Powering Demand:

Solar Photovoltaic Subsidies in California

Ken Reddix

Department of Economics
University of North Carolina at Chapel Hill

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Outline

1. Motivating the Project
2. Modeling Choices
3. Data & Preliminary Results

Current Topic

1. Motivating the Project
2. Modeling Choices
3. Data & Preliminary Results

Solar Industry

- Resurgance of interest in solar energy
- Federal and state dollars funding policies
- Emerging industry globally

Geographical Focus

- California
  - Most succesful state in the US
  - Responsible for more than 60% of solar installations
  - Data on installations
- 1998 - 2006
  - Three different subsidy regimes
  - Capacity based subsidies

Subsidies from 1998-Present

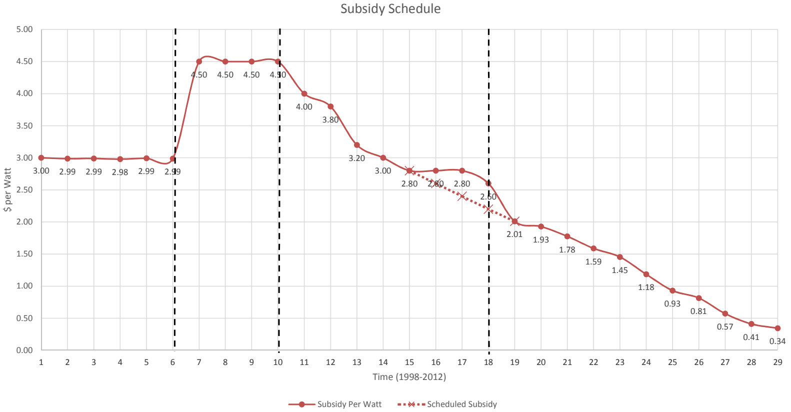

Figure : Subsidies Over Time

Consumer Choice

What product to purchase?

1. Capacity (kW)
2. Efficiency Rate
3. Area of the System (m^2)
4. Other characteristics

When to purchase?

1. Option value of waiting
2. Technology innovation, Prices, and Subsidies

Consumer Tradeoffs in the Market for Solar

Benefits:

1. Income Stream
2. Warm Glow
3. Signaling Green

Costs:

1. High up front cost, $35,000
2. Foregoing future technology, subsidies, and prices

Research Question:

How do subsidies affect the consumer's purchasing decision?

Solar Policy

- Policy Counterfactuals (Lobel & Perakis 2011, Burr 2012)
  1. Changes in subsidy levels affect adoption rates
  2. Capacity Based vs Production Based Policies

Significance of the Research

1. Improves characterization of the market
    - Including consumer and product level heterogeneity
    - Accounting for multiple levels of uncertainty
    - Introduction of newly assembled data set
2. Enriches policy design and testing
    - Improves accuracy of policy predictions
    - Opens up room for new designs

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Households:

- $i = \{1, \ldots, N\}$

Choice Set over Capacity:

- $s \in \{0, 1, 2, 3, 4\}$

Discrete Time Infinite Horizon

- $t = \{1, \ldots, \infty\}$

State Space

- $\Omega_t = \{\omega_t, \epsilon_t\}$
- $\omega_t = \left\{P_t^e, P_t^{SP}, Z_t, \tau_t\right\}$

Consumer's Utility From Purchasing

$$V_i(\omega_t, \epsilon_t, s_{it}) = \underbrace{\theta_1 \delta_i^f(\omega_t, s_{it})}_{\textbf{NPV}} + \underbrace{\theta_{i2} z_{st}}_{\textbf{Solar PV Char}} - \underbrace{\alpha_i^{SP}\left(p_{st}^{SP} - \tau_{st}\right)}_{\textbf{Price} - \textbf{subsidy}} + \epsilon_{ist}$$

where,

$$\delta_i^f(\omega_t, s_{it}) = E\left[\sum_{\tau=t}^{\infty} \beta^{\tau-t} \underbrace{\alpha^e \bar{p}_i^e q_{is\tau}^{SP}}_{\textbf{Solar Elec Gen}}\right]$$

Consumer's Utility From Not Purchasing

$$V_i\left(\omega_t, \epsilon_t, 0\right) = \epsilon_{i0t} + \beta \overbrace{\int_{\omega_{t+1}} EV_i\left(\omega_{t+1}, s_{it+1}\right) p\left(\omega_{t+1} \middle| \omega_t\right) d\omega_{t+1}}^{\textbf{Expected Future Utility Staying in the market}}$$

where,

$$EV_i\left(\omega_{t+1}, s_{it+1}\right) = ln\left\{\sum_s e^{V_i\left(\omega_{t+1}, s_{it+1}\right)}\right\}$$

Consumer's Maximization Problem

$$max \left\{ \overbrace{V_i\left(\omega_t, \epsilon_t, 0\right)}^{\textbf{Value Of Waiting}}, \quad \underbrace{max_s V_i\left(\omega_t, \epsilon_t, s_{it}\right)}_{\textbf{Utility maximizing product choice}} \right\}$$

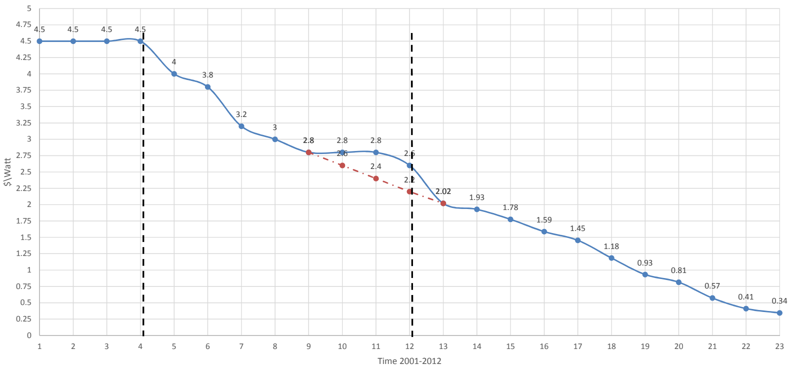
Supply Side

- Lack of data on the supply side of the market
- Assuming states evolve according to an AR(1) process

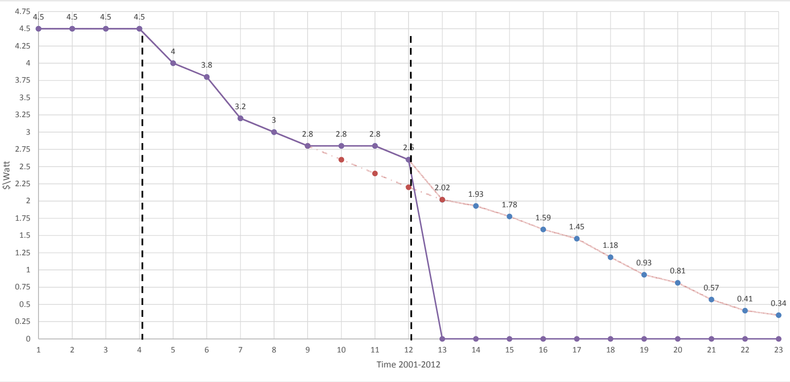
$$Z_{t+1}^{SP} = \lambda_1 + \lambda_2 Z_t^{SP} + \nu_{t+1}$$

- Assumes consumers have limited information about future states

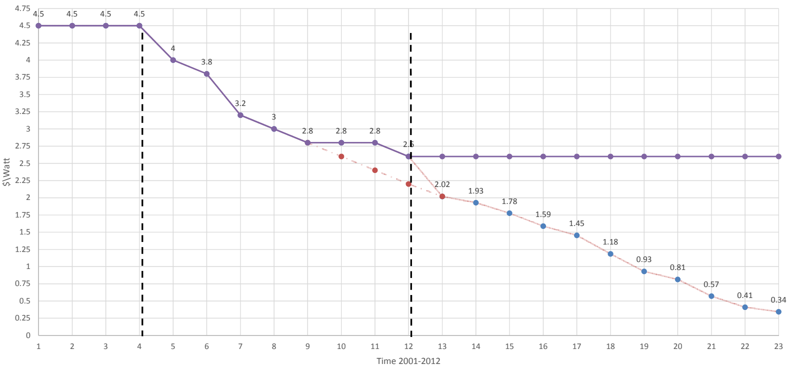
Perfect Foresight Case



Pessimistic Case



Optimistic Case



Assumptions and Restrictions:

1. Electricity Consumption Data is not available
   - Assumption 1: Electricity is a homogeneous good
     1. Utility from consumption of electricity is independent of the purchasing decision
   - Assumption 2: Price of electricity is an average price
2. Restrictions include:
   - Do not model the change in consumption after purchase
   - Do not capture the effect of consumption levels on the decision to purchase

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California Energy Commission Program Data

- Tracks the purchase of all solar panel systems 1998-2006
- Three policy regimes over the time period
- Variables consist of
  1. Physical Location
  2. Total Price Paid
  3. Total Incentive Paid
  4. Capacity
  5. Brand/Model Product Identity
  6. Relevant Dates

Zillow.com: Housing Characteristics Data (Purchasers)

- Real estate website
- Gathered housing characteristics for consumers who purchased
- Variables include:
  1. Housing Value
  2. Square Footage
  3. Number of bedrooms/Bathrooms
  4. Number of Stories
  5. Lot Size
  6. Year Built

DataQuick: Housing Characteristics Data (Non-Purchasers)

- Purpose: To include non-purchasers in the model
- Purchased data that includes the following measures for each zip code:
  1. Count, Mean, Median, Standard Deviation
  2. Quintiles
  3. Correlation Tables
- For each of the following housing characteristics:
  1. Housing Value
  2. Square Footage
  3. Number of Bedrooms
  4. Number of Stories
  5. Year Built

Utility Companies: Electricity Pricing Data

- Electricity rates throughout the sample
- The major utility companies in CA

NOAA & NREL: Weather, Solar Data

- Data on weather throughout the sample
- Retrieved from the closest weather station
- Variables included:
  1. Cooling degree days
  2. Heating degree days
  3. Temperatures
  4. Solar Irradiation

Manufacturer Website: Solar Panel Product Characteristics

- Specification sheets for all panels purchased through 2011
- Variables include:
  1. STC/PTC Capacity
  2. Dimensions
  3. Warranty Information
  4. Efficiency Rates

California Energy Commission: Eligibility Dates

- Variables Include
  1. Approval Date
  2. Exclusion Date

Estimation Procedure:

- Using the Nested Fixed Point Algorithm (NFXP) with full maximum likelihood estimation
- Steps for estimation:
  1. Estimate the parameters for the AR(1) processes that govern consumers beliefs over future states
  2. Given the estimates from step 1, run MLE until convergence:
     1. Calculate the expected value using the NFXP algorithm
     2. Calculate the log-likelihood function

	Case 1	Case 2
log(net price)	-6.523	-6.548
α_2		0.031
Area (m^2)	-0.131	-0.131
Efficiency	1.584	1.587
NPV	1.875	1.517

Next Steps

- Run the model that includes the nonpurchasers.
- Run counterfactual simulations to investigate alternative subsidies
    - Changing subsidy rates
    - Changing consumers information set about future subsidies
    - Targetting consumers

Preliminary Results

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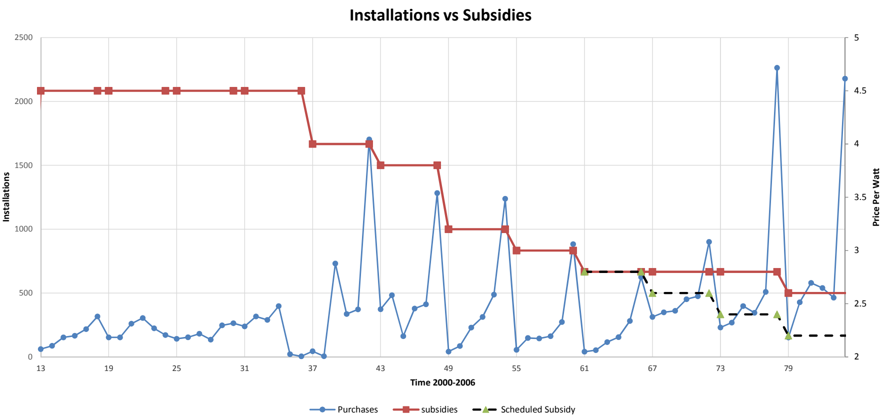

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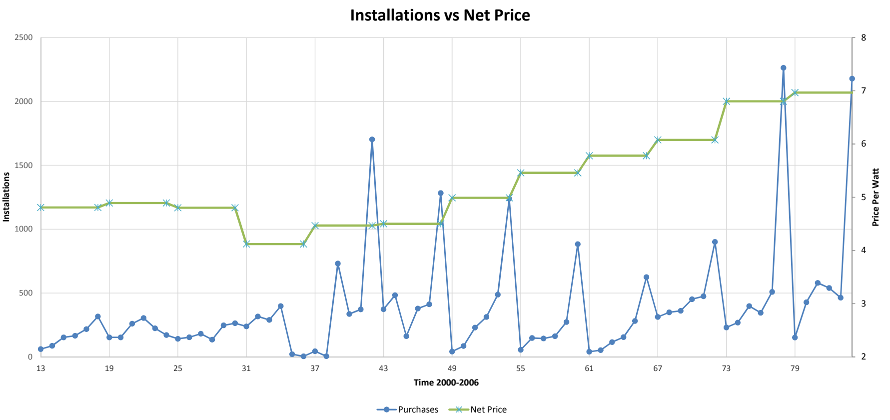

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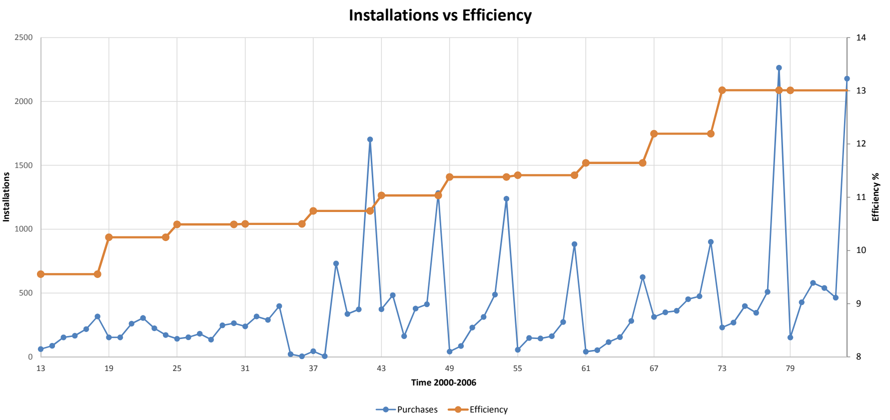

Preliminary Results