Homebuyers' Preference for Installed PV Systems – Discrete Choice Experiment

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Abstract

Purpose – This paper contains the findings of dwelling buyers' preferences towards installed photovoltaic (PV) system on their potential homes and thus provides an insight on the overall impact of PV systems to home purchasing.

Design/methodology/approach – These preferences are determined by a discrete choice model that is based on stated preference data of dwelling buyers in the Eindhoven region.

Findings – The most important findings are that a PV system is on average highly appreciated by dwelling buyers and that this appreciation is relatively larger by dwelling buyers that live in more urban/central neighborhoods.

Research limitations/implications – This paper is essentially exploratory and raises a number of questions for further investigation such as determining the real estate value of installed PV systems.

Practical implications – The findings would suggest that the diversity of homebuyers' preferences would vary. It is dependent on the homebuyers' personal characteristics but also on institutional settings of an energy system. Therefore, the provided insight must be regarded as local and further research is necessary for understanding the impact on the European residential real estate markets.

Originality/value – This paper estimates the impact of the installed PV system on the housing choice by stated choice data on the local housing market.

Keywords: PV system, preferences, Multi Nominal Logit (MNL), willingness to pay (WTP), Eindhoven

1. Introduction

The increasing global wealth and population lead to an equal increase in energy use. Due to limited fossil resources and reputed climate effects, energy efficiency has become a challenging present day problem. Since the built environment has a large share in energy use, all sorts of measures that increase energy efficiency have been invented for buildings. Energy efficiency in the built environment is focusing on both the design of new energy efficient buildings and on the improvement of energy efficiency in the existing stock. However, a problem is that the existing building stock is not renewed as fast as projected (AgentschapNL, 2012).

One of the potential measures is installation of photovoltaic (PV) systems. PV systems are an energy saving solution that is easy to integrate with this existing

Proceedings: ERES2015
pp. 75-83

building stock. PV systems generate electric current from energy of the sun in a way it can be used in the socket (EPIA, 2010). The energy produced by PV cells as share of the total Dutch energy use, including transport, industry and households, is only 0,038%. However, the Dutch growth in PV power generated is not small: 64% growth in from 2010 to 2011 (CBS, 2012) and 138% from 2011 to 2012 (Cobouw, 2013). Due to energy legislation, households pay the highest price per KWh. Saving energy for households has consequently the highest yield. Therefore, owner occupied dwellings produces 60% of all PV energy in the Netherlands. Contrary, rental dwellings do not contribute much because there is a problem of split incentive between the investor in PV systems (the landlord) and the tenant that saves the energy. In the case of an owner occupied dwelling, the investor in the PV system is the same entity that saves the energy. This leads to increasing amount of installed photovoltaic systems on owner occupied dwellings in the Netherlands.

However, the influence of a PV system on the market position of a dwelling is unknown. Therefore, this paper investigates the behavior of dwelling buyers regarding installed PV systems. This has the following practical relevance. First, because little is known about the value effect of PV cells installed on owner occupied dwellings, risk averse investing is only possible if the investor expects to stay in the dwelling during the payback period. More knowledge about the value once installed could change this situation. The expected lifespan of PV panels is at least 25 years (Natuur & Milieu, 2013). It is thus very likely that dwellings with a PV system will enter the market. So far, it is unknown how buyers, sellers and realtors should deal with this new dwelling attribute. In addition, there could be differences between groups of dwelling buyers and their appreciation of PV. Mapping these differences helps to estimate how, where or by who the deployment of PV is mostly appreciated.

2. Measuring the value of PV system

Although many studies researched over the preferences of dwelling owners towards PV panels (e.g. Banfi et al., 2008; Branker et al., 2011; Dastrup et al., 2012; Daziano and Achtnicht, 2014; Eichholtz and Quigley, 2012; Farhar and Coburn, 2008; Jakob, 2006; Kwak et al., 2010; Tommerup and Svendsen, 2006; Zheng et al., 2012) on their roof, the effects of the presence of a PV system once the dwelling is offered on the house market remains unknown. On the other hand many researchers focused on the housing preferences (e.g. Earnhart, 2001; Louviere and Timmermans, 1990; Timmermans and van Noortwijk, 1995). However, limited research has been relevant in efforts to estimate the real estate value effect on dwellings by PV systems. Farhar and Coburn (2008) research is not based on transactions, but on valuations. Although premiums of around 10% were found, they are not realistic anymore because they date before the credit crisis. Another study (Kets, 2006) researched the acceptable earning back periods for PV systems as attribute of a dwelling by direct asking. The results are an average acceptance of four years meaning that people want to pay four times the yearly energy savings for a PV system.

Houses with PV systems have rarely been sold on the market, therefore it is impossible to use market data. Instead, a survey has to be conducted. This can be done by direct or indirect asking. By directly asking responded would state for example the how much would be willing to pay extra for a dwelling with a PV system that saves you €600 per year. Indirect asking can be done by several methods. Discrete choice modeling is one of them. Direct surveying as used by Kets (2006) has some drawbacks (Breidert et al., 2006). People are likely to overvalue because of prestige reasons or undervalue in attempt to keep prices low. Directly asking opinions for unfamiliar products (such as PV systems) is cognitively challenging for respondents. Research has showed that directly asking leads to unstable answers that can change abruptly without any particular reason. Direct surveying is limited in the measurement of trade-off effects. Because of the above reasons not only a direct survey but also an indirect survey is conducted. Indirect data gathering has two suitable methods discrete choice measurement and conjoint measurement. Both methods construct hypothetical options with varying attributes and present these options to respondents in order to gather information about preferences. In a discrete choice experiment (DCE) respondents choose one option out of a selection of options. In conjoint analysis (CA) instead of choosing options, options are ranked or rated. Although CA has its roots in marketing, analysis is purely mathematical (Louviere, 2010; Visser, 2006). The DCE relies more on micro-economic theory. Results have not proved to differ in accuracy between both alternatives but DCA has more possibilities (Breidert, 2006; Louviere, 1994). Myrick Freeman Iii (1991) argues that ranking is not appropriate regarding house buyers because it does not mimic true behavior of really choosing one dwelling. In addition, most of the housing choice research are performed by DCE (e.g. Earnhart, 2001; Louviere and Timmermans, 1990; Timmermans and van Noortwijk, 1995). Therefore, a DCE is chosen for this research.

3. Discrete choice experimental design

The underlying theory of discrete choice models is the random utility theory (RUT). RUT assumes that all individuals when they are able to choose between alternatives, for example a house with a PV system and a house without a PV system, will always choose the alternative with the highest utility (Eq.1). Where U_{in} is the utility of the chosen alternative and U_{jn} are the other alternatives in the choice set that individual n can choose.

$$U_{in} > U_{jn}, \forall j \neq i \qquad (1)$$

RUT assumes (e.g. Hensher et al., 2005) that the utility of a certain alternative exists of a systematic part that is explainable and a random part that is not explainable (Eq.2) where U_{in} is the unobserved utility that an individual n perceives from alternative i and V_{in} is the systematic, explainable component and ε_{in} is the random component. Because of the random component, the probability that an individual will choose a certain alternative can be calculated, but the exact choice cannot.

$$U_{in} = V_{in} + \varepsilon_{in} \qquad (2)$$

The systematic component can be modeled as the sum of part-worth utilities that depend on the different attributes and their levels. Eq. (3) states that the systematic utility V_{in} of an alternative exists of the sum of part-worth utilities where X_{ink} is the value of attribute level k of alternative i that is in the choice set of respondent n. β_k is a parameter that indicates the contribution of attribute k on the utility of the alternative. Such an attribute could for example be the presence of a PV system.

$$V_{in} = \beta_0 + \beta_1 X_{in1} + \beta_2 X_{in2} + \cdots + \beta_k X_{ink} = \sum_k \beta_k X_{ink} \quad (3)$$

By applying system of equations, it is possible to make estimations of β_k. With these estimates, the probability P that alternative i will be chosen from choice set j can be predicted (Eq. 4). This probability is the e-power of the systematic component of i divided by the sum of the e- power of the systematic utility (V_{jn}) of all alternatives.

$$P(i|j) = \frac{e^{\beta_k X_{ink}}}{\sum_j e^{\beta_k X_{jnk}} + e^{\beta_k X_{ink}}} = \frac{e^{V_{in}}}{\sum_j e^{V_{jn}} + e^{V_{in}}}, \forall j \neq i \quad (4)$$

For consumer products, DCE is also used to calculate willingness to pay (WTP) for certain attributes of the product (Hensher, 2005; Breidert, 2006). This can be calculated by dividing the beta of the attribute of which the WTP is calculated (Eq. 5), for example for the PV attribute, by the beta of a monetary attribute β_{price}. These betas must be significant and the monetary beta must belong to a linear coded X_{ink} (Hensher et al., 2005). One might need to convert to the right unit by multiplying with a constant c (Breidert, 2006; Hensher et al., 2005).

$$WTP = \frac{\beta_k}{\beta_{price}} * c \quad (5)$$

It is however doubtful if this method is applicable on dwellings since preferences and financing are much more complex for dwellings than for a product in, for example, the supermarket. Since there is almost no market data of dwellings with PV panels, a revealed preference experiment is not possible. Therefore, a stated preference method is used. This means that true behavior is not observed, but respondents are asked to indicate how they would behave in a hypothetical situation.

In short, DCE starts with lining the important attributes and their levels. Secondly, hypothetical products (dwellings in this case) with variations of these attribute levels are presented to respondents. Respondents are asked to repeatedly make a choice between options or to choose “none of them”. To keep the experiment simple for respondents the effect on choice was researched of a PV system that is feasible on the roofs of almost all row houses in Eindhoven, and that saves €600 in energy costs per year. All hypothetical dwellings are row houses. The attributes and levels are displayed below (Table 1).

Table 1: Attribute and their levels.

Attribute	Attribute level
Price	€180.000 €210.000 €230.000
PV	Yes No
Dwelling size	100m2 120m2 140m2
Location	Within Ringroad Outside Ringroad Outskirts
Building period	>1990 1945-1990 <1945

Instead of applying full factorial design (all possible combination of levels), this study applies fractional factorial design that consists of 18 treatment combinations which are presented in random order in 6 choice sets of three alternatives plus a "no choice" alternative.

4. Multi Nominal Logit (MNL) model of homebuyers preferences

The respondents' characteristics are initial step for understanding the importance preferences estimated by any model Table (2). On-line survey was conducted among 226 respondents.

Table 2: Descriptive statistics

Characteristic		%	#
Location:	Within the Ringroad in Eindhoven	25%	56
	Outside the Ringroad in Eindhoven	42%	95
	Outskirts of Eindhoven	33%	75
	Other	0%	1
Noticed PV in the neighborhood:	Yes(noticer)	61%	138
	No(not noticer)	39%	88
	I do not know	0%	1
Aesthetical appreciation of PV:	Positive	4%	10
	Neutral	53%	120
	Negative	43%	97
Best motive if one would invest:	Idealism	17%	38
	Diminish risks/less dependency energy prices	27%	62
	Good investment	54%	123
	Pioneering/ The image	1%	3

Out of the DCE it was possible to estimate Multi-Nominal Logit (MNL) regression of the dwelling alternatives on choice resulted in the effects on systematic utility V_{in} displayed below (Table 3; Table 4). The rho squared is 0,06. If the location of the respondent is put in the model, rho squared is 0,14.

Table 3. *MNL estimates for all respondes*

Variable	Coefficient	Standard error	beta/std. Er.	P [|Z|>z]
ß0	0,22	0,07793431	2,863	0,0042
ßprice	-0,26530026	0,04702113	-5,642	0,0000
ßPV	0,30793783	0,03732345	8,251	0,0000
ßsize1	0,04169243	0,05298505	0,787	0,4314
ßsize2	0,07587486	0,05351294	1,418	0,1562
ßlocation1	0,06878243	0,05378057	-1,279	0,2009
ßlocation2	0,06396897	0,05216634	1,226	0,2201
ßperiod1	0,52107873	0,05038133	10,343	0,0000
ßperiod2	0,05575443	0,05284788	1,055	0,2914

Table 4. *Part-worth utilities*

Attribute	Attribute -level	Worth		
Choose	Choose a dwelling	+	0,223	*
	Choose "no option"	+	0,000	*
Price	€180.000	+	0,000	*
	€210.000	-	0,265	*
	€240.000	-	0,530	*
PV	PV present	+	0,308	*
	PV absent	-	0,308	*
Size	100m2	-	0,118	*
	120m2	+	0,076	
	140m2	+	0,042	*
Location	Within ringroad	+	0,005	
	Outside ringroad	+	0,064	
	Outskirts	-	0,069	
Period	<1945	-	0,577	*
	1945-1990	+	0,056	
	>1990	+	0,521	*

*Significant with 95% confidence

If the effect of a PV system on the appreciation of a dwelling is positive and large this could mean that increasing the marketability of a dwelling can become one of the primary drivers behind PV deployment. Maybe the in the future people who sell their house install a PV system to make the dwelling more attractive for possible buyers. Of course the experiment done is only a first initiative that is done only for rowhouses in the Eindhoven region. But it seems that the appreciation is indeed large. The PV system had the second largest positive effect on choice for a dwelling. The only effect on choice that was larger than the effect of having a PV system instead of not having a PV system was the effect of a dwelling being built after 1990 instead of before 1945.

The main conclusion is that dwelling buyers really appreciate it if the former owner installed a PV system. However, more noteworthy dwelling buyers' preferences have been found. Firstly, the hypothesis that PV systems will be appreciated more on newer dwellings than on monumental dwellings built before 1945 has to be rejected. However, there is a problem with the rowhouses built before 1945. These dwellings do not exist much in Eindhoven and their appreciation was very different from experiments in other cities showed. Therefore, more research regarding this should be done. Secondly, it was expected that dwelling buyers who were neutral or positive about the external appearance of PV systems would appreciate the systems more on dwellings than dwelling buyers that indicated they did not like the looks of PV. It appeared, however, that the opinion on the external appearance had no significant effect on appreciation of PV systems on dwellings. Despite this conclusion, the fact that only 4% of all respondents like the appearance of PV systems does show opportunities for companies to increase the appreciation of the aesthetics of PV. For example, this could be done through better integration in the dwelling design or through innovative shapes or covers of the PV panels.

Thirdly, if respondents indicated that they had another primary motive to invest in PV (if they would) than the mere investment that earns itself back, they appreciated PV systems relatively more as a dwelling attribute. The explanation for this could be that the investment attributes count for everyone. However, an idealist or person that feels independent of energy prices also, perceives extra utility from that. This comes on top of benefits from the investment. It is not the case that idealists do not save energy with their PV system. This outcome may be helpful for the marketing of PV systems. More focus on the independence of energy prices and the saving of the environment (idealism) is likely to increase the utility that dwelling buyers perceive from PV. This is an interesting matter to research further.

Fourthly, for the Eindhoven region it has been found that people who live more central or urban appreciate PV systems much more. This could indicate that it is wise for PV projects to focus more on urban areas first, at least in Eindhoven.

With this design of the MNL model, it was unfortunately not possible to calculate what premium dwelling buyers would pay if a dwelling has a PV system. However, quite some knowledge has been collected about the attitude of dwelling owners regarding PV technology. It is surprising how positive people react on the uninvited presence of a PV system on the roof of a dwelling one is considering to buy. The output of the discrete choice experiment together with the results of the direct surveying of the WTP leads to the conclusion that people are probably willing to pay at least the replacement value of the system (€5000-€7000). This is exceptional when one keeps in mind that a dwelling buyer wanted to buy a dwelling, not a PV system. Only 22% of all respondents did not want to pay anything for the system.

Reasons for this high willingness to pay might be socially desirable bias often seen in sustainability research (Banfi, 2005). In addition, respondents paid extra attention to the PV attribute because they expected the research was about this. Respondents perceive risk when thinking of installing a PV system. An operative system actually saving €600 per year diminishes this perceived risk and leads to higher perceived utility. Respondents do not only value the PV system itself, but also the orientation of the house that apparently is suitable for installing PV. Just like dwellings with sea view cost a fortune, not because of the window but because of the orientation. Parallel to this in the future it could be that not the presence of a PV system is valued, but the orientation to the sun. Stated preference data leads to less price sensitivity compared to true market behavior or revealed preference (Wardman, 1988).

5. Conclusions and discussion

Although this research was only a first step in investigating this subject, it seems that installing PV is very well possible when one is not sure if one will move in the near future. In fact, there is quite some reason to believe that the high positive influence in the DCE model on choice, caused by a PV system installed, may result in a very welcome incentive for buyers that is relatively cheap. In this stuck dwelling market, allowing sellers to be able to sell their dwelling quicker is very valuable.

This first research to the effect of PV systems on the dwelling market has found some interesting relations. However, a realistic willingness to pay has not been found with this MNL model. A more advanced choice experiment that also takes into account the demographics of the dwelling buyer and his or her financial position and mortgage and tax situation may result in a more realistic WTP outcome.

Nevertheless, this research can be used, for example, by a policy maker to make an affluent decision to subsidizes a total PV system on dwellings that have been for sale for a long time. Then it should be checked, with a control group of comparable dwellings that are also for sale, if the dwellings with a PV system are sold earlier. After the sale, the seller can pay off the PV system. Policy makers in the Netherlands always talk about two important problems they want to solve: 1. the stuck dwelling market and 2. the unsustainable way energy is generated and used. This policy would, if successful, help to solve both problems with the limited investments costs. Another recommendations for further research is to investigate whether the relations that are found, such as between idealism and appreciation of PV, are causal or not. Lastly, the research could be done in other regions and dwelling market segments.

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