived importance of the duration of the support is positively associated with the renewable energy share ($\beta=1.32$ with $p=0.04$), suggesting that investors implicitly believe that the time horizon of the policies currently in place is not inadequate. These results seem to reinforce the impression that investors in our sample are extremely risk averse and have a rather short horizon when they evaluate investment opportunities.

Short term policies that provide high levels of financial incentives for a limited amount of time are strongly preferred over long term policies that guarantee a moderate but stable level of support for a longer amount of time. This finding should be interpreted with care, because the sample is skewed toward venture capital and private equity funds, which have rather short-term investment horizons. A segmentation analysis revealed indeed that, for some particular categories of investors such as infrastructure funds and project developers, the incentive level has a relatively lower importance, while other policy attributes such as the type of support scheme and the duration of support play a more important role in shaping the investors' preferences.

The analysis of the performance model reveals that higher shares of renewable energy technologies in the investment portfolio are associated with a slightly higher performance relative to direct competitors ($\beta=0.05$ with $p=0.04$).

This provides evidence against the conventional wisdom that investments in renewable energy technologies yield lower returns compared to investments in conventional energy systems. It is also interesting to note that the investors' attitude towards technological risk has a strong negative impact on the investment performance. This effect is both direct and indirect through its impact on the renewable energy share in the investment portfolio. Once again, this reinforces the impression that the surveyed investors display aversion not only for financial risk, but also for technological risk. One possible explanation for this result is related to the fact that the majority of respondents in our sample have rather limited experience in the renewable energy sector. Since investors have not accumulated enough experience in an industry that is very promising, but also risky, they might fail to analyse investment opportunities in a proper way, thus privileging short term returns instead of embarking in projects that might guarantee superior returns in the long run.

## 6. Main conclusions and implications for theory and practice

Renewable energy sources have the potential to play a crucial role in reducing carbon emissions and fossil fuel consumption in all sectors of the economy. However, huge additional investments are needed to realize this potential: the draft Copenhagen Climate Treaty issued by several NGOs calls for a doubling of market investments by 2012 and quadrupling by 2020 to attain the proposed carbon emission reduction targets (Meyer et al., 2009). Needless to say, this is particularly challenging in a context of global economic slowdown such as the one the world is currently experiencing. Although investors can play a key role in mobilizing capital to support renewable energy technologies, evidence suggests that they are often reluctant to do so. Clearly, dedicated policies can, and have been implemented to stimulate renewable energy investments. However, many of the efforts conducted so far have been only moderately effective because, by failing to understand the behavioural context in which investors make decisions, they were unable to leverage some of the true drivers of the investment decision process.

In a market economy, the effectiveness of policies aimed at mobilizing renewable energy investments is critically dependent upon their impact on investors' behaviours. To maximize the impact of future policies, policy makers need to get a better understanding of how investors behave, and of how they take their decisions, particularly in regards to the key psychological factors that may influence their behaviors and actions.

Yet, despite this evidence, there is a surprising lack of rigorous empirical studies examining these issues in the energy policy literature. This paper represents one of the first attempts to fill in this gap. Drawing upon studies in behavioural finance, we have put forth a theoretical model that examines how investors a-priori beliefs, their preferences over policy instruments and their attitude toward technological risk affect the decision to invest in renewable energy projects and, in turn, the performance of the investments.

Our analysis has brought some interesting findings to light. In particular, it has revealed that a priori beliefs on the technical effectiveness of the investment opportunities play a much more important role than market beliefs in driving investments, implicitly suggesting that agents consider the proven reliability of a technology as a necessary condition for investing in it, whilst they believe that market inefficiencies can be corrected through the adoption of appropriate policy instruments. The results have also revealed a group of investors with extremely short investment horizons, who have a strong preference for short term policies that provide high levels of financial incentives for a limited amount of time over long term policies that guarantee a moderate but stable support for a longer time.

The paper makes a contribution to the energy policy, strategic management and behavioural finance literatures, and has some important implications for managerial practice. Firstly, the incorporation of cognitive and behavioural elements into the analysis of policy effectiveness is an important theoretical contribution and produces a more accurate description of the relationship between policies and investment. By providing a better understanding of investors' behaviours, the research will help policy makers design more effective policy instruments to support the market deployment of sustainable energy technologies.

The study also contributes to the theory of social acceptance of renewable energy innovation. As observed by Wüstenhagen et al. (2007), while factors influencing socio-political and community acceptance are increasingly recognized as being important in the understanding of policy effectiveness, market acceptance has received less attention so far. By investigating investors' acceptance of climate and energy policies, the present research contributes to fill in this gap.

Finally, our results appear also relevant for practitioners in the sustainable energy market. A priory beliefs and cognitive biases create additional risk elements that restrain the likelihood of raising capital for clean energy investments. The analysis of these elements as opposed to more rational risk factors can help investors get a more balanced view of policy risks and opportunities in this promising business sector.

Like most research, our study is not exempt from limitations. First, the results may be difficult to generalize because the study was restricted to a specific empirical context and the sample is skewed toward venture capitalists and private equity funds. Second, the variables used in the model to measure portfolio performance are self assessed and measured by means of a three-point likert scale. This choice was dictated by the results of the pre-test, which revealed that investors were reluctant to disclose any performance-related information beyond a mere first order assessment of their ranking with respect to peers (below, in line with, above). Although we have controlled the presence of CMV and re-estimated the performance equation through a multinomial logit model, the use of objective, quantitative measures of performance would have been ideal and remains necessary to further validate our findings. Third, although we did control for some exogenous factors, the relatively limited sample size did not allow for a better differentiation among renewable energy investments. The survey included investments in a wide range of different renewable energy technologies with different degrees of innovativeness and risk. Clearly, some of the phenomena observed may be technology-dependent and require further investigation. Finally, we could not exclude a priori the presence of a reverse causal relationship between investment performance and the share of renewables in the investment portfolio. Over time, we would expect that rational investors who obtained above-average returns by adding renewables to their portfolios, will also tend to increase the share of RE in their portfolios in the next investment round. Fully disentangling this reverse causality would require the availability of longitudinal data, which, unfortunately, were not available for this study. We expect to address some of these issues in follow-up works.

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