Adoption of Residential Solar Power Under Uncertainty: Implications for Renewable Energy Incentives

Christoph Bauner
Postdoctoral research associate, Department of Resource Economics,
University of Massachusetts Amherst
Email: cbauner@resecon.umass.edu

Christine Crago
(Corresponding Author)
Assistant Professor, Department of Resource Economics,
University of Massachusetts Amherst
Email: ccrago@resecon.umass.edu

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Christoph Bauner [1] and Christine Crago [1*]

Abstract

Many incentives at the state and federal level exist for household adoption of renewable energy like solar photovoltaic (PV) panels. Although incentives make solar panels an attractive investment from a net present value perspective, the adoption rate is low, suggesting that households are either irrational or apply an abnormally high discount rate. Alternatively, households could be recognizing the benefit (option value) of waiting to reduce uncertainty in net benefits associated with investing in solar PV. We use the option value framework to examine the decision by households to invest in solar PV and quantify the option value multiplier and adoption rate over time for solar PV investments. We find that the option value multiplier is 1.8, which implies that the net present value of benefits from solar PV needs to be almost double the investment cost for investment to occur. Simulated adoption rates show that the adoption rate under the option value decision rule is significantly lower than that following a decision rule based on NPV, and is more consistent with the observed adoption rate of solar PV. Current policies that support the solar PV market are crucial to households' adoption decision. Our simulations show that without tax credits and rebates, the median time to adoption increases by 110% compared to the baseline.

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Concerns about energy security and climate change has prompted federal and state governments in the United States (US) to incentivize clean and renewable energy sources. Solar energy is renewable energy source that has benefited from generous federal and state incentives that support solar power adoption at commercial and small residential scales (DSIRE 2013). One of solar energy's primary benefits is its low carbon emissions. Greenhouse gas (GHG) emissions from electricity produced using a solar photovoltaic (PV) system is over 90% lower compared to electricity from substitutes such as oil, coal and natural gas, making it an ideal renewable energy source (Weisser 2007). In addition, the adoption of solar power contributes to the local economy by providing green jobs. In 2010, $1.1 billion in government funds was used to support solar power (EIA 2011). Several states have also put in place mandates specific to solar power. However, despite generous incentives that have cut payback periods for solar PV systems by as much as 50% for residential installations, the uptake of solar PV has been low. One possible reason for the low uptake of solar PV is the uncertainty of net benefits. Adopting solar PV involves large upfront costs with uncertain future benefits. Furthermore, the investment is irreversible or very costly to reverse. Thus, households may see a benefit or 'option value' in waiting to see how energy prices, government incentives, and solar PV technology will evolve before deciding to invest. The option value model for investment under uncertainty suggests that is that in the context of irreversible (or costly reversible) investments and uncertain future benefits, agents see a value to postponing the investment decision until some uncertainty is at least partially resolved (Dixit and Pindyck 1994). Since policy support for solar power is expected to continue and expand in the future, it is important to examine the effect of uncertainty on households' decision to investment in solar power, and what this effect implies for policies that incentivize adoption of solar PV.

The effect of uncertainty in technology adoption and energy investments has been studied in a number of contexts. Hasset and Metcalf (1992) provide the first formal application of the option value framework to investments in energy efficiency. Using data on electricity prices and capital costs in the U.S. from 1955-1981, they calculate the hurdle rate (i.e. threshold rate of return on investment) for energy efficiency investments to be over 4 times that of the conventional hurdle rate. Isik (2004) uses the option value framework to examine the impact of policy uncertainty on the adoption of site-specific technologies (SST) by farmers in Illinois. He considers the impact of policy changes, specifically the probability that an existing subsidy will be removed and the probability that a subsidy policy will be enforced when none currently exists. He finds that the expectation of a subsidy removal encourages investment, while the probability that a subsidy will be provided in the future delays investment. Subsidies are most effective in inducing adoption if there is an expectation that it will expire soon. Ansar and Sparks (2009) also use the option value framework to examine the effect of uncertainty in the decision to invest in solar PVs. They focus on the role of experience-curve effects that increase the benefits of solar PVs over time by increasing energy savings per unit of investment cost. They also consider the possibility of a downward jump in future benefits that cause benefits to fall to zero. They extend the model developed by Hasset and Metcalf

(1992) by incorporating the effect of experience-curves on the drift and variance of benefits from solar PV adoption. They conclude that the effect of the experience-curve on hurdle rates dominates the effects of the trend in energy prices and other possible shocks to future benefits.

In this article we develop a dynamic stochastic model of household adoption of solar PV systems using the option value framework to examine the impact of uncertainty in households' decision to invest in solar PV. Using data on electricity prices, installation cost, rebates and tax credits, revenue from the sale of renewable energy credits, and energy production of solar PV systems we estimate drift and variance parameters for benefits and costs over time, and derive the optimal investment rule and hurdle rate for solar PV adoption. We then derive the threshold value of discounted benefits that trigger adoption and the length of time for investment to occur under the net present value (NPV) and option value decision rules. We also simulate adoption rates over time and examine the impact of different incentive mechanisms on adoption decision and timing.

This article makes several contributions to the literature. To our knowledge this is the first paper to examine the effect of uncertainty on the impact of policy incentives for solar power. Policies supporting the solar PV market include tax credits, rebates, and an SREC market supported by mandates. These policies contribute differently to uncertainty in net benefits of solar adoption. Rebates and tax credits reduce the initial investment cost, while revenues from a solar renewable energy credit (SREC) market increases benefits, but also increase volatility in annual benefits. In 2012, Massachusetts state and federal rebates and tax credits reduced the total installation cost of a 4-KW solar PV system by 59%, from $22,952 down to $13,587. Adding revenue from the sales of SRECs to benefits from energy savings reduced payback period by 13 years, down to 6 years (Solar Reviews 2013). Since policy incentives play a crucial role in a household's decision to invest, it is important to examine how uncertainty's effect on the household's decision affects the effectiveness of different incentive mechanisms. We extend the analysis by Ansar and Sparks (2009) in a number of ways. First, we consider uncertainty in both benefits and costs of solar power adoption. Ansar and Sparks (2009) do not consider changes in installation costs over time. A significant portion of uncertainty in net benefits may come from uncertainty in future installation costs, which include not only the price of materials but also labor and managerial costs that are related to the level of expertise of installers and the economies of scale that help them reduce cost. In this paper, we use data on installation costs to account for uncertainty in the initial investment cost. Hasset and Metcalf (1992) also consider uncertainty in both benefits and costs of energy efficiency investments. However, the cost uncertainty in their model is only measured using changes in capital costs (represented by the national durable goods index). In our model, we use actual installation costs of solar PV systems. Second, we account for the effect of government policies on benefits and costs. Government policies in the form of rebates and tax credits affect the net installed cost of a solar PV system. Similarly, mandates for solar energy create auction markets for solar renewable energy credits that provide additional revenue to owners of solar PV systems. These policies significantly alter the benefits and costs of solar power, as well as the uncertainty in net benefits.

We find that the option value multiplier is 1.8 which implies that the net present value of benefits from solar PV needs to be almost double the investment cost for investment to occur. Compared to the NPV decision rule that equates net benefits to initial investment

cost, adoption time under the option value decision rule increases by 8-10 years, depending on the assumed energy output from solar PV. Furthermore, depending on the investment decision rule applied, rebates may be preferred to revenue from SREC markets. Although we focus on the solar PV market, the framework developed here can be applied to other renewable energy investments.

The next section provides background on the solar PV market in the US and in the state of Massachusetts. Section 2 presents the model to derive the optimal investment rule. Section 3 discusses data sources. Section 4 presents results and section 5 concludes.

1   Background

The use of solar energy in residences is growing in the United States. Although installed capacity is less than 1% of total energy supply, the compounded annual growth rate for installed capacity is 49% from 2005 to 2011, growing from 27 MW to 297 MW, with about 250,000 residential installations in 2011. Drivers of this trend include the declining cost of PV installation and the availability of many financing options (Fowler 2012). State level incentives also play a key role in reducing the cost of PV installation by providing subsidies via tax credits and rebates. In addition, mandates for solar energy provide a market for selling renewable energy production credits to utilities (DSIRE 2013).

Massachusetts is currently 7th in solar installations by state with total capacity in 2013 of 250 MW. Massachusetts has a Renewable Portfolio Standard (RPS) that requires a portion of electricity supplied to residential and commercial customers to be sourced from renewable energy. The mandate is designed to meet the goal of reaching 15% renewables by 2020, with the percentage continuing to increase by 1% in succeeding years. Within the RPS, a solar carve-out program exists with a goal of reaching 250 MW installed capacity by 2017 and 400 MW by 2020 from systems that are 6 KW or less in capacity. The goal for 2017 was met in 2013, and Governor Duvall has increased the 2020 goals to 1600 MW. In 2013, the minimum compliance standard under the solar carve-out program is approximately 135,495 MWh or 0.2744% of 2011 electricity load (MA-EEA 2013).

Since the 1970s, federal and state subsidies have existed for solar power. Federal and state tax credits amount to 30% and 15% (up to $1000) of installation costs respectively. In 2008, there was a significant increase in incentives for solar PV that came in the form of a system of rebates administered by the Massachusetts Clean Energy Center (MassCEC). In 2013, rebates from the state's Commonwealth Solar program for up to 5 KW of capacity include a base incentive of $0.4 per watt, an additional $0.05 for using components produced in-state, and $0.4 if the value of the home where the panels are being installed qualify as moderate or if family income is below a set threshold. In addition, a $1 per watt Natural Disaster Relief incentive is available to homes that were damaged by a hurricane or tornado. Rebates under MassCEC are not guaranteed. A set amount of funds are allocated per funding cycle. Those who do not qualify for a round of funding must wait until the next round opens (MassCEC 2013). An additional source of revenue for solar PV owners come from the sale of Solar Renewable Energy Certifications (SRECs) to utilities that need those credits to meet their solar energy obligation under the state RPS and solar carve-out program. The market price of SRECs is determined by supply and demand. In 2010 and 2011, SREC prices were

upwards of \$500, reaching \$570 per MW of solar energy produced. However, in the last half of 2012, SREC prices were as low as \$200 per MW. The volatility in SREC prices contributes to the uncertainty in benefits faced by solar PV owners (SRECTrade 2013).

2   Model

The representative household is assumed to minimize the cost of energy required to obtain a fixed comfort level. Initially, the household derives energy from the electrical grid. The household also has the option to invest in a solar PV system to provide all or part of its energy demand. Once the investment is made it is considered irreversible. The trade-off faced by the household is between energy savings from the electricity produced by solar PV and the initial cost of installation. Energy savings are uncertain and depend on the price of electricity and energy output of solar panels. If the price of electricity increases, energy savings will be high, and conversely if electricity prices fall, energy savings over the lifetime of the system will be low and may not be sufficient to offset the upfront investment cost. The investment cost is also uncertain because of changes in the price of PV modules and available rebates from the state and federal government.

Let ω denote the difference in energy cost between the scenarios with and without a solar PV system.

$$\omega = \int_0^L Q_E P_t^E e^{-rt} dt - [\int_0^L (1-\phi) Q_E P_t^E e^{-rt} dt + I_0] \tag{1}$$

where L is the lifetime of the solar PV system, Q_E is electricity consumption, P_t^E is the price of electricity, ϕ is the proportion of energy from solar PV expressed as the ratio of total energy output from solar PV and Q_E, r is the discount rate, and I_0 is the initial investment cost. The first term on the right-hand side of the equation above is the total cost of energy over L-time periods without solar PVs, and the second term is the net cost with a solar PV system. If $\omega \geq 0$, total energy cost is lower with the installation of solar panels.

Equation 1 reduces to:

$$\omega = V_t - I_0 \tag{2}$$

where $V_t = \int_0^L \phi Q_E P_t^E e^{-rt} dt$ is the present value of energy savings over L-time periods at time t. Under the NPV rule, the household should invest in solar panels if $E[\omega] \geq 0$ or the expected present discounted value of V_t is equal to or greater than I_0. However, the NPV decision rule ignores the effect of irreversibility and uncertainty in the investment decision, and the value of waiting to invest at a later period.

The value of V_t varies over time depending on changes in P_t^E which follows a geometric Brownian motion (GBM) process: $dP = \alpha_P P dt + \sigma_P P dz_P$, where α_P is the drift and σ_P is the variance parameter. The initial investment cost also varies over time and depends on installation cost (N_t) and government rebates (R_t) offered at time of installation, both expressed per unit of installed capacity (δ_C). Thus, the initial investment cost at time t is

$I_t = \delta_C(N_t - R_t)$. We assume that V_t and I_t are stochastic and follow GBM according to:

$$dV = \alpha_V V dt + \sigma_V V dz_V \tag{3}$$

$$dI = \alpha_I I dt + \sigma_I I dz_I \tag{4}$$

where dz is the increment of the Wiener process that follows a normal distribution with zero mean and unit variance. The drift and variance parameters are denoted by α and σ respectively. We assume the no correlation between dz_V and dz_I, $E[dz_V dz_I] = 0$ because the underlying causes of uncertainty for the two series are different. Energy savings is primarily affected by energy prices and the location of PV installation while investment cost is primarily affected by the global cost of PV modules and government policy. While in principle the installed base and thus the installation cost of PV modules could affect energy prices, this is not likely to have a significant effect given the limited share of solar power in electricity generation.

Unlike the NPV rule that ignores the potential value of waiting to invest, the option value framework recognizes that the household can maximize its pay-off from investing by waiting to exercise its option to invest at an optimal time. The value of the opportunity to invest in solar panels is $F(V, I) = \max_T E[V_T - I_T]e^{-\rho T}$, where ρ is the risk-adjusted discount rate. The representative household maximizes the expected present value of the pay-off from investing by choosing the optimal time T to make the investment given (3) and (4). The solution takes the form of a threshold ratio of V and I that makes it optimal to invest, $h^* = (V/I)^*$, and is obtained by dynamic programming (Dixit and Pindyck 1994).

The Bellman equation $\rho F(V, I)dt = E[dF(V, I)]$ states that the total expected return on the investment opportunity ($\rho F(V, I)dt$) is equal to the rate of capital appreciation at the region where the option to invest is not exercised. Using Ito's Lemma to expand $dF(V, I)$ and applying free boundary, value matching and smooth pasting conditions, the solution for $F(V, I)$ is obtained, taking the form $A(\frac{V}{I})^\beta$, where β is the positive root of the quadratic:

$$\frac{1}{2}(\sigma_V^2 + \sigma_I^2)\beta(\beta - 1) + (\alpha_V - \alpha_I)\beta - (\rho - \alpha_I) \tag{5}$$

The solution reveals that it is optimal to invest when the following condition holds:

$$V_T = \frac{\beta}{\beta - 1} I_T \tag{6}$$

The equation above shows that uncertainty in future benefits and costs of installing solar PV cause a divergence in the NPV rule of $V_t = I_t$. If $\beta > 1$, the present value of benefits has to exceed investment cost by a factor equal to $\frac{\beta}{\beta-1}$ to induce investment.

3 Data

This section presents data used to estimate drift and variance parameters for V_t and I_t.

3.1 Energy Savings

Annual energy savings are calculated using data on electricity prices and energy output of installed systems. Monthly electricity prices from 1985 - 2013 for Massachusetts towns of

Boston, Brockton, and Nashua were obtained from the Bureau of Labor Statistics (BLS 2013). The price series is seasonally adjusted and indexed using 1982-1984 as base years. Energy output per kW installed capacity can vary for each installation based on factors that affect solar insolation [2] such as location of the house, orientation of the roof or area where solar panels are installed, and the presence of trees and other objects that could prevent exposure of the panels to the sun's rays. We use PVWatts, a tool developed by the National Renewable Energy Laboratory to estimate the energy output per 1 kW installed capacity for six different zip codes in the state of Massachusetts representing different geographical regions in the state. [3] We find that the average energy output of solar panels in the six locations is 1,100 kWh per year for every 1 kW capacity, however this can vary depending on the location of the house and the orientation of the installed panels. We examine a range of energy output levels to show the impact of energy output on the optimal values of V_t and I_t.

3.1.1 SREC Sales

As part of the state solar-carve out program, the Massachusetts Department of Energy Resources (MA-DOER) established a market for solar renewable energy credits (SRECs) in 2010 that allows solar PV owners to sell renewable energy production credits to utilities. Production credits can also be sold to the MA Solar Credit Clearinghouse, which acts as a buyer of last resort and establishes a fixed price less a 5% fee that acts as the price floor for SRECs. SREC prices at the marketplace have been highly variable, ranging from $500 to $570 per MW from 2010 to mid-2012, and dropping to as low $200 per MW from late-2012 to early-2013.

Revenue from SREC sales can make up a significant part of returns from solar PV investments. However, due to the newness of the market and having only three years of price data, we do not include the variability in SREC prices when estimating the trend and variance of V_t. In the sensitivity analysis, we consider a scenario where the level of returns are higher and the variability greater due to revenue from SREC sales.

3.2 Investment Cost

Investment cost per watt is the installation cost minus available rebates from the federal and state government. Data on installation cost for 1998 - 2011 is from the Lawrence Berkeley National Lab (Barbose, Darghouth, and Wiser 2012). Rebates received by over 3,000 residential installations from 2008 to 2013 was obtained from the Massachusetts Clean Energy Center.

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[2] Also called solar irradiation, this is a measure of solar radiation energy received by a given surface area at a particular time.

[3] We use default assumptions for derate factor (0.77), tilt (42.2 degrees latitude), and azimuth (180 degrees).

4   Results

4.1   Option Value Multiplier

Table 1 shows the estimated drift and standard deviation for V_t and I_t. Using these values and a discount rate of $\rho = 0.05$, β is 2.1 and the option value multiplier, $h^* = \frac{\beta}{\beta - 1}$ is 1.8. This implies that the present value of energy savings needs to be 1.8 times greater than the initial investment cost for investment to be triggered.

Table 1: Estimated parameters (standard errors in parenthesis)

α_V	0.0019	(0.0000)	monthly
α_I	-0.0403	(0.0120)	annual
σ_V^2	0.0007	(0.0000)	monthly
σ_I^2	0.0017	(0.0131)	annual

4.2   Critical Values for V and Adoption Time

Using the estimated drift and variance terms and starting values for V_t and I_t, we run 10,000 realization of V_t and I_t over a 40-year period. Figure 1 shows the median of realizations of V_t, I_t, and I_t multiplied by the option value multiplier. Energy savings and installation cost are expressed in per kW installed capacity. Energy savings depend on energy output per kW installed capacity and electricity prices. We generate values of V_t using an initial price of $P_t^E = \$0.146$ per kWH [4] and three levels of energy output corresponding to high (V_t^H), moderate (V_t^M) and low (V_t^L) estimates of energy output from solar PV. As discussed in the data section, the mean energy output estimate for solar PV installations in Massachusetts is 1,100 kWh per year, which we use as our central estimate. We also consider values of 1,400 kWh per year as the high estimate and 800 kWh per year as the low estimate. We use an initial installation cost of \$6487 and rebate of \$3473 to calculate the initial investment cost of \$3014 per kW installed capacity.

Table 2 shows the value of V_t that will trigger investment under the NPV and option value decision rules, as well as the timing of adoption. For moderate energy output, the household would adopt in 18 months under the NPV rule. However, using the option value decision rule, adoption will not occur until 146 months. Under the high energy output case, adoption occurs immediately under the NPV rule because the $V_{NPV} = 3197$ is greater than the initial installation cost of \$3014. In contrast, under the option value rule, adoption will not occur until after 8 years.

4.2.1   Rate of Adoption Over Time

Figures 2 and 3 show the adoption rate over time for NPV and option value decision rules, given different levels of energy output. Using the NPV rule, 100% adoption is met immediately under the high energy output scenario. For moderate energy output and low energy
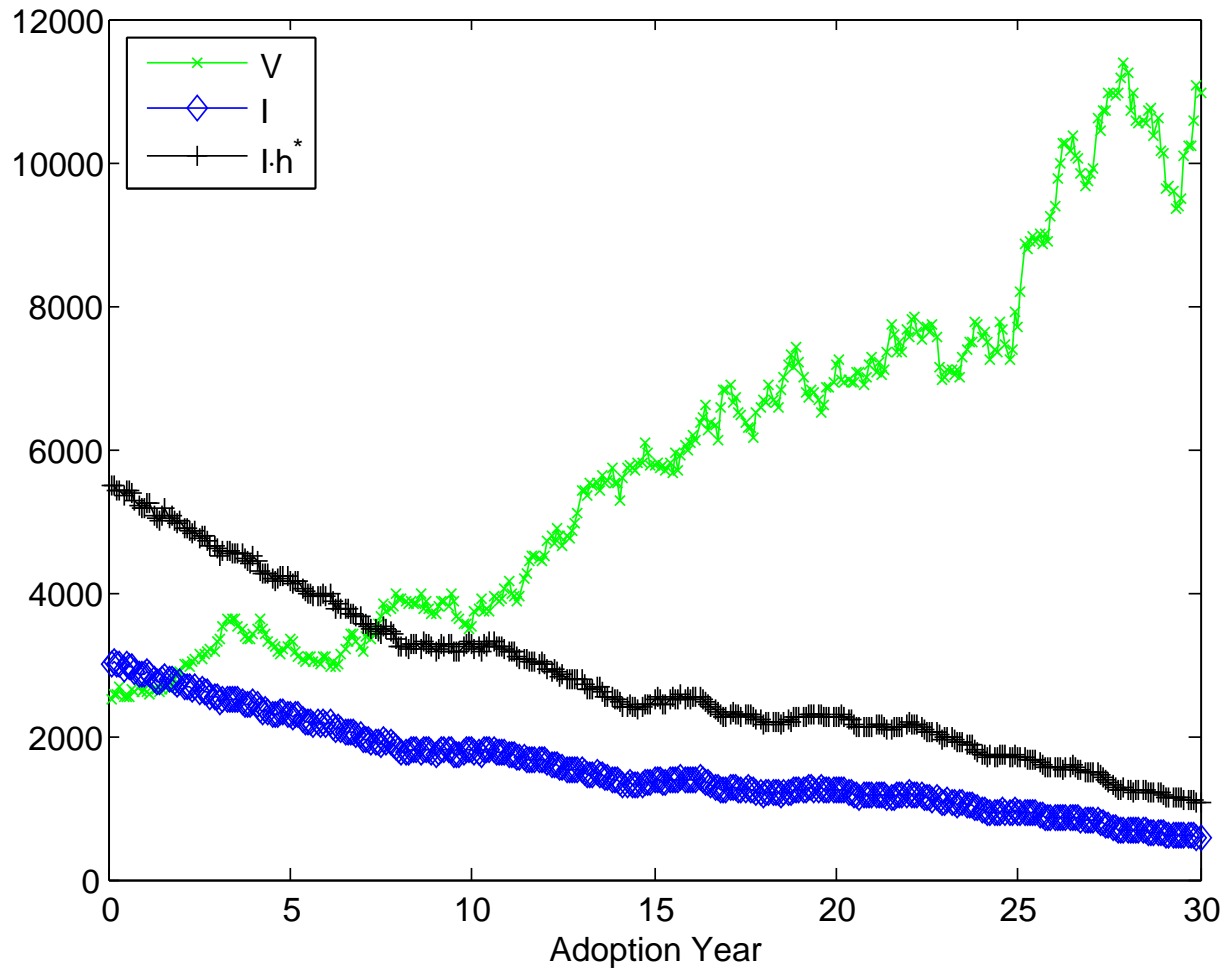
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[4]Average electricity price in MA for 2010.

Figure 1: Trends in V_t and I_t

Table 2: Critical values of V ($ per KW installed capacity) and median adoption time (years.months)

Energy Output	V_{NPV}	T^*_{NPV}	V^*	T^*
Low	2215	7.7	2691	17.7
Moderate	2747	2.6	3341	12.1
High	3196	0.1	3932	8.3

output levels, adoption rates at year 5 are around 80% and 20% respectively. In contrast, under the option value adoption rule, adoption rate is below 0.05% after five years for low and moderate energy output, and 20% for high energy output. Figure 4 compares adoption rates for the two decision rules. Under NPV, full adjustment is almost reached in year 10, while adoption rate is only at 30% under the option value rule. The figures above show the significant effect of uncertainty in delaying adoption of solar panels.

4.3   Policy Implications

The effect of uncertainty in delaying adoption has implications for which policies would be more effective at incentivizing adoption. To examine the effect of various policy options on adoption rates under the NPV and option value framework, we simulate several policy scenarios.

In the no rebate scenario, we assume that there are no rebates so that the initial investment cost faced by households is equal to the installation cost. The drift and variance of investment cost is set equal to the variance of installation cost (rather than the combined variance of installation cost and rebates). State rebates have been experiencing a downward trend from 2008-2013, a period that started with ambitious goals to increase solar adoption in the state. As adoption rates have gone up, state subsidies have been declining.

Revenue from SRECs could also constitute a significant benefit from owning a solar PV system. Annual revenue from SRECs could be as high as $500 per MW of electricity produced for a given term (typically 10 years). However, the price of SRECs is variable, and could drop to as low as $200. The SREC scenarios show cases where there is no rebate but there is an SREC market, and SREC prices are $500 per MWh and $200 per MWh elecricity production. The variance of benefits are doubled (relative to variance of installation cost) in these scenarios to account for swings in SREC prices. We also simulate a case where both rebates and SRECS are present. The variance of benefits are assumed to be double the combined variance of installation costs and rebates. The final scenario is the carbon subsidy scenario, where owners of solar PV systems are given a subsidy for the GHG emissions reductions relative to other sources of electricity such as oil, natural gas and coal. Weisser (2007) reports that the mean GHG emissions (in g CO_2 per kWh) reported from a number of recents studies for coal, oil, natural gas, and solar PV are 1000, 800, 560 and 56 respectively. A $100 subsidy per kW installed capacity represents the case with a carbon tax of $100 per ton CO_2, moderate energy output from solar panels, and electricity from solar replacing coal. A $20 subsidy per kW installed capacity represents the case with a carbon tax of $25 per ton CO_2, moderate energy output from solar panels, and electricity from solar replacing
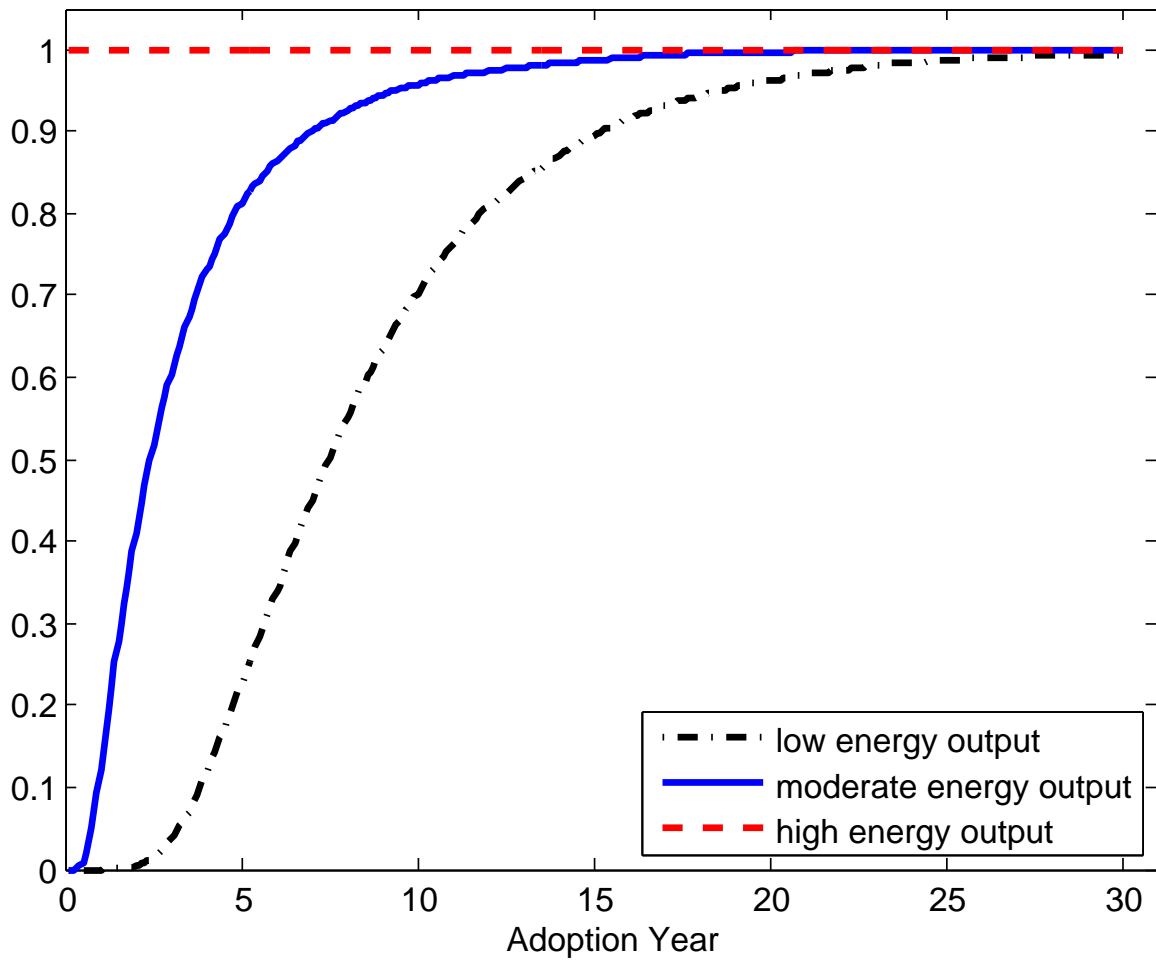
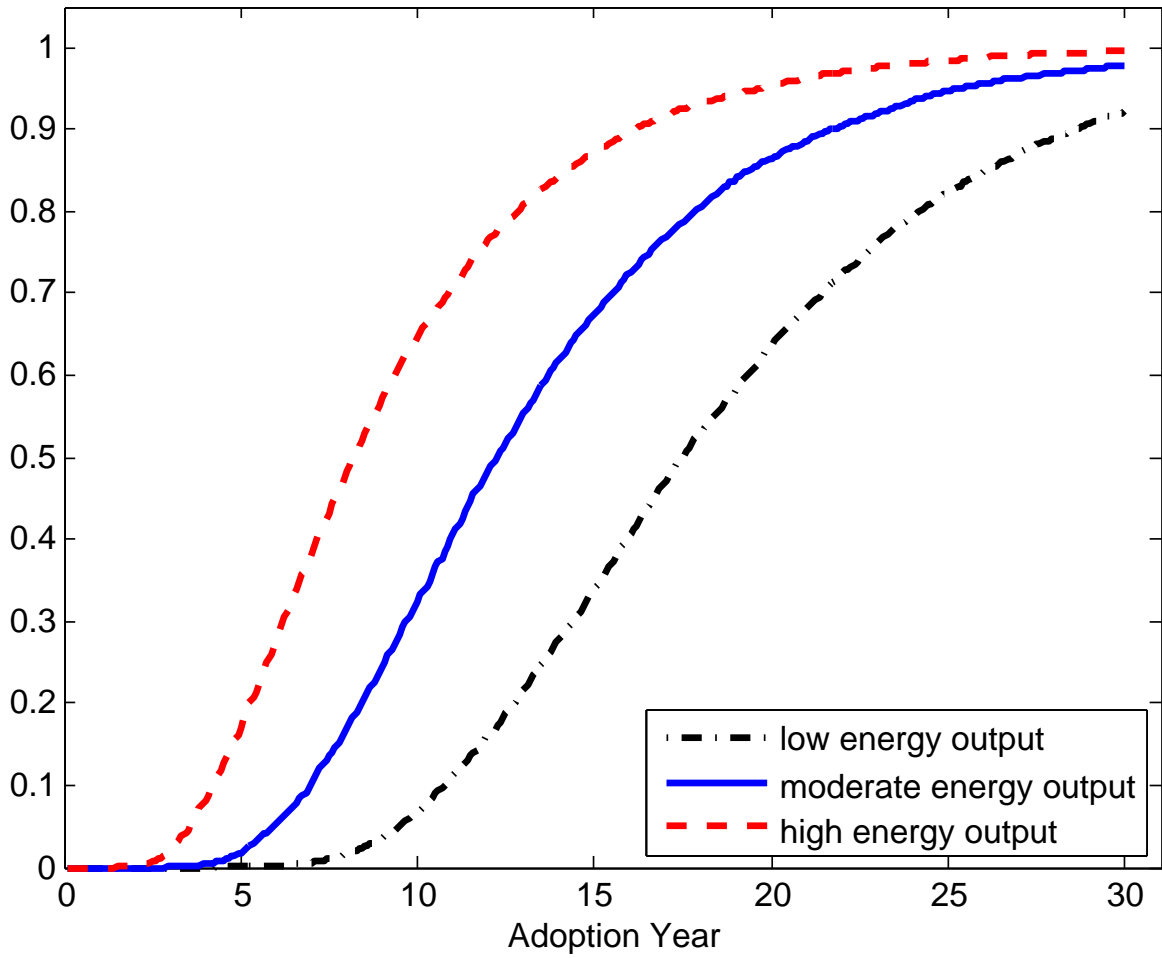Figure 2: Adoption rate for NPV decision rule

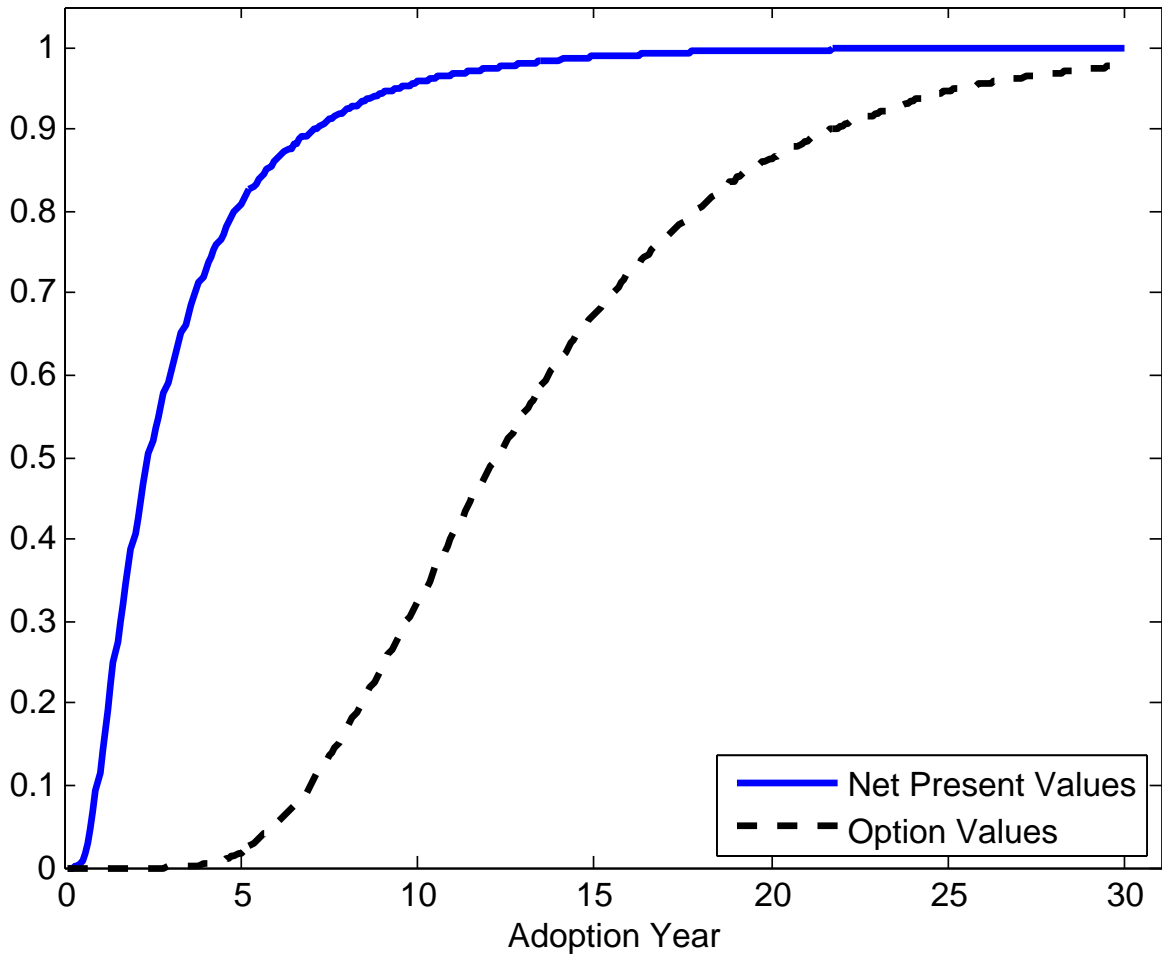Figure 3: Adoption rate for option value decision rule

Figure 4: Adoption rate for NPV and option value decision rules, moderate energy output

oil.

Table 3 shows the threshold value of net benefit and adoption time under the NPV and option value decision rules. Compared to the baseline, adoption time without rebates under NPV increases by 5-fold, while adoption time under option value more than doubles. This suggests that rebates have been effective at increasing adoption, although by a slower rate than what is expected using an analysis based on net present values. Revenue from the SREC market also shorten adoption time relative to the no rebate scenario under NPV and option value decision rules. However, the gap in adoption time between the NPV and option value decision rules is much greater, compared to the Baseline and no rebate scenarios because the added uncertainty associated with the SREC market further delays adoption under the option value framework. With both rebates and SREC market revenues present, adoption occurs immediately under the NPV rule. Under the option value rule, investment will occur immediately with SREC prices at $500 per MWh, but with payments at $200 per MWh adoption will be delayed up to 5.8 years. Under the carbon subsidy scenarios, adoption occurs earlier compared to the no rebate scenario for both NPV and option value decision rules, but the effect is marginal.

The conclusions we draw from these policy scenarios are that existing policies are effective in incentivizing the adoption of solar power; however the effect of these policies are attenuated by the effect of uncertainty in the households investment decision. Under the NPV rule, rebates reduce adoption time by 83% compared to the baseline. Under the option value rule, rebates reduce adoption time by only 53% relative to the baseline. In addition, the order of policy preference to reduce adoption time may be different. Under the NPV rule, a high SREC price by itself leads to a shorter adoption time compared to the rebate policy. However, under the option value rule, the rebate policy is preferred to an SREC price of $500 per MWh. This is because the added uncertainty with an SREC policy encourages waiting to determine if SREC prices will rise or fall.

Table 3: Impact of Policy

Policy	V_{NPV}	T_{NPV}	V^*	T^*
Baseline (Rebate)	2747	2.60	3341	12.10
No Rebate	3564	15.40	4421	25.80
SREC = $500	6426	0.42	7005	14.17
SREC = $200	4675	8.33	5503	22.42
Rebate + SREC = $500	6303	0.12	6303	0.12
Rebate + SREC = $200	4028	0.12	4452	5.83
Carbon subsidy = $100	3527	14.11	4326	25
Carbon subsidy = $20	3551	15.3	4405	25.6

5 Conclusions

In this article, we have demonstrated the effect of uncertainty in a household's decision to invest in a solar PV system. Consistent with previous literature, if households see a value to waiting until some uncertainty about future benefits and costs are resolved, adoption is

slower compared to the case where a household decides based on the net present value of the investment opportunity.

Although the market application of our model focuses on the solar PV market, the conclusions here apply to other renewable energy investments, most of which are subject to large upfront investment costs and uncertain stream of benefits that are affected by energy prices and energy output. Moreover, most types of renewable energy systems receive government incentives that reduce the net cost of adoption.

Simulation of adoption rates using parameter estimates from market data on PV installations in Massachusetts show that under the NPV decision rule that equates net present value of benefits with initial investment cost, full adoption of solar PVs assuming perfect information about the investment opportunity will occur in less than ten years. However, under the option value decision rule that equates net present value of benefits with investment cost times the option value multiplier of 1.8, adoption rate at year 10 is less than 20%.

Simulations of different policy incentives show that depending on the decision rule, a rebate that reduces initial investment cost or an annual revenue stream (that is more volatile) would be preferred. To further incentivize solar power adoption, policy makers have the option to continue providing a high level of rebates to reduce upfront investment cost. Alternatively, they can continue to tighten mandates and drive SREC prices up to provide solar PV owners with revenue to help pay off their investment. Our results suggest that rebates are more effective than an SREC market supported by mandates. Further research could explore the welfare implications of these two policies, since both policies create distortions in the market. Whether the welfare cost of these policy distortions outweigh the benefit of deriving energy from clean and domestically produced solar power is an empirical question.

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