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Multi-state residential transaction estimates of solar photovoltaic system premiums

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As of the second quarter of 2016 more than 1.1 million solar photovoltaic (PV) homes exist in the US. Capturing the value these PV systems add to home sales is therefore important. Our study enhances the PV-home-valuation literature by analyzing 22,822 home sales, of which 3951 have PV, and which span eight states during 2002–2013. We also, for the first time, compare premiums with contributory value estimates derived from the present value of saved energy costs (income approach) and, separately, the replacement cost of systems at the time of sale (cost approach) to examine market signals. We find home buyers are consistently willing to pay PV home premiums across various states, housing and PV markets, and home types; average premiums equate to approximately $4/W or $15,000 for an average-sized 3.6-kW PV system. We find that a replacement cost net of state and federal incentives is a better proxy for premiums than gross installed costs, and that the income approach is a good signal if it accounts for tiered volumetric retail rates. Other results include detailed premium analyses for PV home sub-populations.

1. Introduction

As of the second half of 2016, solar photovoltaic (PV) energy systems have been installed on more than 1.1 million properties in the United States; more than 300,000 systems were installed in 2015 alone [1]. This growth is in part related to the dramatic decrease in installed PV costs over the last 10 years [2] as well as the increase in financing options for property owners installing PV, such as leased PV systems and other zero-money-down purchase options [1]. The U.S. Department of Energy estimates that achieving its SunShot PV system price-reduction targets could result in 108 GW of residential rooftop PV installed by 2050—equivalent to 30 million American homes with PV [3].[1]

As PV installations have proliferated, so has the number of transactions involving homes with PV [4]. Because of this, the real estate sales and valuation communities have evolved accordingly [5]. For example, courses on the valuation and marketing of green features are available through the Appraisal Institute and the National Association of REALTORS®,[2] respectively. New policy documents have been issued by Fannie Mae [6] and the Federal Housing Administration [7], which provide appraisers the tools and guidance for recognizing solar as a potentially valuable asset.

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[1] Assuming the average PV system size of 3.6 kW found for all PV homes in this study.

[2] See, e.g., http://www.appraisalinstitute.org/education/education-resources/green-building-resources/ and http://www.greenresourcecouncil.org/.

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Despite the activity around valuing PV homes, little research documents the premiums for these homes. Farhar and Coburn [8] first documented the apparent increase in values for 15 PV homes inside a San Diego subdivision. This was later corroborated by strong empirical evidence from greater San Diego and Sacramento [9] and from a dataset of approximately 1900 California PV homes [10–12]; these studies employed hedonic pricing models to estimate premiums. Additionally, three appraiser-led studies using paired sales analysis of fewer than 45 homes found further evidence of premiums in Oregon [13] the Denver metro area [14], and from six states in the US [4]. Because the evidence that PV homes garner a premium has focused on a relatively small number of California homes and a few in Colorado, Oregon and other states, there is need for further evidence of premiums outside of California and even inside California using large datasets. There is also a need to analyze transactions that occurred after the housing bubble ended in 2008, because most previous studies analyzed transactions that occurred during that bubble [10–12].

In most local markets, few PV home sales occur, thus appraisers and other real estate professionals (real estate agents, lenders, underwriters, etc.) often cannot compare similar PV and non-PV home sales to derive a PV premium. Because of this, valuation professionals often use other methods to value PV systems, including the income and cost methods [5,15,16]. Although some past studies have compared results from these methods to results derived from transaction analysis [11,14], they have not applied statistical analysis and thus cannot statistically quantify the comparisons. Such a statistical comparison would be a valuable contribution to the literature, especially using a more recent and broader group of transactions.

Other considerations are important as well. The gross installed costs (i.e., costs before state and federal incentives) of PV systems have declined steadily in recent years, while net costs (i.e., with incentives included) have remained fairly stable [2]. There also has been evidence that the new home market in California heavily discounted PV homes during the housing boom and bust (through 2009) in comparison to the premiums garnered by existing home sellers [10,11].[3] Finally, previous literature suggests the need for more research on the market's depreciation of aging PV systems, especially for systems greater than 6 years old, which have not been well studied because of the immaturity of the PV market [10–12].

In summary, the existing literature leaves open a number of questions, each of which the present research seeks to address. Table 1 shows these questions along with models and sample sets, which are discussed later.

This research focuses on only host-owned PV systems and therefore excludes third-party-owned systems, which, we recommend, should be included in future research because they make up a large percentage of the most recent PV installations.

The remainder of this report is organized as follows: Section 2 discusses our methodological approach, Section 3 details the data used for the analysis, Section 4 presents the results, and Section 5 offers conclusions and directions for future work.

[3] These discounts, it was assumed, were offset by decreased marketing times (i.e., "sales velocity") for these homes, a priority for home builders as the market for new homes slowed and inventories increased [8,29,30].

2. Methodological approach

To examine the questions above, this research relies on a hedonic pricing model—the "Base Model"—against which a series of other models are compared. Those other models use a subset of the data (e.g., new or existing homes), an interaction term(s) (e.g., age of the PV system), or other variants to examine the various research questions and test the overall robustness of the results.

The basic theory behind the hedonic pricing model starts with the concept that a house can be thought of as a bundle of characteristics. When a price is agreed upon between a buyer and seller, there is an implicit understanding that those characteristics have value. When data from a number of sales are available, the average marginal contribution to the sales price of each characteristic can be estimated with a hedonic regression model [17–19]. This relationship takes the basic form:

$$\text{Sales price} = f(\text{home and site, neighborhood, and market characteristics})$$

"Home and site characteristics" might include, but are not limited to, the number of square feet of living area and the presence of a PV system. "Neighborhood" characteristics might include such variables as the crime rate and the distance to a central business district. Finally, "market characteristics" might include, but are not limited to, temporal effects such as housing market inflation/deflation.

2.1. Base model

The "Base Model" to which other models are compared uses a relatively simple set of home and site characteristics: size of the home (i.e., square feet of living area); age of the home at the time of sale (in years); age of the home squared (in years); size of the parcel (in acres) up to 1 acre; and any additional acres more than 1 (in acres).[4] It also includes the presence and size of the PV systems. To control for neighborhood, we include a census block group fixed effect, which, in all cases, includes at least one PV home and one non-PV home. Finally, market characteristics are accounted for by including a dummy variable for the quarter and year (e.g., 2013 Q2, 2009 Q1, etc.) in which the sale occurred. This model form was chosen for its relative parsimony, its high adjusted R^2, and its transparency.[5] It is estimated as follows:

$$\ln(P_{itk}) = \alpha + \beta_1(T_i) + \beta_2(K_i) + \sum_a \beta_3(X_i) + \beta_4(\mathrm{PV}_i \cdot \mathrm{SIZE}_i) + \epsilon_{itk} \quad (1)$$

[4] Acres is entered into the model as a spline function using two variables, up to 1 acre (*acreslt1*) and any additional acres above 1 (*acresgt1*), to capture the different values of up to the first and additional acres of parcels in the sample. Therefore *acreslt1* = *acres* if *acres* = 1 and 1 otherwise, while *acresgt1* = *acres*-1 if *acres* $>$ 1 and 0 otherwise. Additionally, square feet and age squared are entered into the model in 1000s to allow for easier interpretation of the coefficients.

[5] Model choice for this work was based on extensive robustness model exploration in previous analysis [10–12]. Other models were explored but are not presented here. They include adding other home and site parameters such as number of bathrooms, condition of the home, and if a pool is present, all of which further limited the dataset but did not substantively affect the results. Similarly, instead of using a fixed effect for sale year and quarter, interacting sale year and, separately, sale quarter, with a geographic variable, such as county, to control for geographic variation in market inflation/deflation was explored with no change to the results.