Empowering Solar Power – Empirical Simulations of European Photovoltaic Project Developers Preferences

Sonja Lüthi

Abstract— Successfully making the transition to renewable energy is high on the policy agenda in many countries around the world. A 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.

Index Terms— Conjoint analysis, investor preferences, modelling, photovoltaic, simulations, solar energy policy

I. Introduction

A promising energy source of the future is solar energy. During the past few years the installed photovoltaic (PV) capacity has been strongly increasing, especially in Germany and Spain. However, the contribution of solar power to the total power production is still negligible. The barriers slowing this transition process are manifold, but 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. 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 [1]. 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 [2] 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 renewable energy companies' point of view is however of high importance because these companies are transfer agents [1]. By entering new countries, they transfer products that are successful in their home markets to markets worldwide. A company 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

Sonja Lüthi studied at the University of Fribourg, Switzerland, Université de Québec à Montréal (uqam) and Concordia University, both in Montréal, Canada. Parallel to her studies she worked with the Swiss Agency for Renewable Energy and Energy Efficiency (AEE).
Since 2007, she is a PhD student at the University of St. Gallen and a project manager at the Institute for Economy and the Environment (IWÖ-HSG), Sonja's current project portfolio includes several energy related projects, among others the EU projects DISTRES and BARENERGY. July 2009-2010 she spent as visiting research scholar at UC Davis and UC Berkeley in California.

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 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.

The 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 important 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.

II. Experimental Design

A. Method

This study applies a multi-stage methodological approach. In the first step, qualitative expert interviews [3] were conducted to explore the PV project developers’ policy preferences. In the second step, and based on the results of the expert interviews, the importance of the most relevant policy attributes was assessed through choice experiments using adaptive conjoint analysis (ACA) [4]. Using this data set, investment likelihood and share of preference simulations are conducted.

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.

In the second step and upon the background of the expert interviews, an adaptive conjoint analysis (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 [5-7], and introduced in marketing research in the early 1970s [8, 9]. Over the last twenty years, it has been frequently used by market researchers for elicitation of consumers’ preferences [9] and it also spread quickly over a wide array of research communities [10]. 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 [11-13]. More recently, conjoint analysis is also used in environmental and resource economics, and in studies on investment behavior [e.g.,14, 15-19]. The methodological approach of this study is novel in that it uses ACA to investigate investor choices among policies.

B. 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/m2*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 kWp.
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.

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

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 years, cap reached in 1 year
Duration of the administrative process	Predicted time from the project submission 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

C. 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 [20]. 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.

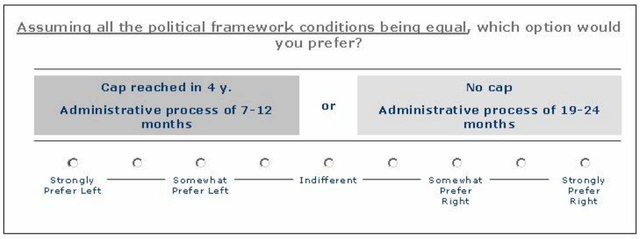

Figure 1: Screenshot of a "Paired-Comparison" question

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.

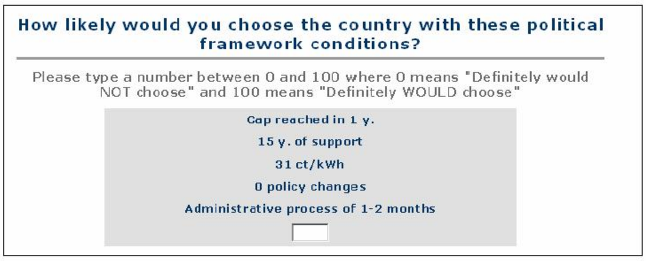

Figure 2: Screenshot of a "Calibrating Concept" question

III. 3. Model Specification

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 [21]. It states that before a consumer chooses a product, he analyzes it in detail to deduct an individual demand function. Thereby he tries to maximize its utility in choosing the product of the highest utility. A consumption decision is thus based on a cost-benefit comparison of the different product alternatives [21]. Lancaster [22] advanced this theory by indicating that not the products themselves but their characteristics bring a benefit. As a result, the benefit of the product is 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). Each attribute has a different value to the consumer (individual utility value) that 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 [23], 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 [24]:

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

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 [25]. The relative importance of each attribute is calculated using the formula (adapted from [26]

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

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

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

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; ΔFiT the difference of the level of feed-in tariff, i.e. 14ct/kWh; and *MaxFiTU* the maximum utility of the attribute "Level of tariff".

IV. Data and Sample

Table 2
Descriptive statistics of European PV project developers in our sample

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
Geographical Distribution of European PV project developers in our sample

	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%		

V. LIKELIHOOD OF INVESTMENT SIMULATIONS

Sawtooth SMRT offers the simulation method "Purchase Likelihood" 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, it is then be possible to define the likelihood that an investor will invest in a specific country.

Likelihoods are estimated for policy frameworks by summing scaled utilities and estimating probabilities with the following formula:

$$p = \frac{e^u}{1+e^u} \tag{4}$$

where p is probability of investment, e the constant e and u the policy frameworks utility.

The market simulator allows linear interpolation within attribute level ranges so that policy frameworks with attribute levels that were not included in the survey, but are between the ones included in the survey, can be simulated. Some interpolations have been made in this research study to simulate policy frameworks of various countries. In general interpolation is likely to produce acceptable results, but they need to be interpreted carefully.

To check the validity of the data and this simulation method, we included three holdout tasks in our survey. 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 were included in the survey (cf. Table 3, Figures 1-3). The project developers' likelihood to invest in the respective policy frameworks can be compared with the model calculations. The calculated mean is 2-19% higher than the mean investment likelihood of the survey respondents. This indicates the high validity of the results and thus allows the calculation of meaningful scenarios.

Table 4
Description of holdout tasks and comparison of project developers' likelihood with SMRT Simulation results

	Holdout 1	Holdout 2	Holdout 3
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%

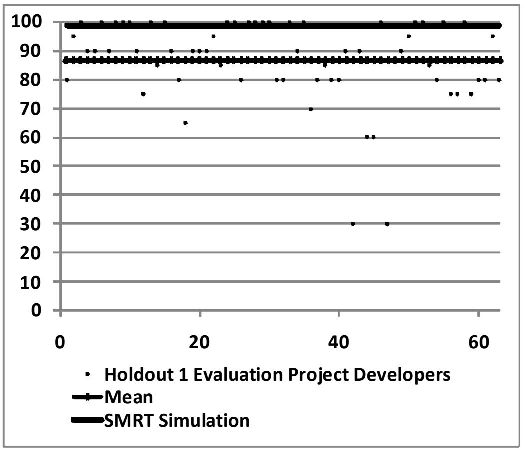

Figure 3: Holdout task 1 - Comparison of PV Project Developers Likelihood to Invest with the Likelihood to Invest SMRT Simulation

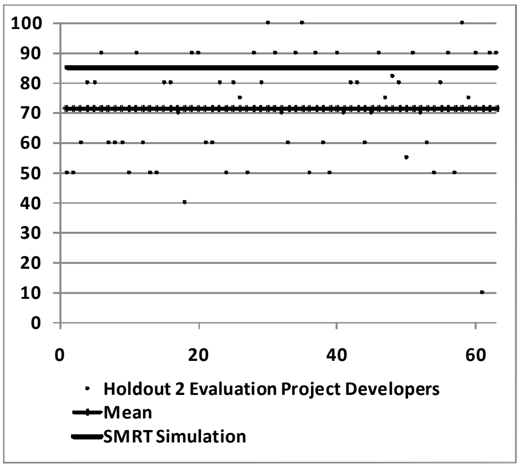

Figure 4: Holdout task 2 - Comparison of PV Project Developers Likelihood to Invest with the Likelihood to Invest SMRT Simulation

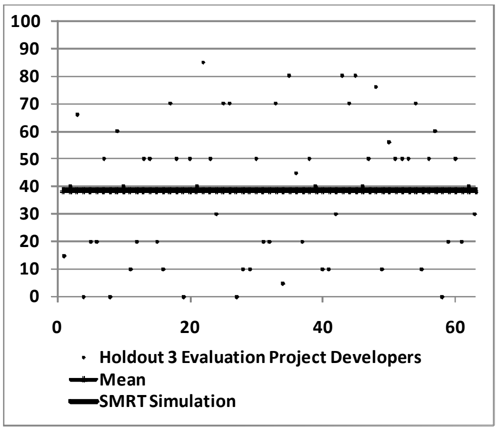

Figure 5: Holdout task 3 - Comparison of PV Project Developers Likelihood to Invest with the Likelihood to Invest SMRT Simulation

In the following, the investment likelihood of the hypothetical European solar PV market in 2007 in Germany, Greece and Spain have been simulated. More details about the PV policy framework conditions of these three countries can be found in Lüthi [27]. The investment likelihood for Germany is 96.1% and thus very high. The likelihood that a project developer would do a PV project in Greece is 57.7% and only 20.6% in Spain.

Table 5
Investment likelihood simulations for the hypothetical European solar PV market in 2007

	Germany	Greece	Spain
Policy Framework			
Duration admin. process (months)	1-2	19-24	7-12
Level of the FIT (ct/kWh)	31*	40	41
Cap	No cap	No cap	Cap reached in 1 y.
Number of PV policy changes	0	0	1
Duration of the FIT (years)	20	20	25
Investing Likelihood (given on a 0 to 100 scale)			
SMRT Simulation	96.1	57.7	20.6

* The FIT for a 500 kWh Greenfield PV installation in 2007 was 40.6 ct/kWh. In Germany, the medium solar radiation is only 900 kWh/m^2 compared to 1.500 kWh/m^2 in Greece and Spain. As a result, the level of FIT for the German policy framework needs to be corrected by a factor of 0.6 and would thus amount only to 24.4 ct/kWh. However, Sawtooth ACA does not allow extrapolation. As a result, the lowest possible attribute level (i.e. 31 ct/kWh) has been chosen for the simulations.

Additionally, this method allows for conducting simulations to estimate the influence of a hypothetical change in the policy design (e.g., an increase in remuneration level or a decrease of administrative process duration) on the project developers' likelihood for investing (on a scale of 0-100) in a certain country. In the following, the Spanish and the Greek situations in 2007 have been analyzed (Table 5 and 6). The attribute levels which were changed from the initial scenario are in bold.

In Spain, one of the 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, 12 or 18 months shorter (7-12, 3-6 or 1-2 months instead of 13-18 months) would bring a significantly higher investment likelihood of 43, 68 or 86, respectively, compared to the initial situation (21).

Besides the administrative process, the tight cap is another important issue in Spain. *Scenario B: Cap* shows that loosening the cap (reached in 4 yr.) or removing the cap (no cap) makes sense to attract project investments since the likelihood of investing increases to 62 or 88, respectively. Further, 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 on a scale from 0-100 from 39 to 68.

Scenario D: FIT illustrates the influence of a rise of the FIT on the investment likelihood. A 4 ct/kWh higher FIT would bring an investment likelihood of 43, i.e., similar appeal for investors as in the case of a 6 months shorter administrative process.

Table 6
Investment likelihood simulations for changes in the PV policy framework of Spain in 2007

	Spain 2007	A Admin. process	B Cap	C Policy stab.	D FIT
Policy Framework					
Admin. process (months)	13-18	**7-12/ 3-6/ 1-2**	13-18	13-18	13-18
FIT level (ct/kWh)	41	41	41	41	**45**
Cap	in 1 y.	in 1 y.	**in 4 y./**	in 1 y.	in 1 y.

	no cap				
PV policy changes	2	2	2	**0**	**2**
FIT duration (years)	25	25	25	25	25
Investing Likelihood (given on a 0 to 100 scale)					
SMRT Simulation	21	43/ 68/ 86	62/ 88	68	43

Regarding Greece (Table 6), the current likelihood of investment of 58 can be significantly improved by shortening the duration of the administrative process. *Scenario A: Admin. process* shows that it for 6 or 12 months would increase the likelihood to invest to 82 or 94.

Another less important barrier in Greece is political instability. *Scenario C: Policy stability* illustrates the importance of a continuous PV policy. Having no negative changes in policy instead of one in the last 5 years increases the likelihood of investment from 58 to 82.

Finally, to reach a higher investing likelihood, other than reducing the policy risks, an increase of the FIT is also possible. To reach an investing likelihood of 85, the FIT needs to be as high as 45 ct/kWh.

Table 7
Investment likelihood simulations for changes in the PV policy framework of Greece in 2007

	Greece (2007)	A Admin. process	B Policy stability	C FIT
Policy Framework				
Admin. process (months)	19-24	**13-18/ 7-12/ 3-6/ 1-2**	19-24	19-24
FIT level (ct/kWh)	40	40	40	**41/ 45**
Cap	No cap	No cap	No cap	No cap
PV policy changes	1	1	**0**	1
FIT duration (years)	20	20	20	20
Investing Likelihood (given on a 0 to 100 scale)				
SMRT Simulation	58	82/ 94/ 98/ 99	82	66/ 85

6. Share of Preference Simulations

So far, we have examined various countries individually. In the following, we simulate the interdependency of different countries. In 2007, the European PV market was mostly dominated by three countries, i.e., Germany, Spain and Greece. As a result, the following simulations look at these three countries.

First, the three countries' share of preferences in the hypothetical market of 2007 are calculated. The Share of Preference model estimates the probability of choosing to invest in the simulated policy framework, arriving at a "share of preference" for each product.

This is done in two steps:

1. Subject the respondent's total utilities for the product to the exponential transformation (also known as the antilog): $s = \exp(utility)$ (5)
2. Rescale the resulting numbers so they sum to 100.

Sensitivity analysis by means of market simulation offers a way to report preference scores for each level of the policy framework attributes. This approach shows how investors' preferences can be improved or worsened by changing its attribute levels one at a time, while holding all other attributes constant at the base case levels.

First, shares of preferences in a base case market are simulated. Second, one level of the policy framework characteristics is changed, while all other attributes are held constant at base case levels. The market simulations are run repeatedly to capture the incremental effect of each attribute level upon market condition choice. After having tested all levels within a given attribute, that attribute is returned to its base case level prior to testing another attribute [28].

Share of preference is one of the factors contributing to market share. It is not possible to simulate market shares with conjoint part-worth utility data as this data cannot account for many real-world factors that shape market shares, such as market maturity, awareness, reactive competitive measures, capital availability, etc. Conjoint analysis predictions also assume that all relevant attributes that influence share have been measured. Therefore, the share of preference predictions are only indications of market shares for each policy base case scenario and can only be interpreted as relative indications of market shares.

Table 8
Share of Preference simulations for the hypothetical European solar PV market in 2007

	Germany	Greece	Spain
Policy Framework			
Duration admin. process (months)	1-2	19-24	7-12
Level of the FIT (ct/kWh)	31	40	41
Cap	No cap	No cap	Cap reached in 1 y.
Number of PV policy changes	0	0	1
Duration of the FIT (years)	20	20	25
Share of Preference			
SMRT Simulation	93.5	5.1	1.4

The Share of Preference simulation shows that the German market was by far the most attractive for solar PV project developers (93.5%) (cf. Table 7).

A. Germany

The sensitivity analyses for Germany (Figure 4) reveal that the 2007 policy framework in Germany was very attractive for solar PV project developers (93.5%), even though the level of the FIT, 31ct/kWh, was much lower than the FIT of Greece and Spain. The analyses show that in the case of a longer administrative duration, a cap or negative PV policy changes, the project developers' share of preference would decrease drastically. If, for example, the administrative duration was 13-18 months, instead of the current 1-2 months, the share of preference would decrease from 93.5% to 34.9%.

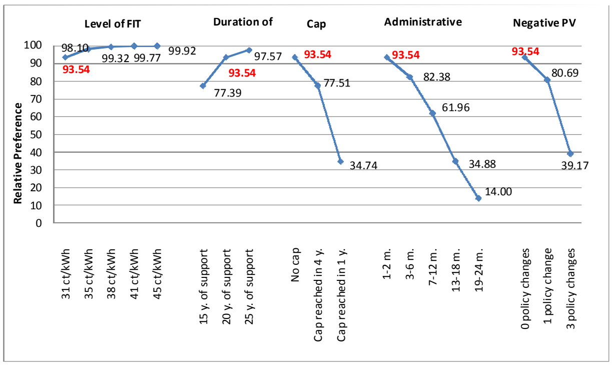

Figure 6: Sensitivity analysis over all attributes in Germany
Bold and red numbers display the base case share of preference.

B. Greece

Figure 5 displays the sensitivity analysis of share of preferences for Greece. The share of preference of the hypothetical market is very low - 5.05%. It can be incrementally increased by an acceleration of the administrative process. Decreasing the duration by 6 months would triple the Greek share of preference (14.74%); and accelerating the administrative process to 1-2 months (like it is the case in Germany), would increase the share of preference to 85.6%.

Higher policy stability or a higher FIT would lead to a higher share of preference.

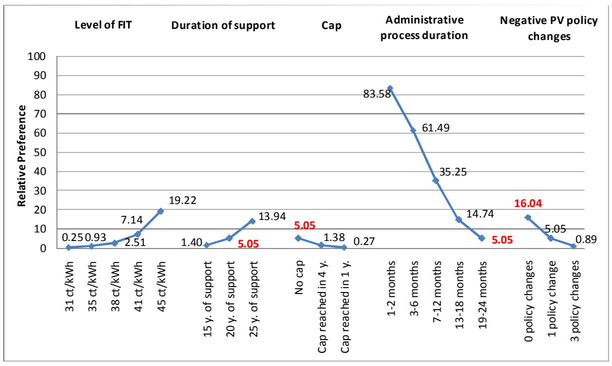

Figure 7: Sensitivity analysis over all attributes in Greece

Bold and red numbers display the base case share of preference. The attribute "Level of FIT" does not display the base case share of preference due to interpolation in the data.

C. Spain

The sensitivity analyses of the share of preferences of the Spanish market reveal two major barriers for investments in PV project. First, the duration of the administrative process is too long. A shorter duration would bring an increase from the current 1.4% to up to 25.5%.

Second, the tight cap also makes the Spanish market for investment very unattractive. Loosening the cap would increase the share of preference to 7.0%, and removing the cap would increase the share of preference to 22.1%.

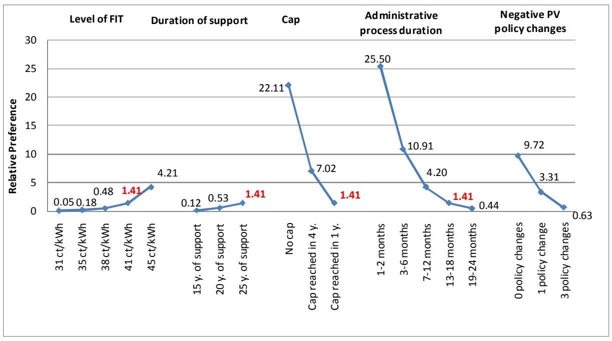

Figure 8: Sensitivity analysis over all attributes in Spain
Bold and red numbers display the base case share of preference. The attribute "Negative PV policy changes" does not display the base case share of preference due to interpolation in the data.

VI. Conclusion

The achievement of energy policy objectives depends on whether public policy effectively influences investor behavior. In the specific case of feed-in tariffs for solar PV, much has been learned in recent years through substantial policy experimentation, but how investors might react to certain policy attributes has been a black box until now. This study opens this black box by conducting a stated-preference survey among European project developers investing in solar energy across different countries.

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 that risk matters in PV policy design. More specifically, this study discloses (by means of different SMRT simulations) the influence of changes in the political framework on the project developers' investment likelihood and share of preferences.

The study shows that in Greece, an incremental improvement of the investment attractiveness could be reached by accelerating the administrative process. The Spanish case study discloses that main barriers are the tight cap and the long administrative process.

At this point, only a few concrete scenarios are estimated. In future studies, the developed simulation tools can be applied to design scenarios and thus give more specific policy design recommendations.

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