

The Positive Feedback Cycle in the Electricity Market: Residential Solar PV Adoption, Electricity Demand and Prices

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Overview

Solar photovoltaic (PV) systems have made it possible for home owners to retrofit their premises to generate their own electricity, thus becoming more self-sufficient. Though, the increasing popularity of residential solar PV systems in electricity markets has led some (Cai, Adlakha, Low, De Martini, & Chandy, 2013) to suggest that it has created a positive feedback cycle or loop. Simply put a positive feedback cycle or loop is a situation where, action A generates more of action B which in turn generates more of action A. In economics a positive feedback cycle results in a systemic risk to the system (Rodrigues et al., 2016; Sahu, 2015).

This study is concerned with whether there is a positive feedback cycle in existence in the electricity market as a result of residential solar PV. The positive feedback cycle in the electricity market is a result of residential electricity customers adopting solar PV systems due to high electricity prices whereby reducing their net purchases from the electricity grid; however, the costs incurred by the electrical utility companies do not decrease in proportion to the decrease in electricity consumed. This is because the electrical utilities have to pay for transmission and distribution infrastructure and these fixed costs are recovered over decades. Electrical utilities will have to raise their price of electricity to make up for the loss and thus incentivise the remaining electricity customers to adopt solar PV systems. Increasing penetration levels of residential solar PV systems onto a grid could further accelerate the positive feedback cycle and potentially force electrical utilities into a death spiral; where electricity price increases will be futile in raising sufficient revenues to cover its total costs (Costello & Hemphill, 2014).

The goal of this paper is to firstly model the positive feedback cycle caused by consumers in the residential sector to deciding to adopt solar PV systems and the resulting implications on demand and pricing in the residential electricity market. Following this, an econometric analysis is performed for the selected group of countries, Australia, Ireland and the United Kingdom to investigate whether a positive feedback cycle is being experienced. Therefore, the objectives are: (1) to find if increasing residential electricity prices will lead to higher installation rates of residential solar PV panels, (2) whether residential solar PV installations lead to higher residential electricity prices, (3) whether residential solar PV installations negatively affect residential electricity demand. The results attained in this paper are meant to inform policy makers and regulators as they consider potential changes to residential electricity rates that could affect PV's role in advancing policy objectives and consumer choice.

Methods

Kaufmann and Vaid (2016) note that empirical studies examining the effects of renewable energy systems on electricity price have used some variants of the following equation, where electricity price is a function of electricity load, renewable energy & non-renewables systems, price of fossil fuels and dummy time variables. Using this equation as a starting point we transformed it into multiple equations, to treat simultaneously residential solar PV uptakes, residential electricity prices and residential electricity demand as endogenous. Given the nature of the positive feedback cycle, a simultaneous equation model (SEM) would be best suited to model this relationship and to ensure the treatment of any endogeneity bias. The three equations that comprise our SEM are shown below:

Equation 1. The Residential Solar PV Uptake equation is a function of the following variables; residential price of electricity, government scheme for the promotion solar PV, average sunlight hours, average cost of solar PV system.

Equation 2. The Residential Price of Electricity equation is a function of the following variables; residential solar PV uptake, coal share used in electricity production, lagged residential price of electricity.

Equation 3. The Residential Electricity Demand equation is a function of the following variables; residential price of electricity, residential solar PV uptake, price of natural gas, average temperature, average income.

SEM may be biased if estimated with ordinary least method due to the inherent correlation among the error terms and the explanatory variables in the specified equations. In this study a three stage least square (3SLS) method (Zellner & Theil, 1962) is employed.

Results

The main results from our regression of the SEM are briefly discussed here. The first equation is the solar uptake equation, the variables included were the ones thought to be the main drivers behind the residential sectors uptake of solar PV systems. However, the variable that is of most importance to us in discovering whether a positive feedback cycle is in effect, is the residential electricity price variable. The positive feedback cycle theorized that an increase in residential electricity price would lead to a higher uptake in solar PV. Results show that a 1% increase residential electricity price will increase residential solar PV uptake by 0.46%, the variable is statistically significant at the 1% level. This result fits into the theory of the positive feedback cycle, according to which, higher electricity prices lead to an increase in the installations of residential solar PV systems.

The next equation in our SEM is the residential electricity price equation, the variable of most interest is the residential solar PV uptake variable, results are in line with the positive feedback cycle, with the variable being statistically significant at the 5% level. Results indicate that a 1% increase in the residential solar PV uptake variable results in a 0.17% increase in the price of residential electricity.

The final equation in our SEM is the residential electricity demand equation, under the conditions of the positive feedback cycle theory, residential electricity demand will decrease as a result of increased solar PV uptake. Results indicate that a 1% increase in the residential solar PV uptake will decrease the amount of residential electricity demand by the residential sector by nearly 1.6%. Also, a 1% increase in the residential electricity price, will lead to a decrease in residential electricity demand by 2.89%.

Conclusions

This study extended previous research by examining the residential electricity markets in three countries: the U.K., Ireland and Australia, to provide evidence of any positive feedback cycle. The empirical analysis used a SEM to illustrate the interactions of residential solar PV uptake, residential electricity prices and demand, and to provide evidence of any positive feedback cycle in the market. To this end, a 3sls regression model was employed in relevance to the pooled panel data set of Australia, Ireland and the UK. The findings documented: a positive relationship between electricity prices and solar PV uptake, a positive relationship between solar PV uptake and electricity price, and finally, a negative relationship between electricity prices & electricity demand. Moreover, a negative relationship was found between solar PV and electricity demand. In other words, the findings indicated that a positive feedback cycle was in effect, as the adoption of residential solar PV systems was leading to a positive feedback cycle via increasing residential electricity prices and decreasing residential electricity demand.

The evidence of the positive feedback cycle in an electricity market could raise issues for electricity utilities, transmission system operators, and government energy departments, as some have suggested that it could result in a utility 'death spiral'. In our analysis, it seems that Australia and the UK would be more at risk due to the larger cumulative capacity of residential solar PV systems added to the grid in a short period of time. To tackle this issue, there needs to be a restructuring of current renewable energy policies. If environmental goals are to be achieved as well, then stakeholders in the electricity market will have to support the adoption of solar PV in a sustainable way, while not punishing non-adopters with higher electricity rates.

References

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