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The value of price transparency in residential solar photovoltaic markets

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ABSTRACT

Installed prices for residential solar photovoltaic (PV) systems have declined significantly in recent years. However price dispersion and limited customer access to PV quotes prevents some prospective customers from obtaining low price offers. This study shows that improved customer access to prices – also known as price transparency – is a potential policy lever for further PV price reductions. We use customer search and strategic pricing theory to show that PV installation companies face incentives to offer lower prices in markets with more price transparency. We test this theoretical framework using a unique residential PV quote dataset. Our results show that installers offer lower prices to customers that are expected to receive more quotes. Our study provides a rationale for policies to improve price transparency in residential PV markets.

1. Introduction

The adoption of residential solar photovoltaic (PV) systems remains relatively uncommon despite the support of national, state, and local policies around the world (Bauner and Crago, 2015; Matisoff and Johnson, 2017; Sarzynski et al., 2012; Shrimali and Jenner, 2013; Hughes and Podolefsky, 2015). For most prospective PV adopters, financial returns – rather than environmental benefits – are the key factor in the decision of whether to adopt, delay, or reject PV (Schelly, 2014; Vasseur and Kemp, 2015; Korcaj et al., 2015; Moezzi et al., 2017; Sommerfeld et al., 2017). Thus prices play a critical role in the efficacy of PV-supportive policies. PV prices have declined significantly over the past decade but remain relatively dispersed, such that some customers receive better deals than others (Gillingham et al., 2016; Nemet et al., 2017a, 2017b; Barbose and Darghouth, 2017). PV price reductions do not necessarily translate to increased deployment if customers have imperfect information about prices and are unable to identify low-priced systems. The ability of customers to identify and compare all available market prices for a given good is known as *price transparency*. In this paper, we use economic theory and an empirical study to show that improved price transparency could foster further PV price reductions.

Residential PV installation costs vary according to site-specific factors such as roofing material and pitch. PV prices are not readily available, as installers tend not to advertise generic prices that do not reflect these site-specific costs. Instead, similar to other related service industries, customers must actively search for quotes to apprise themselves of potential installation prices. Customer search is costly: customers must at a minimum take time to identify and contact potential installers, and incur other costs such as the time to host site inspections before obtaining quotes. In markets with search costs, at least some customers may satisfice and accept the lowest available price after conducting a limited search (Stigler, 1961). As a result, residential PV markets are relatively non-transparent in the sense that most customers base adoption decisions on a limited number of quoted prices (EnergySage, 2017; Moezzi et al., 2017). This outcome violates the assumption of perfect price transparency in models of perfect competition (Tirole, 1988). Thus low price transparency represents a type of market failure that may justify policy interventions to reduce customer search costs and improve customer access to quotes (Nemet et al., 2017b; Gillingham et al., 2016).

Low PV price transparency may undermine policies aimed at increasing residential PV adoption. Customer search costs – no matter how small – allow at least some firms to charge non-competitive prices (Stigler, 1961; Stiglitz, 1979), otherwise known as the exercise of market power. High offer prices resulting from market power could discourage some customers from adopting that otherwise would have adopted at a lower offer price (Nemet et al., 2017b). Even with low offer prices, customer uncertainty and lack of customer confidence in the PV price distribution may discourage potential adopters (Vasseur and Kemp, 2015; Bauner and Crago, 2015). Policymakers may seek to develop policies that reduce customer search costs to increase PV price transparency, drive further price reductions, and support increased adoption.

To our knowledge, no study to date has directly studied the effects of price transparency on PV prices. This research gap is due in part to

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data limitations. Previous PV price studies have used installed system price data that exclude information from unaccepted quotes (Gillingham et al., 2016; Nemet et al., 2017a, 2017b; Barbose et al., 2015). Gillingham et al. (2016) suggest that customer search costs contribute to the result that customers obtain lower prices in markets with more active installers. However the number of quotes received by customers is unobserved in this and other PV price studies. For the first time, we directly study the effects of price transparency by using quote data rather than installed price data. Through quote data, we observe both accepted and unaccepted quotes, and can test relationships between the number of quotes received and prices offered by installers.

Further, we explore price differences between two types of quotes. The vast majority of PV customers receive *direct* quotes: quotes received directly from an installer. Customers obtain direct quotes by contacting – or being contacted by – individual installers. Each additional direct quote entails an additional search, such that obtaining a large number of direct quotes is generally costly to the customer. More recently, some customers have begun to receive *aggregated* quotes: quotes obtained from a third-party quote aggregator that aggregates multiple quotes on behalf of customers. Customers incur a single search cost to obtain aggregated quotes: the cost to deliver necessary information to the quote aggregator. Thus quote aggregation reduces customer search costs relative to direct quote solicitation. By comparing offer prices between direct and aggregated quotes, we quantify the price effects of these lower search costs and increased price transparency.

Our results are consistent with the hypothesis that improved price transparency results in lower PV prices. We find that installers tend to offer lower prices to customers that are expected to receive more quotes. Further, we find that aggregated quote prices are significantly lower than direct quote prices, suggesting that lower search costs from quote aggregation contribute to lower offer prices. Before proceeding to our methods and results, we further develop the theoretical framework behind the hypothesis that price transparency affects prices. In the following section, we use customer search and strategic bidding theory to show that installer prices should be inversely related to the degree of price transparency.

2. Background

Search costs limit customer access to prices and allow at least some firms to exercise market power (Stigler, 1961; Stiglitz, 1979; Diamond, 1971). To explain this result and the implications for residential PV markets, we provide simplified models of customer search and strategic pricing. More complex models and technical derivations are available through the citations.

Assume that a customer is willing to pay v for a PV system. Let $s(n)$ denote a search cost function equal to the sum of search costs incurred to obtain n quotes. Let $p_{min}(n)$ denote some function estimating the expected minimum price obtained after collecting n quotes. A customer has an incentive to search for at least one quote as long as $v - p_{min}(1) - s(1) > 0$. Let n^* denote the maximum number of quotes that a rational utility-maximizing customer will obtain, which satisfies the following condition:

$$n^* = max(n) s.\ t. \quad \left|\frac{\partial p_{min}}{\partial n}\right| > \frac{\partial s}{\partial n} \tag{1}$$

Eq. (1) states that the customer will search for more quotes as long as the marginal benefit of search – the expected price reduction from obtaining an additional quote – exceeds the marginal cost of search. Note that Eq. (1) implies the general result that customer search only occurs in markets with price dispersion (Janssen and Moraga-Gonzalez, 2004; Stigler, 1961; Carlson and McAfee, 1983). That is, the customer must reasonably expect some price reduction from search.

Eq. (1) shows that the number of quotes obtained is a function of search costs. All else equal, customers will obtain more quotes in markets with lower search costs. Thus saying that one market is more transparent than another amounts to saying that one market has lower search costs than another market, assuming price dispersion.

Next we explore how the number of quotes obtained affects installer pricing behavior. Assume that a customer obtains n^* quotes and accepts the lowest price. Let $F(p)$ denote the probability distribution of price offers by all competing bidders. From the perspective of an installer i, the probability of winning the bid at price p_i is given:

$$W(p_i, n^*) = (1 - F(p_i))^{n^* - 1} \tag{2}$$

Where $W(\cdot)$ is the bid winning probability. Eq. (2) states that the probability that installer i offers the lowest price and wins the bid decreases exponentially as the number of quotes increases (Janssen and Moraga-Gonzalez, 2004; McAfee and McMillan, 1987; Friedman, 1956; Holt, 1980). Note that the bid winning probability is also decreasing in price. Eq. (2) can be used to model an installer's expected profit function given the installer's cost c:

$$\pi_i = W(p_i, n^*)[p_i - c_i] \tag{3}$$

Where π_i is installer i's expected profit. Eq. (3) illustrates the installer's dilemma: charging higher prices increases profits on won bids, but reduces the probability of winning bids. Applying the first order condition to Eq. (3) provides a simplified but illustrative bidding rule:

$$p_i^* = c_i + \left|\frac{W(p_i, n^*)}{\partial W(p_i, n^*)/\partial p_i}\right| \tag{4}$$

Eq. (4) is known as a strategic bidding rule where the profit-maximizing price (p^*) may be written as some function of rival behavior (Holt, 1980; Friedman, 1956; McAfee and McMillan, 1987). Eq. (4) shows that installers maximize profits by adding a markup that is a function of the win probability and thus a function of the number of quotes received by the customer. Note that, by the inclusion of the optimal number of quotes obtained n^* in Eq. (4), the optimal strategic price is a function of search costs (Stahl, 1989; Carlson and McAfee, 1983).

Eq. (1) shows that customers obtain more quotes in more transparent markets (lower search costs). Eqs. (2) and (4) establish that installer strategic prices decrease exponentially according to the number of quotes received. It follows that installers will tend to offer lower prices in more transparent markets. In a perfect price transparency market, search is costless ($s(n) = 0$) and the markup in Eq. (4) approaches zero assuming a sufficiently large number of firms. In other words, strategic prices approach marginal cost pricing in fully price transparent markets. At the opposite extreme, if search costs are so high that customers only obtain a single quote, the markup in Eq. (4) becomes increasingly large and the strategic price is the monopoly price (Diamond, 1971). Varying degrees of price transparency between these extremes give rise to price dispersion (Carlson and McAfee, 1983; Stiglitz, 1979; Varian, 1980), with the general result that average prices are falling in search costs These results provide the basis for this study's hypothesis:

Transparency-price hypothesis. PV prices should be lower in more transparent markets where customers receive more quotes.

3. Methods

This section describes our dataset and two approaches to measure the effects of market transparency.

3.1. Data

We use quote data to test the transparency-price hypothesis. An advantage of using quote data – rather than installed price data – is that we observe the number of quotes received by each customer and can