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Abstract

This paper investigates the demand determinants of green power in the U.S. residential sector. The data employed were collected by the National Renewable Energy Laboratory and consist of a cross-section of seven utilities observed over 13 years. A series of tests are performed that resulted in estimating a demand equation using the one-way cross-section random effects model. As expected, we find that demand is highly price inelastic. More interestingly though, is that elasticity with respect to number of customers is 0.52 leading to the conclusion that new subscribers tend to purchase less green power on average than the existing customers. Another compelling finding is that obtaining accreditation will have a 28.5% positive impact on consumption. Knowing that gaining green accreditation is important to the success of programs, utilities may want to seek certification and highlight it in their advertising campaigns.

Keywords: green power; green tariff; voluntary market; renewable energy; price elasticity; panel data

JEL Classification: C33, C51, Q21, Q41

1. Introduction

Driven by a concern for the environment and the dependency on foreign oil supplies, many countries are considering renewable energy as a vital component for reducing greenhouse gas emissions (GHG) and increasing the security of supply. Compared to fossil fuels, renewable energy sources such as wind and solar emit little or no greenhouse gases, and hence benefit the environment by reducing pollution and harmful emissions. The approaches taken to promote renewable electricity have been typically either mandates, market-based incentives, or voluntary initiatives including: (1) imposing a minimum RE requirement on providers,[1] (2) offering economic incentives such as tax credits, rebates, grants, and subsidies,[2] (3) taxing non-renewable electricity or imposing a mandatory fee on all consumers,[3] (4) introducing feed-in-tariffs, and (5) offering consumers the option of participating in voluntary green power programs. As a policy scheme, voluntary green power has the advantages of raising public awareness of the benefits of renewable energy and using little government resources (Gan et al., 2007), however it relies heavily on consumer motivation making it critical that we understand the impact of different factors on demand.

Green power consumption is inherently associated with nondepletable resources and involves positive externalities in the form of environmental benefits. For this reason, green power has been treated as an impure public good (Kotchen, 2005) that has a special characteristic; its consumption generates private and public goods as a joint product (Kotchen, 2006). The public goods in this case refer to the environmental benefits that are both non-rival and non-excludable; enjoying the benefits of reduced air pollutant and GHG emissions by one person does not restrict others from doing that, and there is no way to prevent anyone from enjoying the resulting benefits.

Theoretical models of private provision of public goods suggest that free-riding will lead to inefficient underprovision (Bergstrom *et al.*, 1986; Cornes and Sandler, 1996; Falkinger *et al.*, 2000). It is important to note here that empirically, in many markets, free-riders are found to be fewer than expected and hence contributions are higher than predicted (Clark et al., 2003; Andreoni, 1988; Piliavin and Charng, 1990). This also seems to be true for some environmental goods (see for example Bjorner et al. (2004) and Teisl et al. (2002)). The green power markets, however, are consistent with the theory of underprovision; there is evidence of substantial differences between stated willingness to pay and actual green electricity adoption. Free-riding, however, is only one of many reasons associated with this low level of uptake in many programs. Other possible reasons include: upward bias in contingent valuation (hypothetical bias), lack of awareness and limited marketing, hesitancy in switching suppliers, distrust of suppliers, and of course cost considerations (Diaz-Rainey and Tzavara, 2012; Litvine and Wustenhagen, 2011; MacPherson and Lange, 2013; Wiser, 2003; Gossling et al., 2005; Diaz-Rainey and Ashton, 2008).

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[1] Examples include the Renewable Portfolio Standard (RPS) in the USA and the Renewable Obligation (RO) in the UK.

[2] See Cansino et al. (2010) for a comprehensive review of European incentives.

[3] Such as the non fossil-fuel obligations (NFFO) in the UK and the renewable energy levy (EEG-Umlage) in Germany.

Related to the above-mentioned issue of public goods and free-riding, is the debate about the importance of the 'warm-glow' effect in customers' decision to purchase green power. This refers to customers participating in a green power program because it makes them feel better about themselves (or in some cases because they care about others' opinion of them) , and not because they value the public benefit itself (Andreoni, 1990; Goett et al., 2000; Pollitt and Shaorshadze, 2011). It is important to note here that some consumers increase their electricity consumption after joining a green power program. This is a consequence of the 'buy-in' mentality, whereby the customer participates in the program to reduce the guilt of contributing to harmful emissions as a result of his consumption of conventional electricity (Pollitt and Shaorshadze, 2011). This behavior is closely related to the psychological theory on 'moral licensing', which suggests that individuals use good behaviors to feel less guilty about bad behaviors (Jacobsen et al., 2012). In order to offset this increase in demand, many providers impose a monthly minimum purchase requirement. This could either take the form of blocks where a block can be 100 kWh, 150 kWh, etc., or a fixed proportion of the monthly usage (10%, 25%, or some other level). A few programs additionally require a minimum of one year commitment or more.

Starting in the 1990s electricity providers in several countries started offering green power options. In most cases, offerings take the form of an energy-based product in which consumers voluntarily pay a premium for each kWh consumed to cover the additional cost of generating renewable-based electricity and the utility's expenses in providing the green power option. In a few other cases, consumers are given the option of making a donation to support green electricity, where a minimum fee is sometimes set by the provider. Although Kotchen and Moore (2007) find that contribution-based programs will result in more RE capacity,[4] such programs have had limited success in the development of new renewable capacity. In Sweden for example contribution-based green programs were discontinued, in the U.S. they have declined, and in Australia they have been phased out of the national accreditation program due to their limited impact on RE development.

The performance of energy-based green power programs has been mixed. In some countries the programs had to be discontinued, while in others such as in the US they have seen a steady increase during the past two decades. But, even in countries with booming green electricity sales,

[4] Based on a theoretical utility-maximization model that takes into account the private provision of a public good, Kotchen and Moore (2007) find that a contribution-based program will result in higher provision levels than a green tariff program, with the exception of an all-or-nothing green tariff plan.

the market share is still typically less than 5% and overall customer participation has also still not reached the 5% level, although several individual U.S. green pricing programs have exceeded these participation levels.

It is therefore of utmost importance to understand the drivers of green power demand to be able to grow the markets in the future. Having a more precise knowledge of demand elasticities can better enable suppliers to meet the current and future energy needs of consumers. Also, a better understanding of demand determinants can help guide policymakers, utilities, and marketers in their efforts to expand green power markets. Price elasticities, which measure how sensitive consumers are to changes in premiums, are particularly important in forecasting and policy-making applications.

In view of the importance of demand elasticities,[5] it is not surprising that there exists a substantial body of research aimed at estimating electricity demand elasticities since the 1950s, starting with the pioneering studies of Houthakker (1951a; 1951b). Much of this work was completed in the late 1970s and early 1980s in response to the 1973 and 1979 oil price shocks. There exist few studies, however, that estimate green power elasticities most likely due to the lack of historical data. Since green power programs are relatively recent, it is difficult to obtain an adequate data set to perform an econometric estimation. One exception is the study by Mewton and Cacho (2011) who estimate green power elasticities for Australia in a panel data framework. To our knowledge there exists no study that estimates green power demand elasticities for the USA. In 2014 in the U.S., 4.9 million customers purchased approximately 74 million MWh of green electricity (O'Shaughnessy et al., 2015). Given that the US green power markets are the largest in the world, this constitutes a big gap in the literature that this study aims to fill.

This paper examines the elasticity of residential demand for green power in U.S. utility green pricing programs. Other options for procuring renewable energy exist today, such as installing on-site solar photovoltaics or participating in shared-solar projects, but we focus only on procurement of renewable energy through utility offerings here. We conduct a full-fledged panel data analysis based on a data set comprised of 7 green pricing programs over time with 13 annual observations each (2002-2014). Section 2 of the paper provides a review of the existing literature. In Section 3 we describe the data and the methodology used followed by a presentation and discussion of the

[5] For a comprehensive review of demand elasticities in the energy sector see Cuddington and Dagher (2015).

empirical results in Section 4. Finally, in Section 5 we offer some concluding remarks on the findings together with suggestions for future research.

2. Overview of Markets and Existing Studies

There is a long-standing debate as to whether mandatory schemes, such as fees or standards, or voluntary programs are more effective in the provision of green power. In the former case, the fee or cost of compliance with a standard is typically lower than the premium in voluntary markets[6] and there is no possibility to free ride, whereas in the latter case the premium is higher and free-riding is abundant. Although new renewable energy installed capacity has been growing at a much faster rate than conventional electricity capacity, its impact is still limited (REN21, 2016). Consequently, a growing consensus seems to be that both types of programs are needed to achieve a substantial increase in renewable-energy based electricity. For voluntary markets, where purchases are driven by consumer choices, it is important to understand the factors that can affect demand. This information is important for suppliers, and new market entrants in particular.

The broad literature on green electricity markets, including international experience, examines potential consumers' attitudes and expected behavior,—and in a few cases actual— in those markets. Those studies are generally referred to as 'willingness-to-pay for green power' studies and are primarily aimed at informing policymakers regarding the effectiveness of tools that can be used in shaping policies. They also aim at helping potential suppliers and marketers better understand the important demand determinants for consumers. Among willingness-to-pay studies we can distinguish two interrelated types. The first being the stated willingness to adopt or enroll in such programs (extensive margin) resulting in a percentage estimate and the factors influencing this decision. And the second being the level of participation (intensive margin) or in other words the amount each consumer is willing to pay per time period known as willingness to pay (WTP) in terms of a premium and the factors that affect it. A few studies examine both the extensive margin and the intensive margin simultaneously. The vast majority of existing studies use the Stated Preference methods and in particular, the contingent valuation and the choice experiment

[6] The cost of complying with a renewable energy standard can be lower because there are no costs involved in getting customers to sign up for the program and often larger projects can be used to meet the needs of all of a utility's consumers, without risk that consumers will not procure the electricity.

methods are extensively employed. For a detailed review of both strands of literature, see Dagher and Harajli (2015).

Numerous researchers have investigated the dichotomous decision of whether to participate or not in a green power program in the U.S. and abroad. Most adoption models build on models, insights, and hypotheses rooted in the social psychology (cognitive science) and/or economics disciplines. The findings have been inconsistent for both the percentage estimates and the factors that affect such a decision (see, *inter alia*, Farhar, 1999; Fouquet, 1998; Roe *et al.*, 2001; Wiser, 2003; Zarnikau, 2003; Graham, 2006; Diaz-Rainey and Ashton, 2008; Clark et al. 2003; Swedenergy, 1999; Hansla et al., 2008; Ek and Soderholm, 2008). Considerable divergence was also found between studies examining the level of participation and its determinants (Bollino, 2009; Batley et al., 2000; Nomura and Akai, 2004; Borchers et al., 2007; Gracia et al., 2012; Roe et al., 2001; Zografakis et al., 2010). For example, willingness to participate in green electricity programs are found to vary between 21% to as high as 80%, while the reported median monthly WTP range from negative 0.37 USD to 52.38 USD (Zoric and Hrovatin, 2012; Soon and Ahmad, 2015).

In sum, estimates for willingness to adopt as well as willingness to pay for green electricity vary among studies, as do, albeit to a lesser extent, the identified statistically significant explanatory variables (Dagher and Harajli, 2015). This is expected given the different countries, regions, and time periods, as well the diverse methods and questionnaire designs (including the provision of information) used (Zoric and Hrovatin, 2012).

An even wider disparity is found between estimated figures in the literature and actual behavior, also known as the gap between attitude and actual behavior. All surveys conducted to date have found that at least 20% of the customers are willing to pay extra for renewable electricity, however the actual penetration rates for green power programs is typically only a small fraction of the estimate. For example in the US, the average rates are around 2%[7] (Bird *et al.*, 2007) and less than that for the UK (Bird *et al.*, 2002; Graham, 2006; Diaz-Rainey and Ashton, 2008). Rowlands et al. (2000) conclude that "only a small share of those who say they will pay more actually do so when given the opportunity," while Byrnes *et al.* (1995) estimate this share at 12-15%. Murphy et al. (2005) find that a median ratio of stated to actual value is 1.35, but also note the existence of

[7] Currently, for the top ten performers the range varies from 5% to almost 15% (http://www.nrel.gov/analysis/green-power.html))

some evidence that the ratio increases when public goods are being valued. Goett et al. (2000) also suggest adjusting the WTP figures downwards by a constant factor, because customers in choice experiments have a tendency to de-emphasize price.

Surveying the literature, one can find several attempts at explaining the differences between expressed support as found in studies and actual uptake (Champ and Bishop, 2001; Poe et al., 2002; Gossling et al, 2005; Wiser and Pickle, 1997; Wiser, 2003; Salmela and Varho, 2006; Diaz-Rainey and Ashton, 2008; Farhar and Houston, 1996). The majority of these researchers agree that free-riding is a major factor, as well as upward response biases or hypothetical biases introduced in the surveys. Diaz-Rainey and Tzavara (2012), who develop a model with the intent of explaining the large differences between stated and actual WTP, suggest that the difference can be explained by the extent of market imperfections and failures e.g. insufficient transparency, regulatory failures, etc. Other possible reasons include: lack of consumer awareness, limited variety of products, and insufficient information on products due to limited marketing, as well as hesitancy in switching suppliers, distrust of suppliers, the intangible nature of the product, and most importantly cost considerations (Wiser, 2003; Gossling et al., 2005; Diaz-Rainey and Ashton, 2008). Wood et al. (1995) find that stated WTP overstates respondents' actual WTP and should only be interpreted as reflecting respondents' relative preferences for certain choices over others. Differences in results have been noted between national and local surveys (see, *inter alia,* Batley *et al.*, 2001; Diaz-Rainey and Ashton, 2008), and some researchers have argued that only local area market research can define the percentages of customers actually willing to participate in green energy plans. This discrepancy has been noted by several researchers.

The gaps and drawbacks that plague WTP studies and contingent valuation findings for green power highlight the need for more studies based on existing customers of actual green power programs and their behavior. Despite the burgeoning literature on green power demand only one study uses historical data and estimates demand elasticities (Mewton and Cacho, 2011). Mewton and Cacho (2011) estimate a price elasticity of -0.96, revealing a relatively high response to premium changes in Australia. A major drawback of their work is that they did not separate residential from commercial customers.

3. Data and Methodology

In this paper we focus on green power sales to households, given that residential demand and its determinants are expected to be different from commercial demand. The data used are extracted from annual data collected from utilities and green power suppliers by the National Renewable Energy Laboratory. The quantity of renewable-based electricity consumed (*Q)* is posited to be a function of the premium paid for green power[8] (*P)*, the number of consumers (*N)*, and the certification or accreditation status[9] (*A)*. Income has not been found to be an important determinant of green power demand in several WTP studies (Arkesteijn and Oerlemans, 2005; Kotchen and Moore, 2007; Hansla et al., 2008; Jacobsen et al., 2012), and since we do not have accurate sociological and economic data on the consumers of various utilities, we were unable to include a proxy for household income.

A few other variables that might have some impact on consumption are unfortunately not available, however certification could be serving as a proxy in some cases. Additionality (or knowing that the consumer's actions will result in new renewable energy being added to the grid) has been found to affect commercial and industrial choices and to a lesser extent households' decisions. This is because commercial and industrial consumers frequently use additionality to differentiate themselves from their competitors. The complexity of defining additionality in various contexts has been brought up by several researchers (Diaz-Rainey and Ashton, 2008; Hast et al., 2015; Salmela and Varho, 2006), but in general the idea is to avoid having programs "that provide no additional benefits above those already required by existing legislation promoting renewable energy" (Boardman et al., 2006). The Green Electricity Code of Practice in addition to other studies (Diaz-Rainey and Ashton, 2008) recommend that additionality be a requirement in any certification program. It is thus reasonable to assume that certification could serve as a proxy for additionality. Preference for some renewable energy technologies over others have been found in some studies (Kosenius and Ollikainen, 2013). This criterion, similarly to additionality, is one factor reflecting the overall quality of the product, and again certification could be a good proxy in this case. Given that all the figures we have are aggregates, we are unable to track consumption per customer or even determine how many customers are purchasing the minimum threshold level. Had we had access to this kind of breakdown in consumption, we would have been able to draw

[8] Note that P denotes real price where the Consumer Price Index series sourced from the Bureau of Labor Statistics database was used to deflate the nominal price series.

[9] *A* is a binary variable taking the value of 1 if the program has been certified by a third party and 0 otherwise.

some conclusions regarding the ‘buy-in’ behavior and how widespread it is. For example, Jacobsen et al.(2012) find that at least 45% of respondents exhibit ‘buy-in’ behavior, while Ma and Burton (2016) find that over 60% of the respondents to their survey select the minimum commitment level irrespective of the price premium. Of the seven green power programs we have data on, two do not have any minimum commitment levels, two have a minimum purchase of 100kWh per month, one has a minimum purchase of 150 kWh per month, one had 150 kWh until 2007 and then increased it to 300 kWh, and the last one did not have any minimum threshold level until 2006 when it introduced a minimum of 25% of the monthly usage.

Theoretically, an important determinant of consumers’ demand for any good or service is the price (or in this case the premium) paid for that good or service. However, in green power markets the results have varied; some studies conclude that green power consumers are price sensitive, while others find these consumers to be unresponsive to price changes. A Natural Marketing Institute study (NMI, 2011) finds that with time consumers have become more price sensitive for renewable energy, corroborating the principle that price elasticity is larger in the long-run compared to the short-run. Looking at the New Hampshire pilot program it was found that price was the most significant factor in selecting a supplier (Batley *et al*., 2001). A few years back, when the price premium turned negative in 2005 for a few utilities, green power supplies were sold out completely (Bird and Swezey, 2006). In their survey and focus group discussions, Diaz-Rainey and Ashton (2008) also find that price is critical when choosing a green tariff and that for U.K. customers environmental issues are secondary to cost considerations. Ek and Soderholm (2008) investigate the determinants of the decision to purchase green electricity in Sweden and find that price is important but so is the perceived personal responsibility for the issue and the perceived ability to affect the outcome. In contrast, other experiences such as that of Finland show the opposite; even with green electricity selling at a lower price than brown electricity, enrollment rates are still modest (Salmela and Varho, 2006). One might conclude that price is an important factor when there are competing suppliers, however in markets where there is only one option (one premium) other determinants of demand such as the quality of the product and the trustworthiness of the supplier might dominate.

The number of customers variable is expected to be unit-elastic; a 1% increase in customers should lead to a 1% increase in consumption. If it is greater than one, then this implies newer customers have a higher consumption rate and vice versa. Accreditation status is a binary variable that takes the value of 1 if the program has a Green-e Energy certification by the Center for Resource Solutions,[10] and 0 otherwise. An accreditation scheme guarantees that the supplier is actually procuring the amount of renewable-based electricity to meet its customer obligations and provides confidence, clarity, and consistency to the consumer (Lipp, 2001). In addition, accreditation schemes, such as Green-e, have strict standards for the types of generation that can be included in products, the vintage of resources that can be used, and other provisions to ensure that products are high quality and that consumers are helping to drive new renewables development. In 2014, around 52% of all voluntary renewable energy sales in the U.S. were Green-e Energy certified (CRS, 2015).

In this paper we use a balanced panel data set that includes green pricing program data over time (with a cross-section of N=7 programs and T=13 years from 2002-2014). In order to determine the most appropriate specification, we first conduct the redundant fixed effects test. Consider the following two-way error component model:

$$Y_{it} = \alpha + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \ldots\ldots + \beta_k X_{kit} + u_{it} \tag{1}$$

$$u_{it} = \mu_i + \lambda_t + v_{it} \tag{2}$$

Where μ_i denotes the individual effect, λ_t the time effect and v_{it} is IID (0, σ_v^2). Both are assumed to be fixed parameters for now.

We first test for the existence of individual effects while allowing for time effects:

$$H_0: \mu_1 = \cdots.. = \mu_{N-1} = 0 \qquad \lambda_t \neq 0 \; for \; t = 1 \ldots\ldots T-1$$

And then test for the existence of time effects while allowing for individual effects:

$$H_0: \lambda_1 = \cdots.. = \lambda_{T-1} = 0 \qquad \mu_i \neq 0 \; for \; i = 1 \ldots\ldots N-1$$

Both are F-tests but with different restricted models.

The redundant fixed effects test statistic allows us to reject the null hypothesis that the cross-section effects are redundant (p-value=0.000), however this does not hold for the period effects (p-value=0.088).

Now to test the possibility that μ_i and λ_t are stochastic and not fixed, i.e. $\mu_i \sim IID(0, \sigma_\mu^2)$ and/or $\lambda_t \sim IID(0, \sigma_\lambda^2)$, we employ the Breusch-Pagan LM tests:

[10] Note that this is an independent non-profit organization and not a government-run program like the GreenPower Accreditation Program established in 1997 in Australia to support the growth of the renewable energy industry "by increasing consumer demand and confidence in accredited GreenPower products." (GreenPower, 2015). In our sample, all certified programs received their certification from Green-e.

Test 1: $H_0: \sigma_\mu^2 = 0$ for individual random effects

Test 2: $H_0: \sigma_\lambda^2 = 0$ for time random effects

Other tests that extend the Breusch-Pagan test but differ in that they have a one-sided alternative hypothesis are also employed. The results of LM-type tests (Breusch and Pagan, 1980; Honda, 1985; Moulton and Randolph, 1989; King and Wu, 1997; Gourieroux et al., 1982) all indicate the presence of cross section random effects but no period random effects.

We then employ the Hausman (1978) test that can detect the presence of any endogeneity problem in the regressors. The original one-way Hausman test has been extended for application to a two-way model as in our case. In the first test a two-way mixed model where μ_i is random while λ_t is fixed is compared to a two-way fixed effects model. In the second test a two-way mixed model where λ_t is random while μ_i is fixed is compared to a two-way fixed effects model. The Hausman (1978) test also confirms the conclusion noted above.

Hence, we select the one-way cross-section random effects model as the most adequate. It is of course important to use a correctly specified regression for inference to be valid.

$$Y_{it} = \alpha + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \ldots \ldots + \beta_k X_{kit} + u_{it}$$

$$\text{Where } u_{it} = \mu_i + v_{it} \qquad i=1,2,\ldots N \text{ and } t=1,2,\ldots.,T \tag{3}$$

Each cross section's coefficient is determined by random parameters such that $\mu_i \sim IID(0, \sigma_\mu^2)$. The three widely used Feasible Generalized Least Squares (FGLS) random effects estimators, namely Wallace-Hussein (1969), Swamy-Arora (1972), and Wansbeek-Kapteyn (1982), all have good large sample properties and according to Baltagi (2008) none has superior small sample properties. To estimate our coefficients we use the Wansbeek-Kapteyn method with White's robust covariances. As a robustness check, we employed the other two methods and reached very similar results.

4. Results and Discussion

The econometric results of a log-level regression estimation are presented in Table 1. Consistent with economic theory, the price elasticity of green power is negative and significant at the 10% confidence level; when price increases quantity demanded decreases and vice versa. Even though the coefficient is statistically significant, its magnitude however, reveals that customers are not too sensitive to price changes; when price decreases by 1 percent quantity demanded increases by around 0.3%. In comparison to Mewton and Cacho's (2011) price elasticity of -0.96, US demand seems to be much more inelastic but we need to be careful in the interpretation: this difference could be due to the fact that they did not separate the residential from the commercial customers, who may be more sensitive to prices relative to households.

Nevertheless, our result is not surprising and is similar to the vast majority of those found in the literature in which there is wide consensus that electricity demand is price inelastic (i.e. demand always decreases percentage wise less than the increase in price). Green electricity demand might be even more inelastic if the main driver for signing up is the 'warm glow' effect. Anecdotal evidence from the power sector, however, has been mixed and in some cases contradicts the finding that consumers are insensitive to price changes. For example, even though in some cases the price premium was zero or negative and still the adoption rates were low, there are other cases where when the price was lowered all green power was sold out.

In general, one might have expected customers to react a little more to price changes, however one of the limitations in this study is that we are estimating the price sensitivity of existing customers, customers who may be more environmentally-conscious than non-participants.

Table 1: Green power demand regression estimates

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Consumption	17.232	0.319	54.067	0.000
Price (premium)	-39.738	20.981	-1.894	0.062
Number of Customers (residential)	0.000	0.000	15.984	0.000
Accreditation Status	0.251	0.066	3.791	0.000
Weighted Statistics				
R-squared	0.615	F-statistic		46.348
Adjusted R-squared	0.602	Prob(F-statistic)		0.000

The elasticity with respect to number of customers is 0.52 and highly statistically significant implying that a 1% increase in households will increase consumption by around 0.52%, leading to the conclusion that new subscribers tend to purchase less green power on average than the existing customers. A plausible explanation could be that early adopters are pro-environmental individuals who tend to commit to high levels of green power purchase, whereas newer customers opt for lower amounts, perhaps exhibiting the 'buy-in' mentality (Jacobsen et al., 2012; Ma and Burton, 2016). There could be other explanations as to why newcomers purchase lower amounts of green power relative to early adopters, but we find this to be the most rational one.

Accreditation is associated with higher consumption and the coefficient is statistically different from zero. The percentage change in consumption due to a dummy variable can be calculated as $100(e^{\beta} - 1)$ (Halvorsen and Palmquist, 1980). This implies that getting accredited will have a 28.5% positive impact on consumption; i.e. by obtaining accreditation a program can expect to boost its sales by almost 30%. This could be the result of new customers joining the program and existing customers increasing their demand. Hence, obtaining certification may be one way to increase green power sales. This result is extremely interesting and validates the importance given to certification by researchers studying different geographical markets. It is also possible that accreditation status is associated with other variables not studied here, such as the level of marketing efforts or the overall quality of the product offering.

Given that certification by a reliable third party has existed in the US for some time now, this factor might even be more important in other countries. Diaz-Rainey and Ashton (2008) stress the need for a compulsory, preferably government run, accreditation system to better develop and grow green energy markets in the UK. Lack of trust in product offerings in the absence of accreditation schemes has been cited as a major reason for why WTP estimates have not materialized (Diaz-Rainey and Tzavara, 2012). In Australia where the vast majority of programs are certified, consumers have been found to strongly favor certified products (Paladino and Pandit, 2012; Ma and Burton, 2016). In Finland, the majority of consumers said they lack trust in the electricity providers, and some even expected that these companies will try to mislead them for example by double counting (Salmela and Varho, 2006). In such cases, it wouldn't be surprising that obtaining certification might increase demand perhaps substantially.

5. Conclusion

This paper investigates the demand determinants of green power in the U.S. residential sector. Despite the extensive body of research on willingness-to-pay for green power, only two existing studies (Mewton and Cacho, 2011; Wiser et al. 2005) use historical data and quantify the effects of the determinants of demand. Mewton and Cacho (2011) use data from Australia and the study has a major drawback in that it doesn't separate residential from commercial customers, although it is known that the factors of demand affecting each respective class are different. Wiser et al. (2005) examine drivers of participation in green pricing programs, but over a more limited number of years than that examined in this study.

Using a balanced panel dataset we estimate the effect of price, number of customers, and certification status on green power demand. Although statistically significant, demand is highly price inelastic: when price increases by 1%, demand decreases by almost 0.3%. From a policy perspective, this implies that increasing the premium will lead to an increase in sale revenues according to the well-known relationship between price elasticity of demand and revenues. In that case the result would be an expansion of the program. However, given that renewable electricity generation prices have been decreasing for some time, by just keeping the premiums constant, suppliers should also be able to increase their profits and expand the program.

Given the relative insensitivity of customers to price changes, one might conclude that the disappointing sign-up rates and low levels of commitment may be explained by substantial free-riding and by limited customer awareness or customer inertia (Rose et al., 2002). However, another reason confirmed by this study's findings could be the consumers' lack of trust in providers, causing them to place importance on certification. Knowing that gaining green accreditation is important to the success of programs, utilities may want to seek certification and highlight it in their advertising campaigns. This is especially important in areas where open access for retail energy is allowed. It is also possible that the certification variable captures other program characteristics, such as the quality of the offering, or that utilities that seek certification also place more emphasis on promoting their programs.

Interestingly, the elasticity with respect to number of customers is 0.52, half the expected magnitude. This implies that new subscribers tend to purchase lower amounts of green power on average than the existing customers. Based on this finding, providers need to make sure that any new subscribers are given enough information about the product to make an informed decision about their commitment level and not be held back by uncertainty about product characteristics or fear of double counting. This finding could also be complicated by new offerings introduced in the marketplace over the course of this time period. For instance, the cost of residential solar declined dramatically over this period, and some customers may have opted for on-site solar, rather than a utility option. Given the above findings, raising the minimum level of commitment will very likely lead to increased sales (Wiser et al., 2005; Ma and Burton, 2016). However, other factors such as product quality may be key considerations as well.

Finally, there is general agreement that public good provision increases if the contributions are publicly acknowledged (e.g. token gifts such as pins, mugs, or stickers) (Pollitt and Shaorshadze, 2011). If suppliers can find a way to promote green power consumption as a status symbol perhaps its consumption could be turned into what Veblen (1899) coined as conspicuous consumption. In that case, green power will be seen as a luxury good in comparison to grey power and will become more desirable as a positional good. If our assumption that most consumers purchase green power due to the warm glow effect is true (and specifically as a prestige symbol), it might also be true that they want their altruism to be seen as well. The optimal mechanism of how to identify and give recognition for green power consumers remains to be determined; some providers give out car or home decals or perhaps a mailbox sticker could do the job.

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