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# The Price of Policy Risk –
# Empirical Insights from Choice Experiments with European Photovoltaic Project Developers

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*Abstract*

Managing the transition to a renewable energy future is an important policy priority in many countries. Solar photovoltaic (PV) technology is expected to make an important contribution, but due to relatively higher cost, its growth to date has been largely driven by public policy, notably feed-in tariffs. Feed-in tariffs have been implemented in various countries, however with widely differing outcomes in terms of installed PV capacity. Previous research indicates that the level of policy risk may be an important driver for differences in renewable energy policy effectiveness. More specifically, we suggest that investors who take a decision between PV investment opportunities in different countries carefully weigh feed-in tariff-induced returns against a set of policy risks, and choose the country with the most favorable risk-return profile. We empirically test this model based on a stated preference survey among European PV project developers, consisting of 1575 choice decisions by 63 investors. The findings of our study demonstrate that risk matters in PV policy design, and that a "price tag" can be attached to specific policy risks such as the duration of administrative processes or uncertainty induced by an approaching capacity cap. Governments can build on our empirical results to design policies that will be effective in attracting private PV investment, while at the same time maintaining efficiency by providing an adequate compensation for policy risk.

*JEL Codes:* D81, G11, L94, O33, Q42

*Keywords:* Adaptive conjoint analysis, choice experiment, feed-in tariff, photovoltaic, policy design.

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## 1. Introduction

In order to address the twin challenges of climate change and energy security, governments around the world are increasingly adopting policies to increase the share of renewable energy. While the overall share of renewable energy in global electric power supply is still low, there is significant growth in some subsectors. For example, 39 % of all newly installed power generation capacity in Europe in 2009 was based on wind energy, and the wind turbine industry has grown by 29 % per annum over the past decade. Solar photovoltaics (PV), while starting from lower levels, has seen even higher growth rates from 2004 to 2008. While the cost of wind energy has reached grid parity in good locations and hence it is sometimes the most competitive source of electricity, the cost of solar PV is still significantly higher than that of conventional electricity sources. Therefore, growth of the PV market has been largely driven by policy incentives.

One of the most widely adopted policy instruments to support PV is the feed-in tariff scheme, first introduced in Germany's renewable energy legislation in 1991. More recently, feed-in tariffs have been enacted in a large number of countries, partly as a result of the apparent effectiveness in increasing renewable energy capacity in Germany. As this policy has spread across countries, however, an important empirical puzzle emerged: Seemingly similar policy frameworks have led to significantly different outcomes in different countries. For example, Germany, Spain and Greece all offered feed-in tariffs of approximately 45 ct/kWh for solar electricity generators in 2007, but newly installed capacities in that year ranged from 1.135 MW in Germany through 505 MW in Spain to just 2 MW in Greece (Sarasin, 2009).

An increasing body of research tries to shed light on the reasons behind such differences in energy policy effectiveness. While early contributions in this strand of research have highlighted the importance of sufficiently high support levels and the long-term stability of policy frameworks, more recent work is drawing attention to the importance of policy risk. There seems to be an emerging consensus that an important feature of effective policies is that they succeed in reducing risk for investors. However, empirical evidence on what constitutes the most important risk factors is still limited, and valid results on the relationship between specific attributes of policy risk and investment outcome are difficult to find because there is only a small number of cases where significant levels of new renewable energy capacity have been achieved.

Our research addresses these challenges by moving from an ex post analysis of revealed preferences to an ex ante analysis of stated preferences of key decision-makers in the solar market. We conduct a survey among European PV project developers using choice experiments. This methodology is widely used in marketing research and has recently gained some popularity in the energy and resource

economics literature, but to the best of our knowledge the current paper is the first to apply this methodology to the analysis of investment choices based on renewable energy policy frameworks. As a result, our research allows to empirically measure the "price of policy risk", i.e. investors' willingness-to–accept (WTA) certain policy risks. This allows policymakers to make a more conscious trade-off between the level of feed-in tariff offered and the reduction of important policy risks for investors, ultimately leading to more efficient policy frameworks.

The structure of the paper is as follows. The next section reviews existing literature on renewable energy policy effectiveness and the role of policy risk in renewable energy investment. Section 3 describes our experimental design, and the estimation model is specified in section 4. Section 5 outlines the data and sample; section 6 presents and discusses the empirical results. Section 7 concludes with implications for policy makers and suggestions for further research.

## 2. Literature Review

Investigating the efficiency and effectiveness of renewable energy policies has become a popular theme among energy economics researchers. An extensive number of country-level case studies have been carried out across different geographies, renewable energy technologies, and policy instruments (Breukers and Wolsink, 2007; Jacobsson and Lauber, 2006; Lipp, 2007; Toke et al., 2008; Wüstenhagen and Bilharz, 2006). While some early works pointed to a potentially higher efficiency of trading schemes such as renewable portfolio standards, quota systems and green certificates (Kühn, 1999; Lenz and Pfaffenberger, 1999), feed-in tariffs – especially in the case of Germany – soon built up a reputation for being relatively more effective in bringing about new renewable energy capacity (Rickerson and Grace, 2007). As more countries introduced renewable energy policy schemes, an additional insight emerged, namely that the answer to the question which energy policy is most efficient and most effective may actually be: "It depends." For example, as much as trading schemes appear to be an elegant way of minimizing cost to society in economic models (Palmer and Burtraw, 2005), their implementation in real life suffered from limitations including market power and transaction cost (Amundsen and Mortensen, 2001; Bergek and Jacobsson, 2010; Jacobsson et al., 2009; Jensen and Skytte, 2002; Menanteau et al., 2003; Verbruggen, 2004; Verhaegen et al., 2009). Conversely, feed-in tariffs seemed to work well in Germany, but are sometimes criticized for their relatively high cost especially in the case of PV (Frondel et al., 2008), which may also be related to market power of incumbents (Ropenus and Jensen, 2009), and their implementation in other countries showed a striking variety of outcomes (Campoccia et al., 2009; Lüthi, 2010; Rowlands, 2005). Recent analyses, on the other hand, demonstrate that well-designed feed-in tariffs might actually outperform trading schemes on both efficiency and effectiveness (Butler and Neuhoff, 2008; OECD/IEA, 2008; Ragwitz et al., 2007).

One way of summarizing the state of debate is that for many renewable energy policies, the devil is actually in the details (Ringel, 2006), and it is a fine-tuned set of ingredients of a country's policy mix rather than any archetype of a "price-driven" or "quantity-driven" policy instrument that results in efficient and effective deployment of renewables (Dinica, 2006; Menanteau et al., 2003). Those ingredients that policy makers have to get right beyond the ideal choice of policy type include a series of so-called non-economic barriers to renewable energy implementation (OECD/IEA, 2008), such as social acceptance (Toke et al., 2008; Wüstenhagen et al., 2007), planning restrictions (Nadaï, 2007) or connection charges (Butler and Neuhoff, 2008).

A recent stream of research has highlighted the importance of risk in policy design. Variations in policy outcomes can thus be traced back to variations in the level of risk implied by different policies. This has been offered as an explanation for why feed-in tariffs have resulted in higher levels of new renewable energy capacity than green certificate systems (Mitchell et al., 2006). Lowering risk is a particularly important feature of policy design because of its impact on financing cost for renewable energy projects (De Jager and Rathmann, 2008; Langniss, 1999; Wiser and Pickle, 1998). Policies that effectively reduce (perceived) risk for investors are more likely to result in large-scale deployment of renewable energy. There have been various calls for including an investor perspective in the analysis of energy policies (e.g., Birol, 2003; Gross et al., 2009; Menichetti and Wüstenhagen, 2010), and yet there is relatively little empirical evidence so far about how policies and their risk are actually perceived by investors (Bürer and Wüstenhagen, 2009; Masini and Menichetti, 2010). The analysis presented here is an attempt to contribute to this emerging stream of research, and at the same time to address two limitations of previous research that remain largely unaddressed: First, much of the previous research trying to assess the impact of risk on renewable energy policy effectiveness is based on country-level case studies, which inherently limits the analysis to aggregate measures of risk in a given country, rather than leading to specific insights about the importance of individual risk components. Second, the empirical literature has largely relied on ex-post analyses of revealed preferences, i.e. realized investments. This may be fine in slow-moving markets where long time series are available, but creates a problem in the dynamic renewable energy market in that it inherently limits analysis to those few countries that already offer some history in deploying renewables, and in that the policy recommendations based on such ex-post analyses might systematically come too late. What we suggest is to move towards choice experiments with investors as a way to get real-time information about how policy risks affect today's investment, and hence tomorrow's installed capacity (Usher, 2008).

## 3. Experimental Design

### *3.1. Method*

The objective of this study is to investigate the influence of the most important attributes of solar energy policies on the decision of a PV project developer to invest in a given country, in order to empirically measure investors' willingness-to-accept specific policy risks. As a result we aim at providing recommendations for the design of effective PV policies. Investigating the influence of policy attributes on investor decisions can be done through either revealed or stated preference approaches. Revealed preference approaches are based on an ex-post analysis of actual investment decisions. An important requirement thus is that sufficiently long and detailed time-series data are available. In the case of international solar energy investments, we are addressing a phenomenon that has only emerged in the last 2-3 years, and hence only a limited amount of country-level data would be available for analysis. Stated preference approaches, on the other hand, can overcome some of the challenges of revealed preference methods. By confronting respondents (in this case, investors) with hypothetical, but realistic choice situations, they allow to study decision behavior in real time, or even before it actually occurs in the field. Consequently, they have become popular in marketing research with regard to understanding consumer preferences for newly developed products (Green and Srinivasan, 1990). One particularly popular method are choice experiments, also referred to as conjoint analysis in the marketing literature. Conjoint analysis was initiated by mathematical psychologists (Anderson, 1970; Kruskal, 1965; Luce and Turkey, 1964), and introduced in marketing research in the early 1970s (Green and Srinivasan, 1990; Orme, 2007). Over time, the use of choice experiments and conjoint analysis has spread from its origin in marketing research to a wide array of research communities such as entrepreneurship (Lohrke et al., 2010), environmental economics (Ahn et al., 2008; Boxall et al., 1996; Burkhalter et al., 2009; Casey et al., 2008; Chattopadhyay, 2009; Farber and Griner, 2000; Glenn et al., 2010; Roe et al., 1996), transportation economics (Hensher, 1994; Hensher, 2010; Train and Wilson, 2008), and energy efficiency research (Banfi et al., 2008; Moxnes, 2004; Poortinga et al., 2003).

The methodological approach of this study is novel in that it uses choice experiments to investigate investor choices among policy frameworks. Hence we argue that an investor's choice among different opportunities to invest in international solar energy projects is essentially similar to the decision of a customer to buy a new product. In particular, we conjecture that these investment decisions comply with the fundamental assumptions underlying conjoint analysis (Lancaster, 1966), namely that investors will choose from a given choice set the alternative that maximizes their utility, and that this utility can be described as the sum of part-worth utilities of the alternatives' attributes. The next section below will provide more detail about how we selected and operationalized the attributes of the choice experiments.

A number of different variations of conjoint analysis are available (Backhaus et al., 2006; Orme,

2007; Priem and Harrison, 1994). For example, full-profile methods such as choice-based conjoint Analysis (CBC), where respondents have to make trade-offs between all attributes of the choice alternatives simultaneously, can be distinguished from partial profile methods such as adaptive conjoint analysis (ACA), where respondents are first asked to rank the importance of attributes followed by choice tasks that gradually build up complexity (Sawtooth Software, 2007). Another design decision is between paper-and-pencil approaches and online surveys. We decided to use an online version of ACA, which is preferable over CBC in the case of smaller samples and in rather explorative settings where the key attributes of the choice situation are not obvious to the researcher ex ante.

### *3.2. Selection of Attributes and Levels*

A qualitative pre-study was carried out to find out which attributes influence the location decision of a PV project developer. For this reason, eight expert interviews (Flick, 1995) have been conducted with PV project developers and other solar or project development specialists. The market professionals were asked to recount their location decision process and to explain the different influencing factors. In this way the roles of host country characteristics as determinants in investment choice patterns, especially in regard to policy attributes, were reviewed. Based on this qualitative pre-study, an online questionnaire consisting of two parts was compiled: The ACA experiment about the importance of PV policy attributes, and questions to obtain background information about the experience and activities of the project developers and their firms.

The interviews confirmed the prominent role of policy conditions among the factors influencing a PV project investment decision. These political conditions include the availability of financial incentive schemes, the application procedure, policy targets for the future share of solar energy, and the stability of support policies. Besides political conditions, legal, economic and climatic conditions have been mentioned in the pre-study. Those included legal conditions such as mandatory interconnection standards, legal security, and the enforcement of private property rights. Economic conditions included currency risk, whereas an obvious example of climatic conditions was the level of solar radiation, which directly influences a project's profitability. To reduce the number of attributes to a manageable number, we decided to exclude factors from further analysis that were relatively homogeneous among the countries studied. For example, legal security can be described as sufficiently high in the European countries we investigated, as opposed to for example in some developing countries, which were not the focus of this study. Also, currency risk played a minor role because most of the countries considered were part of the European single currency area. As for solar resources, we decided to keep this factor constant by asking respondents to assume a solar radiation of 1'500 $kWh/m^2*a$. This is a realistic value for a number of the Southern European countries that attract a substantial part of the investments done by our target population of PV project developers. Apart from solar radiation, a second factor that was

kept constant was the type and size of the assumed project: A greenfield solar plant with an installed capacity of 500 $kW_p$.

Based on the qualitative pre-study, five attributes were finally chosen for the ACA experiment, which reflected key factors determining the level of risk and return for investors: ‘Level of tariff’, ‘Duration of tariff’, ‘Existence of a cap’ (or the time until the cap is reached), ‘Duration of the administrative process’ and ‘Policy instability’ (operationalized as the number of significant unexpected policy changes in the last 5 years). Table 1 shows a description of each attribute, together with the levels presented in the survey.

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Insert Table 1 about here

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### *3.3. Questionnaire design*

The computer-based ACA survey was designed with Sawtooth, which is the standard software solution for the design and analysis of conjoint experiments in marketing research (Sawtooth Software, 2007). At the beginning, the respondents are asked to compare attribute pairs (cf. Fig. 1). Each question showed descriptions of hypothetical political framework conditions for two countries composed of different levels including two attributes at the beginning, then three, and then four. Assuming that the conditions were identical in all other ways, respondents should indicate which country they would preferably choose as the next project location. Rather than being asked to simply choose one or another, investors could provide differentiated answers on a nine point scale ranging from ‘strongly prefer left’ to ‘strongly prefer right’. The number of "Paired-Comparison" questions to be asked is equal to 3*(N–n–1)–N, where N is the total number of levels and n is the total number of attributes, i.e. 3*(19–5–1)–19=20.

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Insert Figure 1 about here

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In the last section, the questionnaire included a series of "Calibrating Concepts" where the product alternatives are described by levels of all attributes (cf. Fig. 2). These concepts are calculated individually for each respondent based on his previous answers. The respondent is asked to indicate a "likelihood of choosing" between 0 and 100 about each. To assess the spread, the concept with the lowest estimated utility is presented first and then the one with the highest estimated utility.

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Insert Figure 2 about here

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## 4. Model Specification

ACA is based on microeconomic consumption theory. This theory analyzes the economic decisions, and especially the consumption decisions, of private households (Kreps, 1990). It states that a consumption decision is based on a cost-benefit comparison of the different product alternatives (Kreps, 1990), and that the consumer chooses the product that maximizes his utility. Lancaster (1966) advanced this theory by indicating that products can be considered as bundles of attributes, and that the utility $U$ of a product is the sum of the part-worth utilities of its attributes (1 to $m$). However, it is not possible to completely describe any product in terms of its attributes; there will always be some unknown or intangible characteristic ($e$) which may also provide utility. As a result, the other underlying foundation of conjoint analysis is Random Utility Theory (Mansky, 1977), which allows the direct utility function of a person to be broken down into observable (deterministic) and unobservable (stochastic) parts. The preference model can thus be described as (Kappelhoff, 2002):

$$U = \sum_{i=1}^{m} u_i + e \qquad (1)$$

This study does not evaluate the choice among products but among countries and thus transfers this concept to renewable energy investment. Analogous to a product with multiple attributes, the policy framework of a country can be described as a bundle of attributes. As stated in the previous chapter, this study has chosen the level of return, plus a set of policy risks, as the main attributes determining investor choices. A utility maximizing PV project developer aims at investing in the country with the highest utility. As in the case of a choice among products, also when choosing among policy frameworks, there is an inevitable trade-off between the different attributes, and any attribute change influences the attractiveness of the respective country for the project developer. A higher level of return, for example, increases the utility and thus the attractiveness of a country whereas higher policy risks decrease the country's utility.

The data from the ACA questionnaire is used to estimate the part-worth utilities of the different attribute levels, the relative importance of each attribute, and the investors' WTA for certain policy risks. The average part-worth utilities are based on the individual part-worth utilities estimated with the hierarchical Bayes method. Part-worth measures the contribution of attribute levels to the overall utility

of a product. The utilities are interval data, meaning they are scaled to an arbitrary additive constant to sum to 0 within each attribute. Therefore a negative part-worth value for a certain attribute level does not indicate that this attribute level is unattractive per se, but it shows that it is less preferred than other levels of the same attribute with a higher part-worth value.

The relative importance of each attribute can be estimated from the ACA data by considering how much difference each attribute could make in the overall utility of the product, i.e. between the highest and the lowest utility value of each attribute. That difference is the range in the attribute's utility values. The bigger the range is, the more a variation in the attribute can lead to a variation of the overall utility (Backhaus et al., 2006). The relative importance of each attribute is calculated using the formula (adapted from (Clark-Murphy and Soutar, 2004)

$$RI_l[\%] = \frac{(MaxU - MinU)i}{\sum(Max - Min)i} x100 \quad (2)$$

where $RI_i$ is the relative importance of the i$^{th}$ attribute; *MaxU* the maximum utility of the i$^{th}$ attribute; and *MinU* the minimum utility of the i$^{th}$ attribute.

As the monetary variable feed-in tariff is included in the study, the marginal WTA certain policy risks can be derived using the formula

$$WTA_l\left[\frac{\text{ct}}{\text{kWh}}\right] = -1(U_l - MaxU_l)\frac{\Delta FiT}{MaxFiTU} \quad (3)$$

where $WTA_l$ is the implicit WTA of the attribute level $l$; $U_l$ the part-worth utility of the attribute level $l$; $MaxU_l$ the maximum part-worth utility of the attribute in question; $\Delta FiT$ the difference of the level of feed-in tariff, i.e. 14ct/kWh; and *MaxFiTU* the maximum utility of the attribute "Level of tariff".

## 5. Data and sample

The results presented in this paper are based on a unique dataset collected through an online survey conducted in October-November 2008. The population of interest for the survey is European PV project developers which are engaged in or are considering undertaking PV projects abroad in other European countries. There is no universally agreed upon definition of a project developer and his business. In general we can define three main types of firms engaged in the project development business:

- Highly specialized, typically small firms whose exclusive business focus is to develop renewable energy projects. Due to the lack of capital or financing, they often sell the project to later-stage investors during or after the development process.
- Vertically integrated, typically larger firms, who plan, build, own and operate renewable energy projects. They are often customers of the first group.

- A wide range of others, for whom the development of renewable energy projects is an activity outside their core business. These include electric utilities, financial investors (including banks, pension funds or insurance companies), equipment suppliers, and land or building owners. Depending on their focus and risk/return expectations, they get involved in various stages of project development.

Given the wide range of players and the emerging nature of this industry, it is hard to determine an exact number for the total size of this group. The European Photovoltaic Industry Association (EPIA) membership directory lists 83 companies, but this includes firms on different parts of the value chain, including not just those involved in project development, but also manufacturers of solar cells, modules, etc. 27 of these members are active in project development. The German solar industry association, Bundesverband Solarindustrie (BSi) has 786 member firms, including not just PV firms but also companies active in solar thermal energy. 81 of these firms are categorized as solar PV project developers. However, only a part of them are actually investing outside of Germany, and hence relevant for the purposes of this survey. We have not compiled exact numbers for other countries, but based on industry magazines and conversations with industry experts, we assume that the number of European PV project developers who engage in cross-border investments in the typical project size assumed in the survey (500 kW) is somewhat smaller in other significant PV markets such as Italy, Spain and France than in Germany. Furthermore, there is a small number of international project developers in each of a variety of other European countries including Switzerland, UK, Benelux, Czech Republic and Scandinavia. Consequently, we can confidently estimate the size of the total target population of our study to be in the range of 200 project developers.

The PV project developers were solicited to participate in the survey by phone and/or e-mail, at a solar industry fair, by means of an article on an industry-specific news website (www.solarserver.de), and an insert in a solar industry journal.

135 respondents logged on to the survey website and 63 questionnaires were completed, corresponding to a net response rate of about one third of the target population. The relatively high drop-out rate may have been a result of the length of the ACA questionnaire, which took an average 20 minutes to complete – a significant time investment for a busy international manager. Each project developer completed 25 choice tasks, resulting in a final data set of 1575 choice decisions.

A descriptive summary of the sample is given in Tables 2 and 3. Table 2 summarizes the type, size, focus and experience of the firms in our sample, while Table 3 provides evidence about the geographical distribution of respondents and their firms.

In terms of firm type, 30.2 % of respondents indicated their firm was a specialized (early-stage) project developer, while 50.8 % were vertically integrated firms, which would develop, build, and

sometimes also own and operate a project. The remaining 19.0% are others, including financial investors and utilities. Regarding the stage of activity in the project development cycle, 56% of the respondents' companies are active in all stages of the project cycle, 33% in the planning, 6% in the construction and 2% in the operation and maintenance phase.

The sample is about evenly split between experienced project developers (4 or more years of experience: 44.4%) and those that are relatively new to the industry (up to 3 years of experience: 55.6%). This illustrates the emerging nature of the PV industry, but also indicates that our sample includes a substantial portion of experienced professionals. In terms of the number of projects realized, 49.2% of the interviewed persons have been involved in 1-9 projects and 39.7% in 10 or more PV projects. 11.1% (seven respondents) had considered investments, but not actually completed a project yet. Six project developers have even worked on more than 100 projects. 33.3% of the realized projects were smaller projects with an installed capacity of less than 100 kW, 23.8% of the projects are between 100 and 500 kW, 39.7% between 500 kW and 10 MW, and 3.2% are bigger than 10 MW. Taking a look at firm size, there is a relatively large share of small and medium-sized firms in our sample (77.8% of firms have less than 100 employees), again reflecting the entrepreneurial character of this newly emerging industry.

Table 3 provides some information about the geographic distribution of our sample and gives evidence for the high degree of internationalization in the sector. In terms of country of origin, German project developers represent just under half of the sample (48.0%), followed by developers from Spain (17.3%), Italy (10.7%), and several other countries. As for target countries for investments, 69.8% of the firms are active in Germany, 57.1% in Spain, 49.2% in Italy, 30.2% in Greece, 27.0% in France, and 17.5% in Portugal. To make sure our respondents were qualified to answer the choice tasks related to assessing policy frameworks, we also asked them for their familiarity with solar energy policies in those countries. The results suggest that (self-declared) policy knowledge of respondents is high, and corresponds well to the target countries they invest in: 77.8% of the interviewed PV project developers said they are familiar with the PV policy situation of Germany, 71.4% of Spain, 58.7% of Italy, 42.9% of Greece, 36.5% of France, and 19.0% of Portugal.

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Insert Table 2 about here

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Insert Table 3 about here

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## 6. Results

We report estimation results in three steps: relative importance of attributes (6.1), part-worth utilities (6.2) and investors' implicit willingness-to-accept certain policy risks (6.3).

### *6.1. Relative Importance of attributes*

Using Eq. (2) the relative importance of attributes can be calculated. Results are displayed in Table 4. The two most important attributes in our model are duration of the administrative process (25.6 %) and level of the feed-in tariff (24.4 %). The existence of a cap and the number of PV policy changes are of medium importance with 18.7% and 17.7% respectively. The lowest importance (13.6%) is attributed to the duration of the feed-in tariff.

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Insert Table 4 about here

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### *6.2. Part-worth utilities*

Average part-worth utilities and standard deviations for each attribute level are displayed in Table 5. The part-worth utility analysis confirms that there is a linear relationship between attribute levels and utility, indicating that all else being equal, respondents consistently preferred choice alternatives with higher levels for each attribute. This is a first confirmation for the validity of the results. Standard deviations are generally low, with some exceptions for extreme attribute levels. For example, the standard deviation for a tight cap (reached in 1 year) is higher than for a loose cap, indicating some heterogeneity in investors' assessment of how strongly they would avoid this particular policy risk (see section 7.2). The two most important attributes, level of feed-in tariff and duration of administrative process, show the largest spread between the average utilities of their highest and lowest attribute levels, and are also associated with the lowest standard deviations, indicating a relatively homogeneous assessment of those risks by investors. The low distribution is also confirmed by an analysis of the correlations. Correlation coefficients of all respondents were close to 1 (0.95-0.99).

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Insert Table 5 about here

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### *6.3. Investors' implicit Willingness-to-Accept certain Policy Risks*

In a next step, to facilitate interpretation of results and comparison of utilities across attributes, we calculated investors' willingness-to-accept (WTA) certain policy risks using Eq. (3). Results are presented in Figure 3 and briefly discussed below.

The choice experiments included three attribute levels regarding the *existence of a cap*: no cap, a cap that is going to be reached in 4 years (loose cap), and a cap that is going to be reached in 1 year (tight cap). The analysis shows that removing a loose (tight) cap will allow governments to attract the same level of investment at a feed-in tariff that is about 4.71 (10.94) ct/kWh lower than in the base case. Regarding the policy risk *duration of the administrative process*, Figure 3 shows that for every half-year increase in the duration of the administrative process, a government has to pay project developers a feed-in tariff premium of 3.68 ct/kWh (all else being equal). With regard to *policy stability*, the study estimates that compared to full policy stability, in low risk conditions (one significant unexpected policy change in the last 5 years) the feed-in tariff needs to be 4.10 ct/kWh higher, whereas in high risk conditions (three significant unexpected policy changes in the last 5 years) a price premium of 10.28 ct/kWh will be required to maintain the same level of attractiveness. Finally, also the *duration of the support* is associated to a price tag. If the duration of a feed-in tariff is reduced from 25 to 15 years, the incentive needs to be 7.86 ct/kWh higher as compensation.

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Insert Figure 3 about here

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## 7. Conclusion

### *7.1. Summary and implications for policy makers*

Achieving energy policy objectives depends on whether public policy effectively influences investor behavior. In the specific case of feed-in tariffs for solar PV, there has been substantial policy experimentation and learning over recent years, but how investors react to certain policy attributes has been a black box so far. We have opened this black box by conducting a stated-preference survey among European project developers investing in solar energy across different countries.

Contributing to a growing research stream that uses choice experiments in energy economics, this study is one of the first empirical contributions that investigate the influence of renewable energy

policies on investors' decisions. Transferring a particular version of choice experiments that has proven successful in marketing research (adaptive conjoint analysis) to energy economics research, we determined the relative importance of certain policy risks, and quantified the premium demanded by investors to accept those risks. On a solid empirical basis, our research allows policy makers to assess the costs and benefits of reducing various elements of policy risk.

Overall, these finding confirm the importance of "non-economic" barriers – such as duration of the administrative process and political instability – to the deployment of renewable energy and thus demonstrate that risk matters in PV policy design. Project developers in our sample perceived the duration of the administrative process, followed by the level of the feed-in tariff as the most important attributes in the decision to invest in solar energy projects in a given country. We extend previous research by showing that a price tag can be attached to specific policy risks. This allows policy makers to quantify and prioritize the influence of specific policy risks on investment behavior. This study shows that accelerating administrative process, removing a cap, increasing policy stability and/or increasing the duration of support are important ways in which policy makers can increase their country's attractiveness for renewable energy investors. For each of those policy risks, our empirical results provide evidence for the level of risk premium that PV project developers will demand. Governments can build on these findings to design policies that will be effective in attracting PV investment, while at the same time maintaining efficiency by providing an adequate compensation for policy risk. In particular, policy makers should be aware that long administrative processes and, to a somewhat lesser extent, policy risks related to the existence of a cap and a substantial number of unexpected policy changes, have a cost attached to it that will need to be reflected in a higher level of feed-in tariffs to attract solar project developers.

### *7.2. Limitations and further research*

Being one of the first of its kind in empirically investigating the reactions of international renewable energy investors to policy risk with choice experiments, this study is subject to some limitations that provide starting points for further research. First of all, our findings on the relative importance of different policy attributes in explaining the decision to invest in a given country is obviously limited to those attributes included in our experimental design. While the careful selection of attributes based on qualitative expert interviews gives us confidence that we have indeed picked relevant attributes for the choice situation under consideration, unobserved factors may play a role, particularly when it comes to transferring our findings to different contexts, such as renewable energy investment in emerging or developing countries. We would particularly highlight aspects of overall political stability, currency risk or legal security, which we did not include in our study because they are sufficiently similar within the European countries we investigated. Other unobserved factors include language, country size, personal

contacts and social acceptance of the new technology (Wüstenhagen et al., 2007). We have decided not to include those factors in our choice experiments because they can be influenced by policy makers only to a limited extent, but it seems plausible that they would also play a role. For example, all else being equal, a project developer may consider the fixed cost of starting operations in a large country like Spain more worthwhile than in a small country like Cyprus. These potential moderating factors should be kept in mind when interpreting our results.

The second limitation of our study is the size of our sample. Our sample consists of 63 early-stage European project developers conducting 25 choice tasks each, resulting in a total of 1575 observations. Out of the family of choice experimental methodologies, we have used ACA as it is particularly suitable for smaller sample sizes, and we are well in the range of minimum sample sizes recommended in the ACA literature. Nevertheless, further research should aim at validating our findings with larger sample sizes, with other types of investors (e.g. later-stage project financiers) or in other geographic regions (e.g. North America, Asia). We would note that when further researchers are picking up on this suggestion, they should be conscious about the quality and consistency of the sample. The target population of our survey was a set of professional, real-world decision makers in an early-stage growth market, hence unlike surveys in more mature markets or with consumer or student samples, recruiting will inevitably remain a key challenge for follow-up research on renewable energy investors.

A third limitation is that our results are based on stated preference data. We have consciously chosen a stated preference design to address some of the challenges of doing an analysis of revealed preferences in an early-stage growth market, such as the absence of sufficiently long time series and the difficulty to disentangle the importance of different policy attributes in explaining aggregate outcomes (such as installed capacity). However, future research should further explore the possibility of comparing our findings with revealed preference data, especially as feed-in tariffs continue to spread across more countries and hence longer time series become available.

A fourth limitation lies in our operationalization of policy stability. Our model and findings suggest that less policy changes are better, which is in line with previous research highlighting the importance of stable framework conditions for effective deployment policies for renewable energy, and makes intuitive sense in cases where successful policies have been changed with negative consequences for renewable energy investment flows. On the other hand, there are situations in several countries where existing policies are clearly ineffective, such as Switzerland's feed-in tariff for solar energy, where an extremely tight cap led to a waiting list of 3000 projects immediately after the policy had been introduced. It would be a misinterpretation of our findings to suggest that such ineffective policies should be kept constant. Instead, the positive valuation of policy stability that we and others identified seems to suggest that policy makers should conduct such changes with care and in a predictable manner, and that it is a good idea to reduce the frequency of changes to a necessary minimum. Finally,

there also is empirical evidence for non-linear reactions to policy stability, whereby announced policy changes initiate a boom-bust cycle. A prime example for this is the Spanish market for PV, which collapsed in 2009 due to policy changes, but this was preceded by a record year of installations in 2008 as international project developers rushed to Spain to implement their projects ahead of the expected changes. Our model and findings fail to explain such short-term cycles. While it is questionable whether they are desirable from a long-term policy perspective, such phenomena certainly provide interesting opportunities for further research taking a behavioral finance perspective.

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**Table 1**

| Attributes | Description | Attribute levels | | | | |
|---|---|---|---|---|---|---|
| **Level of Feed-in Tariff** [ct/kWh] | The amount paid per kWh fed into the grid. | 31 | 35 | 38 | 41 | 45 |
| **Duration of Feed-in Tariff** [years] | Number of years for which the feed-in tariff is guaranteed. | 15 | 20 | 25 | | |
| **Existence of a cap** | Presence of a market cap limiting the promoted PV capacity, and if a cap exists, the predicted time until it will be reached. | No cap | Cap reached in 4 years | Cap reached in 1 year | | |
| **Duration of the administrative process** [months] | Predicted time from the project submission until all permits are obtained. | 1-2 | 3-6 | 7-12 | 13-18 | 19-24 |
| **Significant unexpected policy changes in the last 5 years** | A change is considered as significant if it leads to more than 15% of feed-in tariff reduction. | 0 | 1 | 3 | | |

**Table 2**

| | | |
|---|---|---|
| **Firm type** | Specialized project developer | 30.2% |
| | Vertically integrated project developer | 50.8% |
| | Other (investors, utilities, etc.) | 19.0% |
| **Firm size** | 1-9 employees | 34.9% |
| | 10-99 employees | 42.9% |
| | 100-499 employees | 15.9% |
| | > 500 employees | 6.3% |
| **Firm's amount of annual PV project investment (million Euros per year)** | 1-9 mio. € | 20.6% |
| | 10-99 mio. € | 38.1% |
| | 100-499 mio. € | 19.0% |
| | > 500 mio. € | 3.2% |
| | Not disclosed | 19.0% |
| **Cumulative number of projects realized** | Total (entire sample) | 3800 |
| | Median (per respondent) | 5 |
| | 0 | 11.1% |
| | 1-9 | 49.2% |
| | 10-99 | 30.2% |
| | > 100 | 9.5% |
| **Average size of realized projects (installed capacity)** | < 100kW | 33.3% |
| | 100-500kW | 23.8% |
| | > 500kW | 42.9% |
| **Firm's focus of activities along the project cycle** | Planning phase only | 33% |
| | Construction phase only | 6% |
| | Operation phase only | 2% |
| | Full project cycle | 56% |
| | Other | 3% |
| **Solar industry experience** | 1 year | 27.0% |
| | 2-3 years | 28.6% |
| | 4-6 years | 27.0% |
| | 7-9 years | 6.3% |
| | 10-12 years | 6.3% |
| | >12 years | 4.8% |

**Table 3**

| | Country of origin (headquarter) | Target country (investments) | Familiarity with country's energy policy |
|---|---|---|---|
| **Germany** | 48.0% | 69.8% | 77.8% |
| **Spain** | 17.3% | 57.1% | 71.4% |
| **Italy** | 10.7% | 49.2% | 58.7% |
| **Greece** | 2.7% | 30.2% | 42.9% |
| **France** | 4.0% | 27.0% | 36.5% |
| **Portugal** | 1.3% | 17.5% | 19.0% |
| **Other** | 16.0% | N/A | N/A |

**Table 4**

| Attribute | Average Importance | Std. Dev. |
|---|---|---|
| **Duration admin. process** | 25.56 % | 2.99035 |
| **Feed-in Tariff level** | 24.37% | 2.81874 |
| **Cap** | 18.72% | 3.94464 |
| **Solar policy changes** | 17.74% | 3.55881 |
| **Feed-in Tariff duration** | 13.61% | 3.43082 |

**Table 5**

| Attribute | Attribute Level | Average Utilities | Std. Dev. |
|---|---|---|---|
| **Level of Feed-in Tariff** | **45 ct/kWh** | 59.74827 | 8.62023 |
| | **41 ct/kWh** | 28.84705 | 5.76723 |
| | **38 ct/kWh** | 0.24914 | 3.53770 |
| | **35 ct/kWh** | -26.75979 | 6.43930 |
| | **31 ct/kWh** | -62.08466 | 6.31125 |
| **Duration of Feed-in Tariff** | **25 years** | 32.71007 | 7.37141 |
| | **20 years** | 2.61501 | 5.67514 |
| | **15 years** | -35.32509 | 10.43541 |
| **Existence of a cap** | **No cap** | 44.63848 | 8.88140 |
| | **Cap reached in 4 years** | 4.34342 | 6.86344 |
| | **Cap reached in 1 year** | -48.98190 | 11.79732 |
| **Duration of the administrative process** | **1-2 months** | 63.34953 | 7.41443 |
| | **3-6 months** | 31.31598 | 5.69055 |
| | **7-12 months** | 0.95482 | 4.68233 |
| | **13-18 months** | -31.16203 | 5.61814 |
| | **19-24 months** | -64.45829 | 8.70599 |
| **Significant unexpected policy changes in the last 5 years** | **0 policy changes** | 41.31774 | 7.86433 |
| | **1 policy change** | 6.06824 | 6.39600 |
| | **3 policy changes** | -47.38598 | 10.81301 |

**Table captions**

**Table 1: Attributes and Attribute Levels used in the ACA experiment**

**Table 2: Descriptive Statistics of European PV project developers in our sample**

**Table 3: Geographical Distribution of European PV project developers in our sample**

**Table 4: Relative Importance of Attributes**

**Table 5: Average Utility Estimates (Zero-Centered Diffs) and standard deviations (Hierarchical Bayes Model with all normally distributed part-worth utilities)**

**Figure 1**

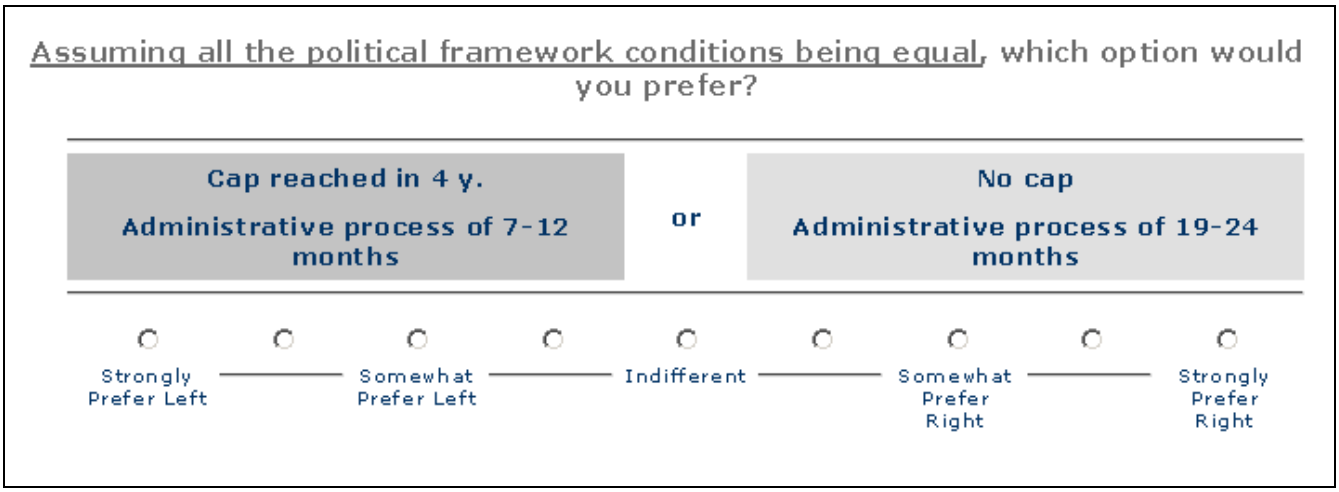

Assuming all the political framework conditions being equal, which option would you prefer?
Cap reached in 4 y.
Administrative process of 7-12 months
or
No cap
Administrative process of 19-24 months
Strongly Prefer Left
Somewhat Prefer Left
Indifferent
Somewhat Prefer Right
Strongly Prefer Right

**Figure 2**

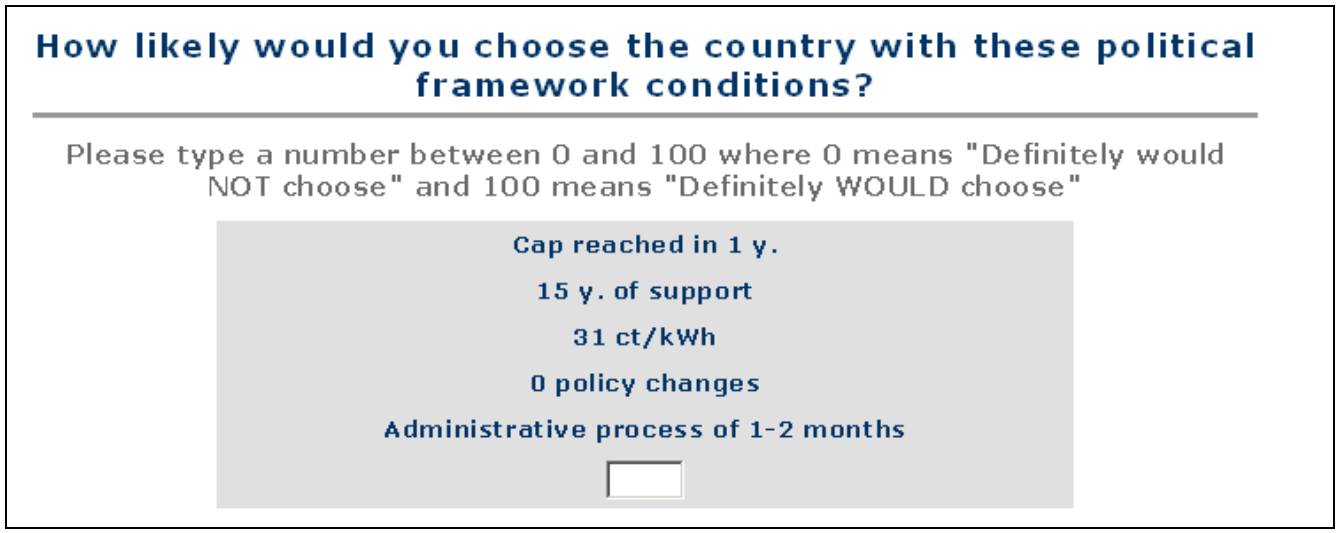

How likely would you choose the country with these political framework conditions?
Please type a number between 0 and 100 where 0 means "Definitely would NOT choose" and 100 means "Definitely WOULD choose"
Cap reached in 1 y.
15 y. of support
31 ct/kWh
0 policy changes
Administrative process of 1-2 months

**Figure 3**

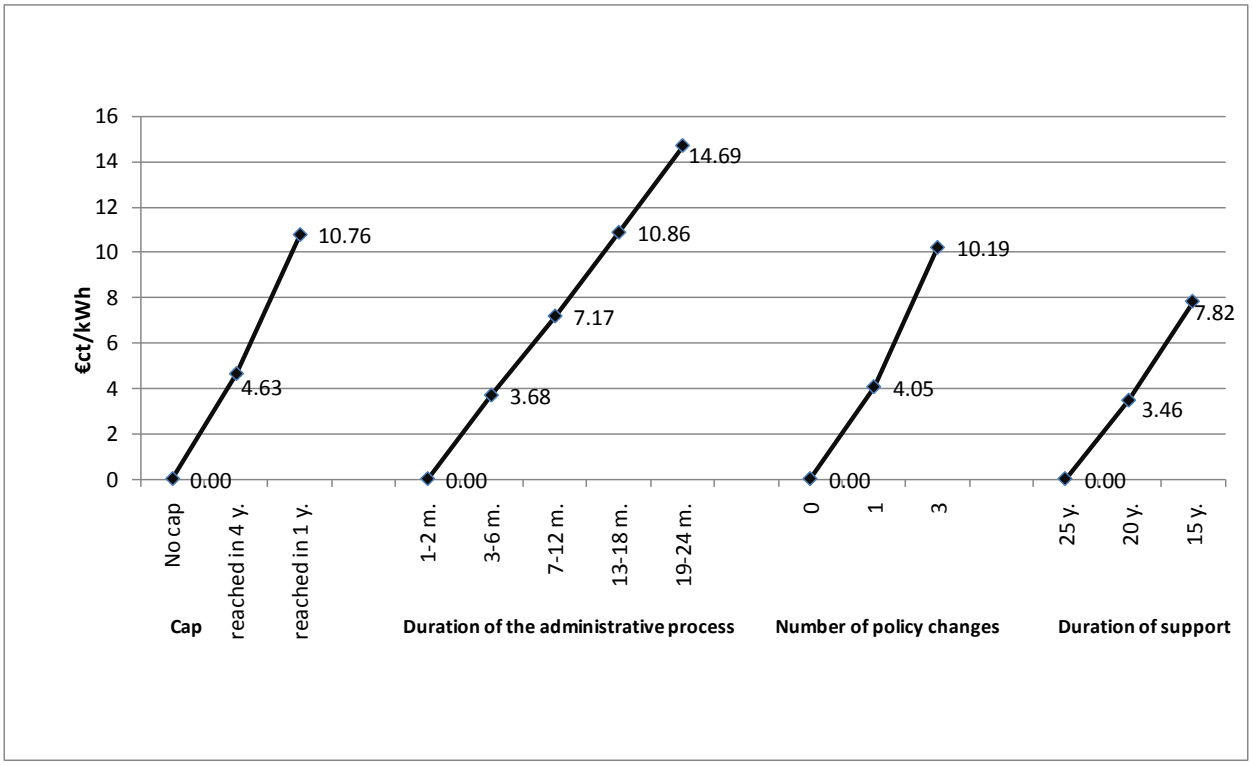

€ct/kWh
16
14
12
10
8
6
4
2
0
0.00
4.63
10.76
0.00
3.68
7.17
10.86
14.69
0.00
4.05
10.19
0.00
3.46
7.82
No cap
reached in 4 y.
reached in 1 y.
1-2 m.
3-6 m.
7-12 m.
13-18 m.
19-24 m.
0
1
3
25 y.
20 y.
15 y.
Cap
Duration of the administrative process
Number of policy changes
Duration of support

**Figure captions**

**Figure 1: Screenshot of a "Paired-Comparison" question**

**Figure 2: Screenshot of a "Calibrating Concept" question**

**Figure 3: Willingness–to-accept certain policy risks**