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

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Abstract

Successfully making the transition to renewable energy is high on the policy agenda in many countries around the world, and one technology that has particular potential for contributing to a future low-carbon energy supply is solar photovoltaic (PV) technology. Given the current cost of PV, market diffusion crucially depends on policy incentives such as feed-in tariffs (FITs), which have been implemented in a number of countries. FITs have been praised for their effectiveness but have also received mixed reviews when it comes to assessing their efficiency. A key empirical puzzle is why similar FITs lead to differing outcomes (in terms of newly installed PV capacity) in different countries. Previous research suggests that answering this question requires a better understanding of policy risk, rather than just the level of return (e.g. the level of the FIT).

This study contributes to this literature by conducting choice experiments to empirically examine the influence of certain aspects of policy risk on the decision of a PV project developer to invest in a given country. Choice experiments are widely used in marketing research and have recently become increasingly popular in environmental and resource economics because they allow for modeling of realistic trade-off situations while avoiding some of the pitfalls of social desirability bias. Based on an original data set of 1575 choice decisions by 63 PV project developers in Europe, this study demonstrates that risk matters in PV policy design, and that a price tag can be attached to specific policy risks. 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.

1. Introduction

A promising energy source of the future is solar energy. With regards to photovoltaics (PV) the installed capacity has been strongly increasing during the past few years, especially in Germany and Spain. The PV project development business is growing rapidly, leaving enormous scope for others to take advantage of the opportunities in all parts of the value chain.

However, the contribution of solar power to the total power production is still negligible. The barriers slowing this transition process are manifold, but are to a large extent related to the current high prices. PV is still an early-stage technology and the transition from central to distributed power production brings along transition costs. The cost disadvantage of PV technology is also influenced by subsidies for conventional, non-renewable energy sources and a lack of internalization of external costs. Furthermore, the investment profile is different compared to competing technologies (i.e. higher initial cost, lower operating cost, and lower fuel price risk). Other barriers to diffusion of solar energy are related to path dependencies (e.g. market power of incumbent energy firms) and cognitive factors (e.g. valuation methods that favor large-scale power plants).

Because of these barriers, the PV market is not yet self-sustaining but dependent on policy. To facilitate the emergence of this clean technology industry and to reach a self-sustaining market, effective policies and financing mechanisms are required. Policy can help to reach grid parity and thus transform the market into a self-sustaining market.

Thanks to effective incentives for PV systems by national and local governments, countries like Germany have become front runners in the adoption of PV panels (Jacob *et al.*, 2005). But what are effective financing schemes and how should an effective PV policy be designed? To date the literature has been limited in scope as it has rarely studied the effectiveness of policy schemes from the point of view of the renewable energy companies. Among the notable exceptions is the work of (Wiser & Pickle, 1998) who analyzed, by means of case studies, the influence of renewable energy policies on the financing process and on financing costs. Doing so, they provided insights on the important nexus between renewable policy design and project financing.

To analyze the PV companies' point of view is of high importance because these companies are transfer agents (Jacob et al., 2005). By entering new countries, they transfer products that are successful in their home markets to markets worldwide. PV project development companies will however only enter a market which provides interesting framework conditions. Motivated by this fact, this paper addresses the question of policy effectiveness by analyzing the PV project developers' point of view. Specifically, it aims at identifying, in a first step, the most relevant PV policy-related factors in the location decision for a PV project. Here it puts forward the hypothesis that return attributes are not of higher importance than "non-economic" policy risk attributes. In a second step it then calculates the investors' willingness-to-accept certain policy risks.

The question analyzed in this paper is thus motivated by a lack of knowledge of the observed phenomenon and a gap in the literature. It is addressed by a multi-stage methodological approach consisting of qualitative expert interviews and a quantitative adaptive conjoint analysis (ACA). The expert interviews identify the most relevant factors influencing the location decisions; the ACA allows a quantitative estimation of the relative importance and the utility of these factors. The combination of qualitative and quantitative data is an exclusive characteristic of this study. Expert interviews provide, on the one hand, detailed in-depth understanding, and the ACA data, on the other hand, allow statistical precision and generalization.

This study makes a methodological contribution by using the choice experiment in the context of policy making for the first time. So far, the choice experiment was used mainly in the domain of market research and recently also in some studies about investment behavior. The conjoint analysis has im-

portant advantages in comparison to a direct survey, which underlies much more the distortions of socially desired answers.
The outline of the paper is as follows. The next section develops the methodology. Section 3 provides the theoretical framework of conjoint analysis. Section 4 presents the results of the expert interviews, meaning the different policy-related factors influencing the location decision as well as their importance. In section 5, the experimental design of the conjoint analysis is outlined and section 6 evaluates the data collected in the empirical adaptive conjoint analysis. Concluding, section 7 presents policy recommendations, sheds light on the main limitations of the study and suggests directions for further research.

2. Methodology

This study applies a multi-stage methodological approach. In the first step, qualitative expert interviews (Flick, 1995) were conducted to explore the PV project developers' policy preferences. In the second step, the importance of the most relevant policy attributes was assessed through choice experiments using adaptive conjoint analysis (ACA) (Hartmann, 2002).
The expert interviews were 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 their business models were identified and the roles of host country characteristics as determinants in PV location patterns, especially in regard to the PV policy factors, were reviewed. As a result, this preliminary study established the relevant attributes in the location decision to be included in the questionnaire.
In the second step and upon the background of the expert interviews, an ACA was conducted. This is a well established PC-based market research technique to determine the optimal features of projected, as yet undeveloped products and services. ACA belongs to the family of conjoint experiment methods. Conjoint experiment was initiated by mathematical psychologists (Anderson, 1970; Kruskal, 1965; Luce & Turkey, 1964), and introduced in marketing research in the early 1970s (Green & Srinivasan, 1990; Orme, 2007). Over the last twenty years, it has been frequently used by market researchers for elicitation of consumers' preferences (Green & Srinivasan, 1990) and it also spread quickly over a wide array of research communities (Shin & Park, 2008). At the beginning, conjoint studies mainly analyzed the importance of product attributes and price. Later, concerns shifted to the simulation of customers' choices, and to the forecast of market responses to changes in the firm's products or those of its competitors (Batsell & Lodish, 1981; Ben-Akiva & Gershenfeld, 1998; Louviere & Woodworth, 1983). More recently, conjoint analysis is also used in environmental and resource economics, and in studies on investment behavior (e.g. Franke *et al.*, 2006; Muzyka *et al.*, 1996; Riquelme & Rickards, 1992; Shepherd & Zacharakis, 1999; Zacharakis & Meyer, 2000; Zacharakis & Shepherd, 2001). The methodological approach of this study is novel in that it uses ACA to investigate investor choices among policies.
The conjoint analysis approach suits this study well and also enables the alleviation of some shortcomings of previous research on location decision making. Most studies analyzing decision making used post-hoc methodologies (e.g. Ajami & Ricks, 1981; Cheng & Kwan, 2000; Larimo, 1995; Ulgado, 1996), which may generate biased results (Shepherd & Zacharakis, 1999; Ulgado & Lee, 2004). The respondents had to evaluate location factors in terms of their importance to the most recent location decision. So, they made the location decision at different points in time, with various firm resources and constraints, and under different environmental conditions. Also, the location alternatives were different. These variations can significantly affect a factor's importance. Conjoint analysis however is a real-time method (Shepherd & Zacharakis, 1999) and respondents have to make their decision based

on an identical set of alternatives to select from (Ulgado & Lee, 2004). This enables the elimination of many of the biases mentioned above.

Second, investors surveyed in past studies were often asked to evaluate location attributes individually (e.g. Ajami & Ricks, 1981; Ulgado, 1996). In reality however, firms evaluate their location alternatives as a group of varying location characteristics. Location decision-makers trade-off the different factors in comparing the available alternatives. PV project developers, for example, may want to invest in a certain country even if the feed-in tariff (FIT) is lower because the administrative procedure is very short. For that reason, an approach that asks respondents to assess a location site as a combination of attributes is more realistic (Ulgado & Lee, 2004).

Third, conjoint experiments enable the conducting of statistical tests at the individual level because a sample of one is sufficient to obtain statistical power to test for significance (Shepherd & Zacharakis, 1999). To generalize the results a greater sample size is required.

There are a number of conjoint methods and each method is suitable for different types of research questions[1]. Among the different conjoint-based techniques, ACA is the most suitable for the present study for several reasons:

A) The method chosen should adequately reflect how decision makers decide in actual situations. ACA breaks down the decision process in several steps, starting with a rating and ranking of the different attributes and levels. In decisions in the business-to-business context, and especially in the PV project location decision process, the evaluation of groups of factors is common (Kuhlen, 2008).
B) ACA has an adaptive computer administered interview format which asks each respondent in detail only about the factors of greatest relevance for him or her (Sawtooth Software, 2007). This customized approach minimizes the number of responses needed, the number of questions and the time required to complete the survey (Metegrano, 1994; Orme, 2007; Sawtooth Software, 2007). For this reason, a small sample size of around 60 appears to be sufficient (Shepherd & Zacharakis, 1999). This is ideal for studies on populations of small size and difficult to contact (Shepherd & Zacharakis, 1999) which is especially true for studies involving PV project developers.
C) The customized approach has also a big advantage over full-profile approaches[2] (where the product alternatives are described by levels of all attributes) as choice-based conjoint (CBC) in regard to the motivation of the survey participants (Hartmann, 2002). The rating and ranking approach is a much more enjoyable way of collecting data than the full-profile, as the respondent does not have to read and process several full-profile concepts before giving each answer. This approach keeps the respondent from becoming overloaded and confused (Sawtooth Software, 2007). Low motivation may negatively influence the validity – as the participants answer the questions less carefully – and the generalization of the results, because of a high dropout rate.
D) Last but not least, after completion of each ACA interview, the estimated individual preferences of the respondent are directly available for discussion or analysis. This allows the interviewer – before starting the on-line survey and by means of a couple of test interviews – to check if the questions are clear and if all of the most influencing attributes have been included.

3. Theoretical Framework

The ACA method is based on the microeconomic household/ consumption theory. This theory analyzes the economic decisions, and especially the consumption decisions, of private households (Kreps, 1990). Needs and desires drive an individual's purchase behavior. Before a product is chosen, it is

[1] For a summary of the different methods of conjoint analysis see Backhaus (2006), Orme (2007), Oschlies (2007) and Priem & Harrison (1994)

[2] In full-profile approaches, the product alternatives are described by levels of all attributes.

analyzed in detail to deduct an individual demand function. Thereby each household tries to maximize its utility. A consumption decision is thus based on a cost-benefit comparison of the different product alternatives (Kreps, 1990). Lancaster (1966) advanced this theory by indicating that not the products themselves but their characteristics bring a benefit. The benefit of the product is thus the sum of all product characteristics.

Based on this theory, the concept underlying ACA and conjoint analysis in general is that every product and service can be described in terms of its attributes, or characteristics, with different levels. A car for example has the color as an attribute, and this color can be red or blue (levels of the attribute). The consumer has a certain preference (utility) for each of the different colors (van Schaik *et al.*, 1998). Each attribute has a different value to the consumer (utility value), and those individual utility values can be quantified. The preference U for a certain product represents the sum of the partial utilities u of the different 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 provide utility. As a result, the other underlying foundation is the Random Utility Theory (Mansky, 1977), which allows the direct utility function of a person to be broken down into observable and unobservable parts. The preference model can thus be described as (Kappelhoff, 2002):

$$\mathbf{U} = \sum_{i=1}^{m} u_{i} + \mathbf{e}$$

This study does not evaluate the choice among products but among countries. Analogous to a product with multiple attributes, the political framework of a country is composed of several attributes. More importantly, there is an inevitable trade-off between the different attributes. Consequently, any attribute change influences the value of the respective country. The project developer tries to maximize his benefit by trading off different country-specific characteristics. The benefit of a country is the sum of the country-specific characteristics' utilities.

4. Results of the Expert Interviews

The interviews with eight experts confirmed that the policy conditions are currently the factors influencing a PV project location decision the most. These political conditions include the public incentive schemes, the application procedure, political solar energy target, and political stability.

The most common and effective incentive scheme in Europe is the FIT. Here, the level, duration, and yearly reduction of the tariff as well as the presence of a limitation of the promoted capacity (i.e. existence of a cap) are taken into account in the location choice. Sometimes, other incentive schemes such as investment subsidies and tax exemptions provide additional support.

Regarding the application procedure, the duration and the complexity of the approval procedure are of primary importance. A project developer is interested in realizing a project as soon as possible. If the procedure to get the necessary permissions is long and complicated, and especially if it is uncertain when and if at all the permissions are forthcoming, project developers hesitate to invest.

Furthermore, the PV policy stability is taken into account. If significant unexpected changes in the policy have occurred frequently, a project developer hesitates to enter the market because planning security is not provided.

Further, most of the countries have fixed political targets for renewable energies and sometimes in particular for solar power. If the gap between the actual and the targeted amount is large, there is a high probability that the country will undertake stronger efforts to promote renewable energy in subsequent years. This is however a long-term process and thus of lower importance for project developers.

To a large extent linked to the political conditions are the legal factors. The legal conditions include regulatory requirements, a legally regulated FIT, legal back-up of the repayment, and safe law enforcement. A FIT can only be guaranteed if power utilities are obliged to accept feed-in power (power purchase agreement). In the context of the FIT payments, safe law enforcement and legal repayment back-up are also important. Further, clear regulatory requirements and a legal obligation for electricity suppliers to accept feed-in lead to a more efficient application procedure. The interviewed experts are all active only in European countries where safe law enforcement is provided and consequently not decisive in the location choice.

Besides policy conditions, the solar irradiation is another influencing factor. However, because the current level of FIT in countries where PV project developers are active is relatively high, the solar resource is of a minor importance in explaining the differences in return from one country to another.

Also of secondary importance are currently the economic conditions, because the PV market is still strongly dependent on public policy and not yet self-sustaining. The market demand and potential is thus artificially created through FITs. However, as soon as grid parity is reached and the market is self-sustaining, these factors will be of high importance.

5. Experimental Design

Sample

The population of interest of the ACA survey is PV project developers from Germany, Italy, Spain, Greece and Switzerland which are engaged in or are thinking about undertaking PV projects abroad in another European country. The online survey has been conducted in October-November 2008. The PV project developers were solicited to participate in the survey by phone and/or e-mail, at a solar industry fair, by an article on the Solarserver website (www.solarserver.de) and a leaflet in a solar industry journal.

Selection of Attributes and Levels

Based on the qualitative pre-study, a questionnaire consisting of two parts was compiled: The ACA interview about return and risk factors of PV policy, and questions to obtain background information about the project developers' experience and activities, and about the companies they are working for.

In the expert interviews, the decision-influencing attributes could be identified. Besides being relevant to the location decision, attributes need to fulfill several criteria to be included in the ACA survey (Backhaus *et al.*, 2006) (cf. Tab. 1). So, as the study aims at giving policy recommendations, only attributes shall be included in the choice experiments that can be influenced by policymakers. This is not the case for 'Solar radiation' and economic factors, and only partly for 'Local production' and the legal factors. Furthermore, attributes need to be independent, i.e. the utility of the attribute and the perceived utility of a level should not interact with other attributes. 'Market demand' and 'Market potential' are currently not independent but linked to the attractiveness of political conditions. Finally, attributes should be compensatory, i.e. attributes and levels have to be able to substitute each other in investors' perceptions.

As a result, five out of twelve attributes fulfill all requirements (cf. Tab. 2) and were chosen for the ACA experiment: 'Level of tariff', 'Duration of tariff', 'Existence of a cap' (or the time until the support cap is reached), 'Duration of the administrative process' and 'Significant unexpected policy changes in the last 5 years' (support policy stability).

Attributes	relevant	can be influenced	independent	compensatory
Level of the FIT	X	X	X	X
Duration of the FIT	X	X	X	X
Existence of a cap	X	X	X	X
Duration of the administrative process	X	X	X	X
Support policy stability	X	X	X	X
Gap to political solar target	0	X	X	X
Regulated feed-in	X	0	X	X
Law-enforcement	X	0	X	X
Market demand	0	—	—	X
Market potential	0	—	—	X
Local production	0	0	X	X
Solar radiation	0	—	X	X

Tab. 1: Attribute selection (X=criteria fulfilled; 0=criteria partly fulfilled; — = criteria not fulfilled)

Tab. 2 shows a description of each attribute, together with the levels the attributes taken in the survey. These attributes and their respective levels form a collection of 2,800 different combinations (The number of combinations corresponds to the multiplication of the number of attribute levels.). As the power production of an installation is strongly connected to the solar radiation, the type and the size of the installation and to have a comparable initial position for the decision-making, these aspects are predefined in the questionnaire: solar radiation: 1,500 kWh/m^2; installation type and size: Greenfield solar plant of 500 kW.

Attributes	Description	Attribute levels
Level of FIT	The amount paid per kWh feed into the grid.	31, 35, 38, 41, 45 ct/kWh
Duration of FIT	Number of years for which the FIT is guaranteed.	15, 20, 25 y. of support
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 is reached.	No cap, cap reached in 4 y., cap reached in 1 y.
Duration of the administrative process	Predicted time from the project sub-mission until all permits are obtained.	Administrative process of 1-2, 3-6, 7-12, 13-18, 19-24 months
Significant unexpected policy changes in the last 5 years	A change is considered as significant if it leads to more than 15% of FIT reduction.	0, 1, 3 policy changes

Tab. 2: Attributes and attribute levels used in the ACA experiment

Questionnaire design

The computer-based survey questionnaire proceeds in a fixed order (adapted from Sawtooth Software (2007)):

1. The first step usually defines the "Preference for Levels". The respondents rate the levels in regard to their relative preference. This section is omitted in the questionnaire as the respondent's preferences for the attributes' levels are obvious.

2. In the “Attribute Importance” section, the relative importance of each attribute to the respondent is determined. The participants are asked to assign their importance to the difference between the most and the least relevant levels per attribute. As suggested by King *et al.* (2005), the "Attribute Importance" questions were skipped and more "Paired-Comparison" questions were added instead (see next section).
3. In the "Paired-Comparison" section, the computer program forms pairs which respondents have to compare (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. A nine point scale was given including ‘strongly prefer left (or right)’, ‘somewhat prefer left (or right)’ and ‘indifferent’. For the compilation of each "Paired-Comparison" question all prior answers including prior trade-offs were used. 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.

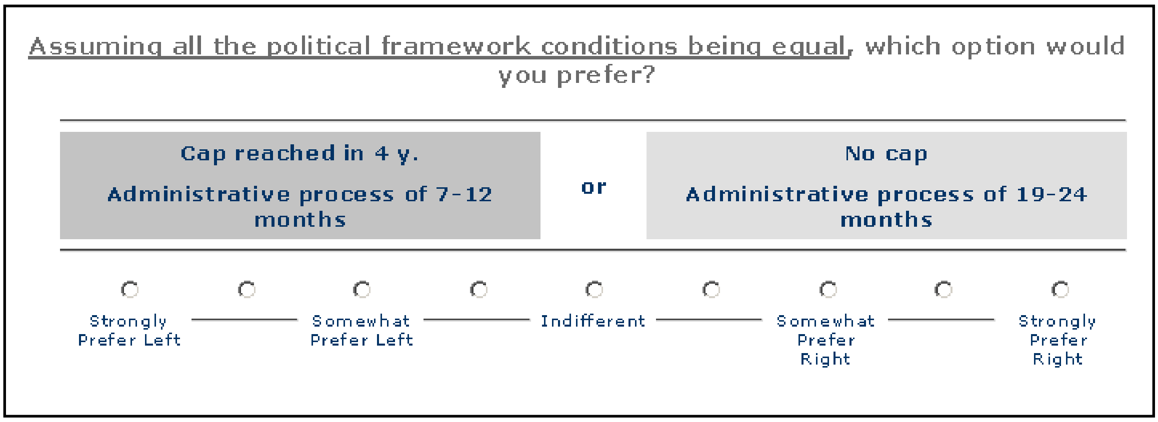

Fig. 1: Screenshot of a "Paired-Comparison" question

4. In the last section, the computer composes a series of "Calibrating Concepts" where the product alternatives are described by levels of all attributes (cf. Fig. 2). The respondent is asked a "likelihood of choosing" between 0 and 100 about each. To assess the spread, the mathematically worst concept is presented first and then the best one.

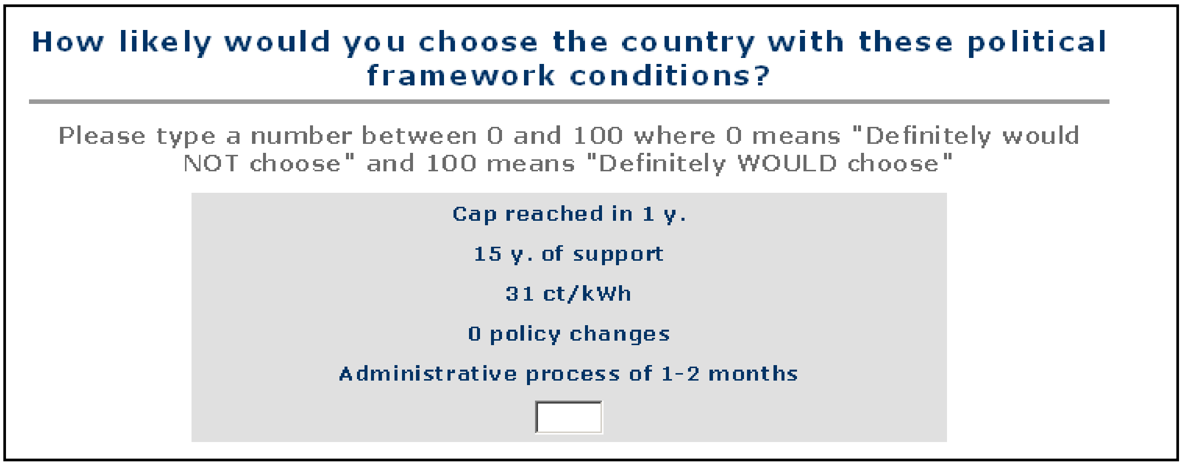

Fig. 2: Screenshot of a "Calibrating Concept" question

Data Analysis

Descriptive statistics were obtained from the background data and responses to the ACA questionnaire. For the background data, information about the respondents (profession, professional experience, and knowledge) and their company (activities, headquarters location, and countries in which it is active) are provided.

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' willingness-to-accept certain policy risks; as well as to perform likelihood of purchase simulations.

Before estimations with the ACA data can be made, the part-worth utility values need to be normalized. Initial utility estimates are based on the respondent's desirability ratings for attribute levels together with ratings of attribute importance. The initial estimates are updated during the experiment. As the initial position of the utility estimation is different for each participant, the utility values must first be scaled so that utilities can be compared across participants. The utilities are scaled in such a way that the sum of the utility ‘points’ across all levels for a respondent is equal to the number of attributes times 100 (Metegrano, 1994).

6. Results

Background characteristics

135 respondents logged on to the survey website and 63 questionnaires were completed. Each project developer made 25 choice tasks, resulting in a final data set of 1575 choice decisions. The ACA interview was time-efficient; the duration had a median of 20 minutes.

80% of respondents were project developers. About 50% work vertically integrated i.e. they are involved in the planning and the building of PV plants, whereas the other 30% are just concerned with the planning. The remaining 20% are investors and project or business managers also involved in project location decisions. More than 80% have less than 7 years of experience: 27% have 1 year, 29% 2-3 years, and 27% have 4-6 years of experience. This illustrates how recent the PV business is. 44% of the interviewed persons have been involved in 1-10 projects and 38% in more than 10 PV projects. Three project developers have even worked on more than 100 projects. 36% of the realized projects are of a capacity smaller than 100 kW, 22% of the projects are between 100 and 500 kW, 38% between 500 kW and 10 MW, and 4% are bigger than 10 MW.

70% of the companies where the respondents work are active in Germany, 57% in Spain, 49% in Italy, 30% in Greece, 27% in France, 17% in Portugal, and 14% in Switzerland. 78% of the interviewed PV project developers know well the PV policy situation of Germany, 71% of Spain, 59% of Italy, 43% of Greece, 37% of France, 19% of Portugal, and 13% of Switzerland. These numbers show the prominent role of Germany and Spain and so it is not surprising, that more than half of the project developers interviewed (58%) work for a company having its headquarters in Germany. The other companies' headquarters are located in Spain (17%), Italy (10%), and several other countries.

Part-worth utilities

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, but it shows that it is less preferred than other levels of the same attribute with a higher part-worth value.

The dispersion of the population can be measured by the standard deviation. A high standard deviation indicates that the data points are dispersed over a large range of values, while a low standard deviation indicates that the data tends to be very close to the same value (the mean).
Average part-worth utilities and standard deviations for each attribute level are displayed in Tab. 3. The part-worth utility examination confirms that always the lowest level had the lowest relevance for all project developers. This makes sense intuitively and supports the validity of the results. Standard deviations are all very low indicating a low distribution. 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). A low average part-worth utility and a low standard deviation indicate thus that such an attribute level is very unattractive (e.g. “31 ct/kWh”).

Attribute Level	Part-worth Utility	Standard Deviation
Level of FIT		
31 ct/kWh	-62	6
35 ct/kWh	-27	6
38 ct/kWh	0	4
41 ct/kWh	29	6
45 ct/kWh	60	9
Duration of the administrative process		
1-2 months	63	7
3-6 months	32	6
7-12 months	1	5
13-18 months	-31	6
19-24 months	-64	9

Attribute Level	Part-worth Utility	Standard Deviation
Duration of FIT		
15 y. of support	-35	10
20 y. of support	3	6
25 y. of support	33	7
Cap		
No cap	44	9
Cap reached in 4 y.	5	9
Cap reached in 1 y.	-49	12
Number of policy changes		
0 policy changes	41	8
1 policy change	6	6
3 policy changes	-47	11

Tab. 3: Average part-worth utility estimates and standard deviations by attribute levels (hierarchical Bayes models with all normally distributed part-worth)

Relative Importance
From the ACA data, the relative importance of each attribute can be estimated 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 (cf. Fig. 3) . 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 (K. Backhaus *et al.*, 2006). The relative importance of each attribute was calculated using the formula (adapted from Clark-Murphy & Soutar (2004))

$$RI_i[\%] = \frac{(MaxU - MinU)i}{\sum_i (Max - Min)i} \text{ x } 100$$

where RI_i is the relative importance of the ith attribute; *MaxU* the maximum utility of the ith attribute; and *MinU* the minimum utility of the ith attribute.

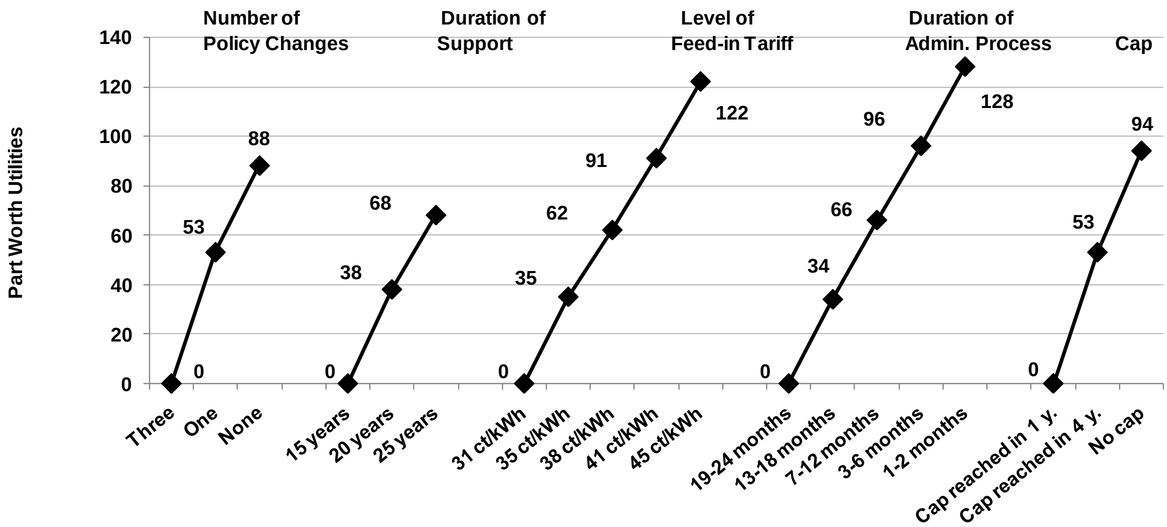

Fig. 3: Range of the total utilities for each attribute

The analysis of the relative importance of the attributes reveals the highest importance for the duration of the administrative process with 26%. Almost as important is the level of the FIT (24%). The existence of a cap and PV policy changes are of medium importance with 19% and 18% respectively. The lowest importance (14%) is attributed to the duration of the FIT.

PV project developers are thus particularly sensitive to the duration of the administrative procedures, followed by other policy risks (policy changes, existence of cap). Duration of support is relatively less important. This indicates that a more effective administrative procedure enables a lower FIT, without a loss of attractiveness for PV project developers.

Investors' implicit Willingness-to-accept certain Policy Risks

In the next step, path-worth utilities are converted into project developers' implicit willingness-to-accept certain policy risks using the formula

$$WTA_l \left[\frac{\mathbf{ct}}{\mathbf{kWh}}\right] = \frac{U_l \times \Delta FIT}{MaxU_{FIT}}$$

where WTA_l is the implicit willingness-to-accept of the attribute level l; U_l the part-worth utility of the attribute level l; ΔFIT the difference of the level of FIT, i.e. 14ct/kWh; and $MaxU_{FIT}$ the maximum utility of the attribute "Level of the FIT".

Fig. 4 shows that for every half-year increase in the duration of the administrative process, a government has to pay project developers a FIT premium of about 4 ct/kWh (all else being equal).

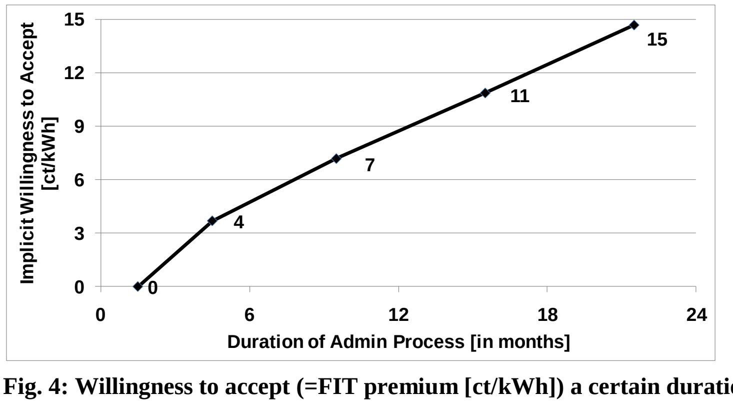

Fig. 4: Willingness to accept (=FIT premium [ct/kWh]) a certain duration of the administrative process

The choice experiments included three attribute levels regarding the existence of a cap, being 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 FIT that is about 5 (11) ct/kWh lower (Fig 5).

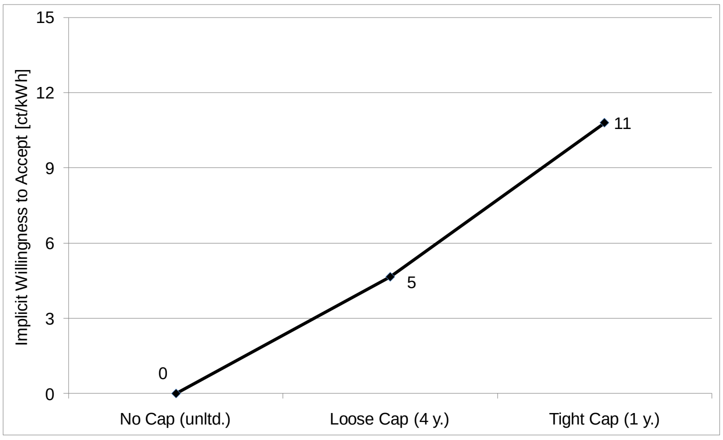

Fig. 5: Willingness to accept (=FIT premium [ct/kWh]) a loose/tight cap

With regard to the policy stability, the study estimates that compared to no policy risk conditions, in low risk conditions (one significant unexpected policy change in the last 5 years) the FIT needs to be 4 ct/kWh, in high risk conditions (three significant unexpected policy changes in the last 5 years) 10 ct/kWh higher to keep its attractiveness (Fig. 6).

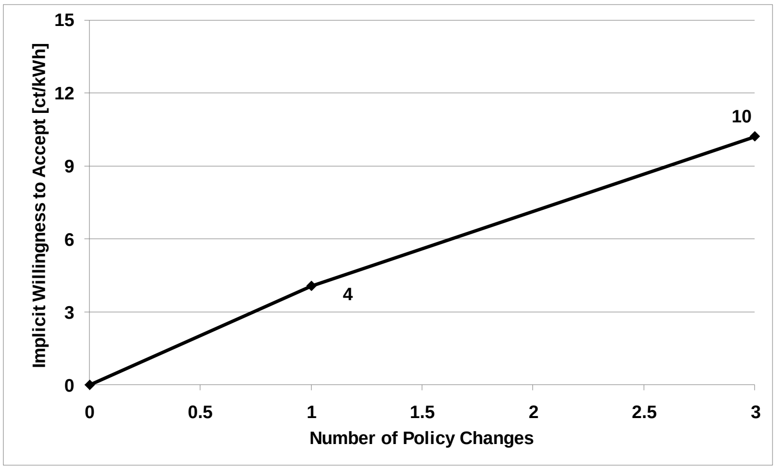

Fig. 6: Willingness to accept (=FIT premium [ct/kWh]) a certain number of policy changes

Simulation of Project Developers' Preferences (Likelihood of Purchasing)

Sawtooth offers the simulation method "Purchase Likelihood" (*SMRT Simulation*) to estimate the level of interest for a certain combination of attribute levels. The utilities are scaled so that an inverse logit transform provides estimates of purchase likelihood, as expressed by the respondent in the calibration section of the questionnaire. The simulator estimates how each respondent might have answered if presented with any concept in the calibrating section of the interview. The likelihood projection is given on a 0 to 100 scale.

This method can be used to investigate the likelihood of project developers investing in a certain country (i.e. a specific combination of attribute levels). Using a combination of attribute levels from the conjoint design it is possible to simulate the effective market framework in a certain country. Based on the results of the conjoint analysis (i.e. the investors' relative importance of various attributes) it will then be possible to define the likelihood that an investor will invest in a specific country.

Prediction of choice among holdout tasks can be used to check validity of this simulation method. Holdout tasks are constructed as the concepts in the calibration section of the survey but are not used by the Sawtooth program for estimating the preferences (part-worth utilities) of the respondents. In the present study, three holdout tasks have been included in the survey (cf. Tab. 5). Holdout task 1 describes the German, holdout task 2 the Greek and holdout task 3 the Greek PV policy framework in 2007.

Figs. 7-9 illustrate the project developers' likelihood of investing in each holdout task, the mean of these data, and the SMRT Simulation value for each holdout task. The simulations by Sawtooth are 2-19% higher than the mean investment likelihood of the survey respondents. This indicates the high validity of the results and allows thus the calculation of meaningful scenarios.

	Holdout 1 Germany (2007)	Holdout 2 Greece (2007)	Holdout 3 Spain (2007)
Policy Framework			
Duration admin. process (months)	1-2	19-24	13-18
Level of the FIT **(**ct/kWh)	35	45	41
Cap	No cap	No cap	Cap reached in 1 y.
Number of PV policy changes	0	1	1
Duration of the FIT (years)	20	20	25
Investing Likelihood (given on a 0 to 100 scale)			
Mean of project developers' likelihood	87	72	38
SMRT Simulation	99	85	39
Difference in percent	14%	19%	2%

Tab. 4: Description of holdout tasks, project developers' likelihood and SMRT Simulation

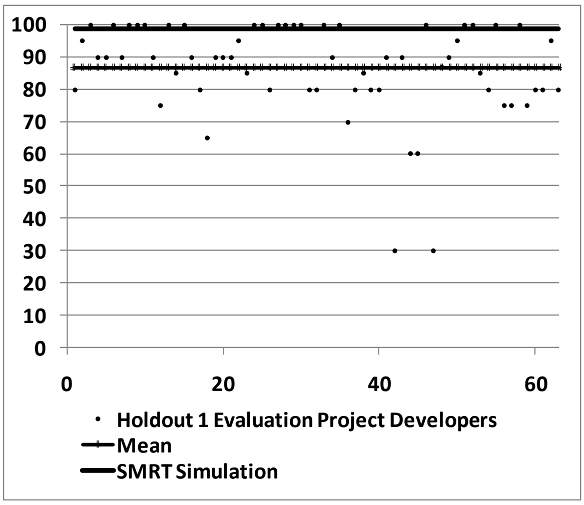

Fig. 7: Holdout task 1 – Germany

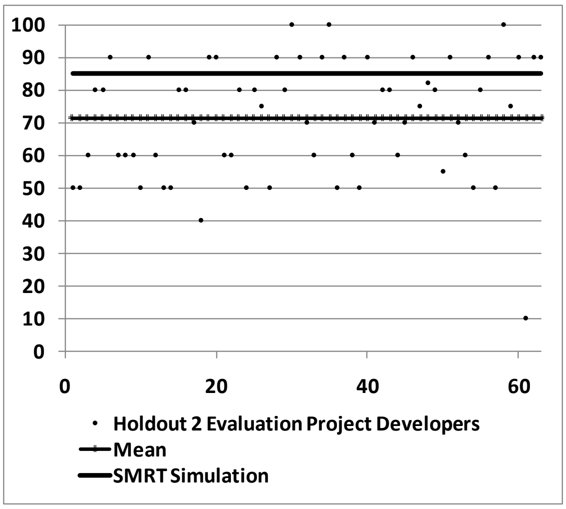

Fig. 8: Holdout task 2 – Greece

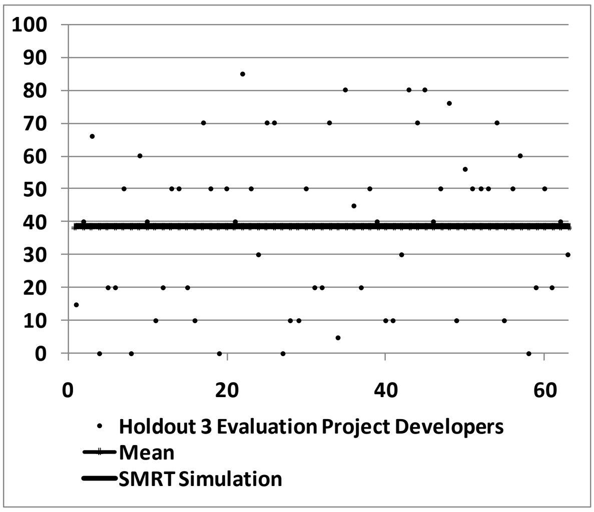

Fig. 9: Holdout task 3 – Spain (2007)

Additionally this method allows for conducting simulations to estimate the influence of a hypothetical change in the policy design (e.g. increase in remuneration level, decrease of administrative process duration) on the project developers' likelihood for investing in a certain country. In what follows, the Spanish situation is analyzed (Tab. 5). The attribute levels which were changed from the initial scenario are in bold.

One of the policy risks policy makers can influence to some degree is the duration of the administrative process. *Scenario A: Admin. process* reveals that an administrative process that is 6 or 12 months shorter (7-12 or 3-6 instead of 13-18 months) would bring a significantly higher investment likelihood of 66 or 84, respectively, compared the initial situation (39).

Besides the administrative process, the tight cap is another important issue in Spain. *Scenario B: Cap* shows that loosening the cap (reached in 4 y.) or removing the cap (no cap) makes sense to attract project investments since the likelihood of investing increases to 81 or 95, respectively.

Finally, the importance of a continuous PV policy is illustrated in *Scenario C: Policy stability*. Having no changes in policy instead of one in the last 5 years increases the likelihood of investment from 39 to 68.

	Spain (2007)	A Admin. process	B Cap	C Policy stability
Policy Framework				
Admin. process (months)	13-18	**7-12/ 3-6**	13-18	13-18
FIT level (ct/kWh)	41	41	41	41
Cap	in 1 y.	in 1 y.	**in 4 y./ no cap**	in 1 y.
PV policy changes	1	1	1	**0**
FIT duration (years)	25	25	25	25
Investing Likelihood (given on a 0 to 100 scale)				
SMRT Simulation	39	66/ 84	81/ 95	68

Tab. 5: Investment likelihood simulations for changes in the PV policy framework of Spain in 2007

7. Conclusion

The achievement of energy policy objectives, and thus the transition to a sustainable energy system depends on whether policy instruments effectively influence investors' behavior.

Applying a sophisticated research method from another field (marketing), this study is one of the first empirical contributions that investigates the influence of renewable energy policies on investors' decisions. By means of different estimations and simulations based on ACA data the relevance of different policy factors and the costs of different policy risks have been quantified. Based on this solid empirical basis, it is possible to develop specific scenarios that enable policy makers to assess the costs and benefits of reducing various elements of policy risk.

The key finding is that risk matters in PV policy design, and that a price tag can be attached to specific policy risks. More specifically, the attributes “Duration of the administrative process” and “FIT level” were perceived as the most important attributes in the location decision. SMRT Simulations and willingness-to-accept estimations revealed that a reduction of the administrative process of 6 months enables a 4 ct/kWh lower FIT without a loss of attractiveness for PV project developers to investing in the given country. The waiver of a cap also allows having a lower FIT: removing a cap which is expected to be reached in one (four) year(s) will allow governments to reduce the FIT by about 11(5) ct/kWh. The third policy risk analyzed in this study is political instability. Compared to one significant unexpected policy change in the last 5 years, respondents accept a 4 ct/kWh lower FIT if the political conditions are stable. Theses estimations confirm prior research that points to the importance of policy risk and "non-economic" barriers – such as duration of the administrative process and political instability – to the deployment of renewable energy.

Governments can build on these empirical results to design policies that will be effective in attracting PV investments 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 the feed-in tariff to attract solar project developers.

As with any piece of research, this study is subject to some limitations that provide starting points for further research. This study has focused on the political factors, however, there are other factors that influence the location decision of PV installations and of which the relevance could be estimated in further studies. Such unobserved factors include language, country size, personal contacts and the population’s attitude towards the new technology.

The study discloses (by means of SMRT simulations) the influence of changes in the political framework on the project developers’ investment likelihood. At this point only few concrete scenarios are estimates. In future studies, the developed simulation tools can be applied to design scenarios and thus give more specific policy design recommendations.

Even though a sample of 60 is often described in the literature as being sufficient for an ACA survey, the empirical basis of 63 participants’ results in a limited power of the study and is a limiting factor when trying to make accurate generalizations. The results should for that reason be interpreted carefully and the sample size should be increased in future studies.

The ACA data and thus the implicit willingness-to-accept is based on stated preference data. This data could be validated by cross-checking it with revealed preferences (especially as longer time series become available). The data could also be cross-checked with "rational" financial evaluation of projects to explore behavioral biases (e.g. duration vs. level of the FIT).

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