BERKELEY LAB
Lawrence Berkeley National Laboratory

Environmental Energy Technologies Division Lawrence Berkeley National Laboratory

Incentive Pass-through for Residential Solar Systems in California

C.G. Dong[1], Ryan Wiser[2], Varun Rai[1]

[1] University of Texas at Austin, [2] Lawrence Berkeley National Laboratory

October 2014

This analysis was funded by the Office of Energy Efficiency and Renewable Energy (Solar Energy Technologies Office) of the U.S. Department of Energy (DOE) under Contract No. DE-AC02-05CH11231

SunShot U.S. Department of Energy

Presentation Structure

- Overview
- Methods
- Data
- Results
- Conclusions

Both "Structural Modeling" and "Reduced-form Regression" Approaches Are Conducted, in Parallel

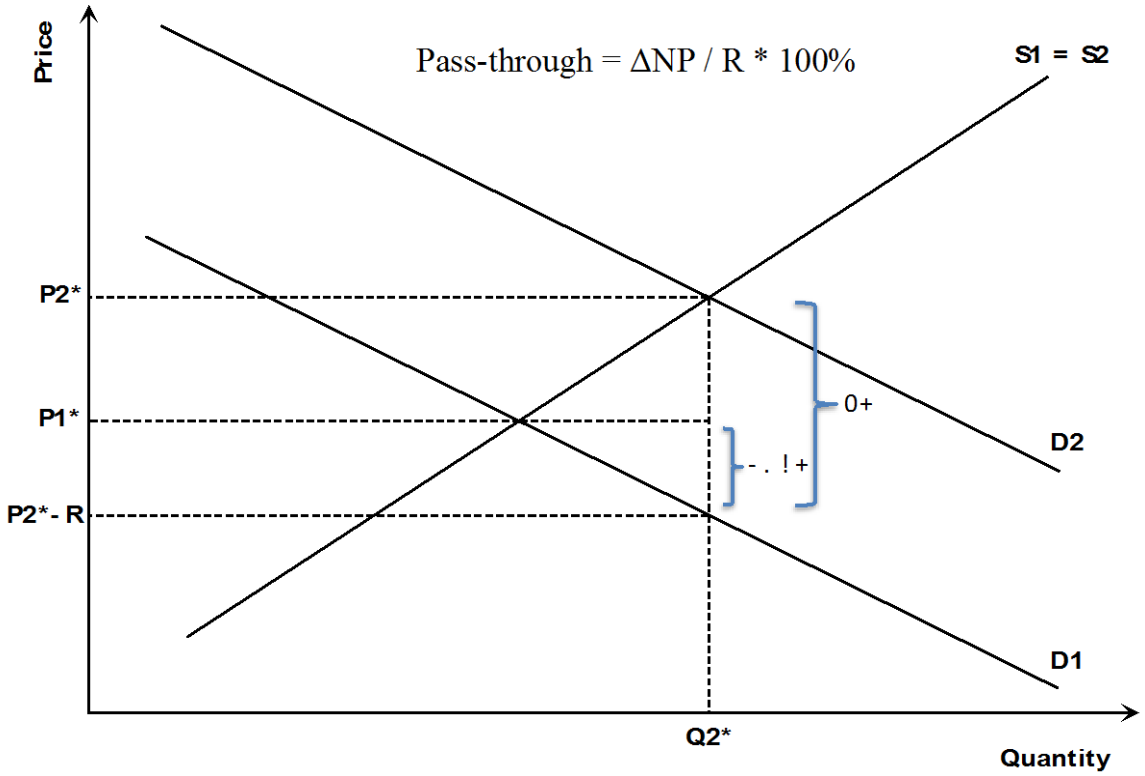
Background

- The deployment of solar photovoltaics (PV) has grown rapidly over the last decade, partly as a result of various government incentives.
- The California Solar Initiative (CSI) and its predecessor, the Emerging Renewables Program (ERP), are collectively the largest and longest running state-level incentive programs for residential PV systems in the U.S., with rebates changing over time.
- The degree to which these incentives have been passed-on to the intended recipients (PV customers, versus being retained by installers) has not been studied systematically.

Research Question and Objectives

- **Research Question:** To what degree have the financial incentives offered by the CSI and ERP been passed through from installers to PV customers ("incentive pass-through").
- **Study Scope:** Focus on incentive pass-through for CSI/ERP residential PV rebates from 2001-2012, excluding "appraised-value" third-party owned (TPO) systems: further analysis required to determine if results broadly apply to other state PV incentive programs, to other customer segments, to all TPO systems, or to all forms of financial incentives for PV (considering not only direct rebates, but also electric bill savings and federal tax incentives).
- **Implications on Program Design:** Incentive pass-through has implications for PV incentive programs, given that the goal of these programs is to improve the customer-economics of PV. Understanding incentive pass-through also illuminates the level of installer competition present in local PV markets and can suggest which types of policy designs might be most effective.

Definition: Incentive Pass-through



The introduced incentive level R in period 2 moves the demand curve from D1 to D2, and a new market equilibrium emerges at (P2*, Q2*) assuming the supply curve remains the same: S1 = S2. The net price paid by consumers in period 1 is the market price P1*, while in period 2 it is (P2* - R), so the net price change is ΔNP. Then, the pass-through rate is defined as ΔNP/R *100%.

Two Methods Applied: Structural Modeling and Reduced-Form Regression Analysis

- Both commonly used to evaluate pass-through rates by controlling for numerous variables and isolating the effects of incentive levels on system prices.
- Two approaches are complementary:
  - Structural modeling has a strong theoretical basis and can produce reliable results for relatively small markets.
  - Reduced-form regression analysis is straightforward, easy to interpret, and does not require as many structural assumptions.
- Similarity of results using both approach lends credibility and demonstrates a degree of robustness.

Method I: Structural Modeling

- Typical in the tax or subsidy incidence literature, in studies on the impact of changes in cost on price, and in market power evaluations.
- Specify the demand and supply relation at the market level (one county), then derive the pass-through rate formula.
  - Demand: $Q = Q(P, X) \qquad P = \tilde{P} + s$
  - Supply relation: $\tilde{P} + s + \theta^* P_Q Q = C_Q = MC(Q, Z)$
  - Pass-through rate: $-\frac{d\tilde{P}}{ds} = \frac{1}{1 + \theta^*(1 + A + E)}$

$$A = -\frac{C_{QQ}}{\theta^* N \cdot P_Q} \quad \text{and} \quad E = -P_{QQ}\frac{Q}{P_Q}$$

- Estimate parameters involved in the pass-through rate formula, and estimate pass-through rate for each county.

Method II: Reduced-form Regression Analysis

- Run statewide regression of system-level net price (i.e. post-rebate) on rebate levels, along with other control variables and fixed effects.

$$(NetPrice)_{ijgt} = \beta_0 + \beta_1(Rebate)_{it} + \beta_2 X_{it} + \beta_3 Y_{jt} + \beta_4 Z_{gt} + \beta_5(Cost)_t + \varepsilon_{ijgt}$$

i – a system; j – an installer; g – a zip code; t – a time interval

X – system characteristics; Y – installer experience and density; Z – demographics

Cost – hardware cost and labor cost

ε – zip code and monthly fixed effect, and idiosyncrasies

Note: $(-\beta_1)$ x 100% is then the pass-through rate in percentage terms

- Also run the same regression for each of the larger counties in California to obtain county-specific pass-through rates.

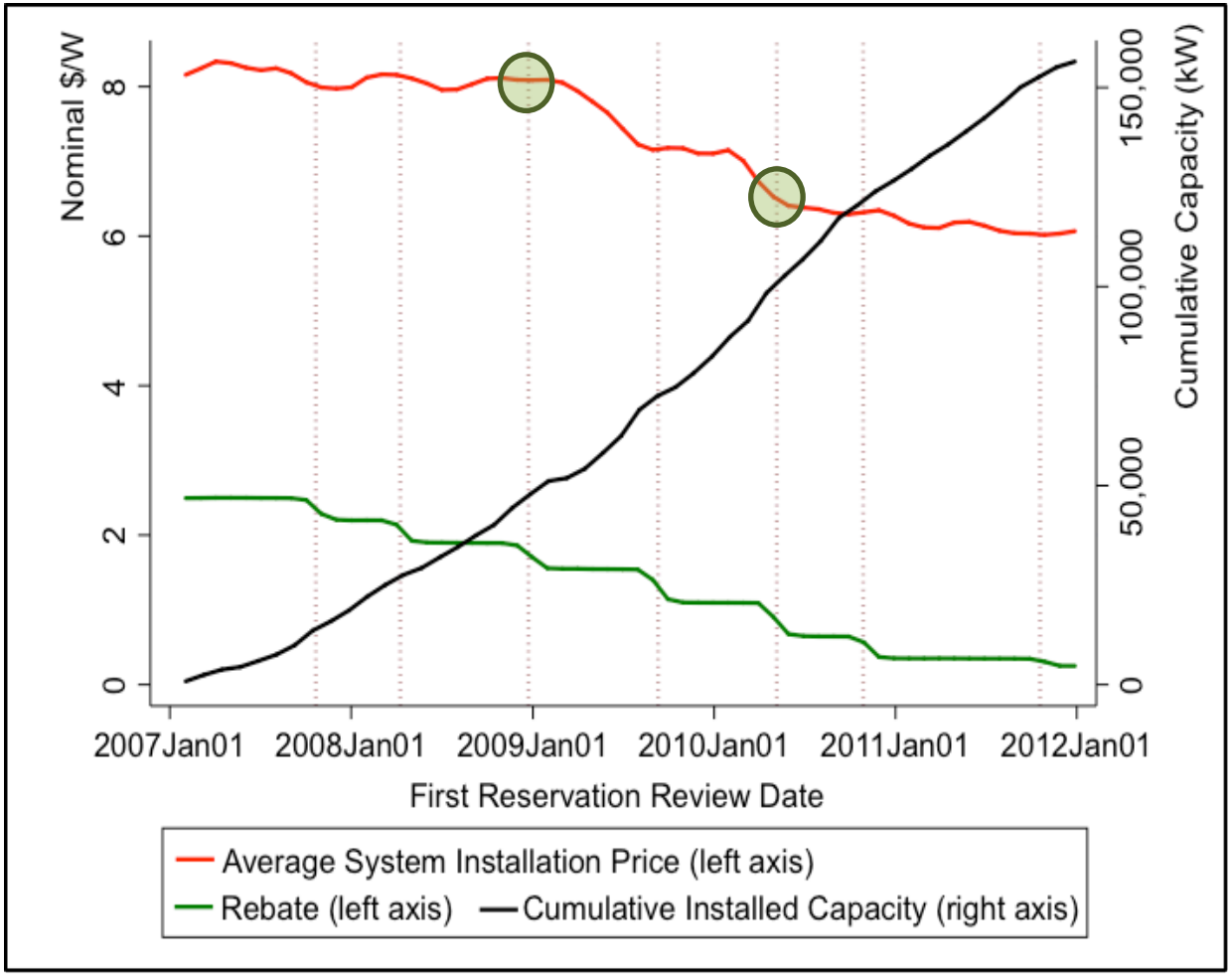
Data Sources

- Dataset leveraged LBNL's Tracking the Sun (TTS) VI report, and complemented it with wage data from BLS and social demographic data from the Census Bureau.
- TTS data contain PV system information on:
  - price and rebate level; date of installation; system size; geographical location; customer segment (residential, commercial, or other); technology type (module and inverter manufacturer and model, tracking system vs. fixed-tilt); hardware cost
  - can also infer BIPV vs. rack-mounted PV; thin film vs. crystalline modules; Chinese made vs. non-Chinese made modules; and micro-inverters vs. central or string
  - can further calculate county-level installer experience, county-level installer density
- Various screens applied to select data for use in this analysis:
  - focus on <10 kW systems from CSI and ERP installed from 2001-2012
  - remove outliers: extreme cost or rebate per W, battery back-up, self-installed
  - third-party owned systems installed by integrated companies also excluded, as prices reported in these cases are likely to represent appraised value (not installed price)

Data Showcase: PG&E within CSI

First circle tends to show complete pass-through, because the pre-rebate price did not change before and after the rebate step-down (net price increased by the same amount of rebate level reduction).

Second circle tends to show incomplete pass-through, since the pre-rebate price declined at same time as the rebate.



Summary Statistics: Structural Modeling

We averaged all the variables to the county-level for those 49 counties in California with the longest PV installation history (>= 30 months).

Variables (County Level)	Mean	Std. Dev.	Min	Max	N
Installation price (real $/W)	8.50	1.94	2.71	21.48	5,677
Net price (real $/W)	6.19	1.23	0.20	18.24	5,677
Rebate (real $/W)	2.32	1.44	0.12	6.50	5,677
Monthly installation (kW)	80.36	150.3	0.58	1,799	5,677
TPO share	0.10	0.21	0	1	5,677
Summer season	0.50	0.50	0	1	5,677
# of zip codes	8.14	11.01	1	102	5,677
# of installers	6.92	8.89	1	69	5,677
Financial crisis year	0.09	0.29	0	1	5,677
Hardware cost (real $/W)	5.68	1.27	2.71	7.93	5,677
Labor cost (in $100,000)	2.85	0.80	1.49	6.64	5,677

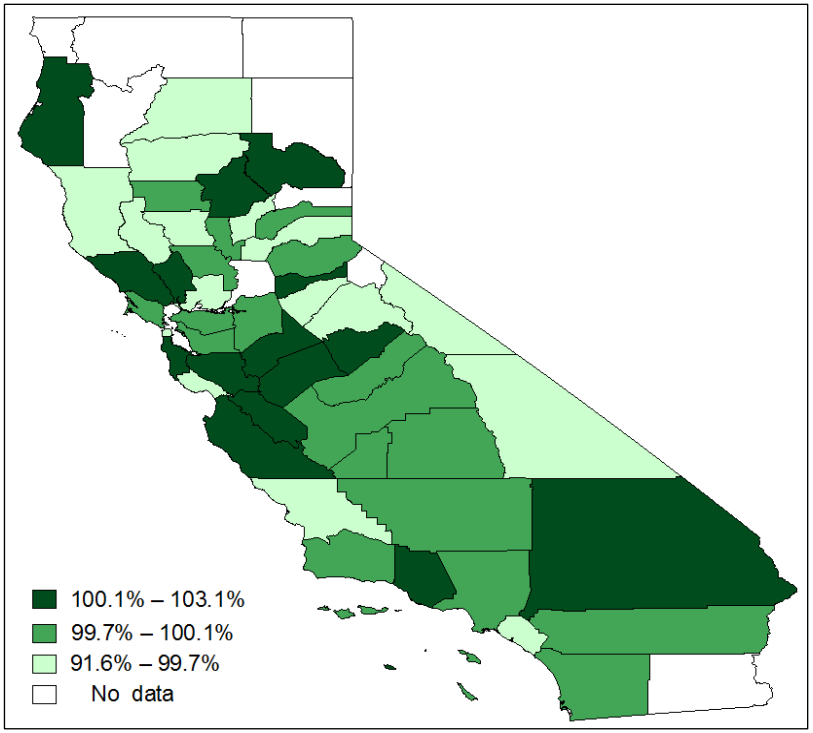
Summary Statistics: Reduced-form Regression

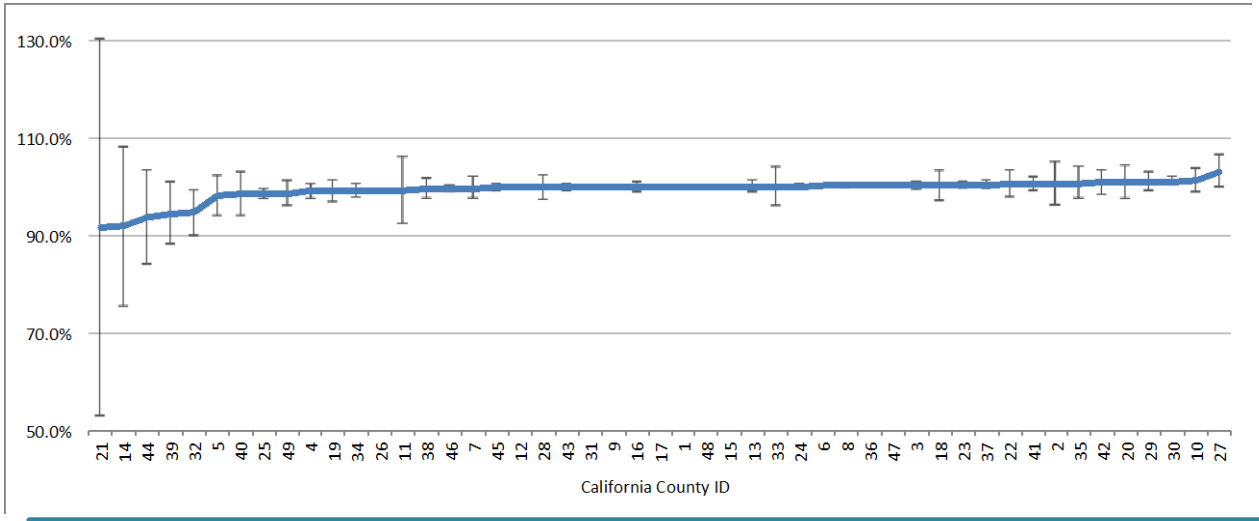
Variables (System Level)	Mean	Std. Dev.	Min	Max	N
Net price (real $/W)	6.211	1.865	2.4E-06	20.697	92,545
Installation Price (real $/W)	7.762	2.225	1.564	25.462	92,545
Rebate (real $/W)	1.551	1.304	0.074	8.825	92,545
System size (kW)	4.737	2.068	0.066	10	92,545
System size squared (kW^2)	26.715	22.046	0.004	100	92,545
Residential system	0.990	0.098	0	1	92,545
Commercial system	0.006	0.080	0	1	92,545
Other customer segment	0.003	0.057	0	1	92,545
TPO	0.235	0.424	0	1	92,545
China module	0.175	0.380	0	1	92,545
Micro-inverter	0.142	0.349	0	1	92,545
Thin-film	0.026	0.160	0	1	92,545
Building-integrated (BIPV)	0.003	0.059	0	1	92,545
Tracking system	0.001	0.025	0	1	92,545
Installer experience	0.325	4.475	0	195.84	92,545
Installer density	0.271	0.229	0	2.542	92,545
Hardware cost ($/W)	4.876	1.302	2.709	7.933	92,545
Labor cost (in $100,000)	3.264	0.894	1.488	6.640	92,545

Social demographic variables are also included, but are not reported here.

Results: Structural Modeling

- County-level pass-through rates vary from 92% to 103%, with an average rate at 99%.
- The 95% confidence intervals are generally narrow, though wider for smaller counties.





Reduced-form Regression Results: Statewide

Pass-through rate coefficient

State-level pass-through rates of 86% to 103%, depending on regression specification.

System characteristics

Installer characteristics

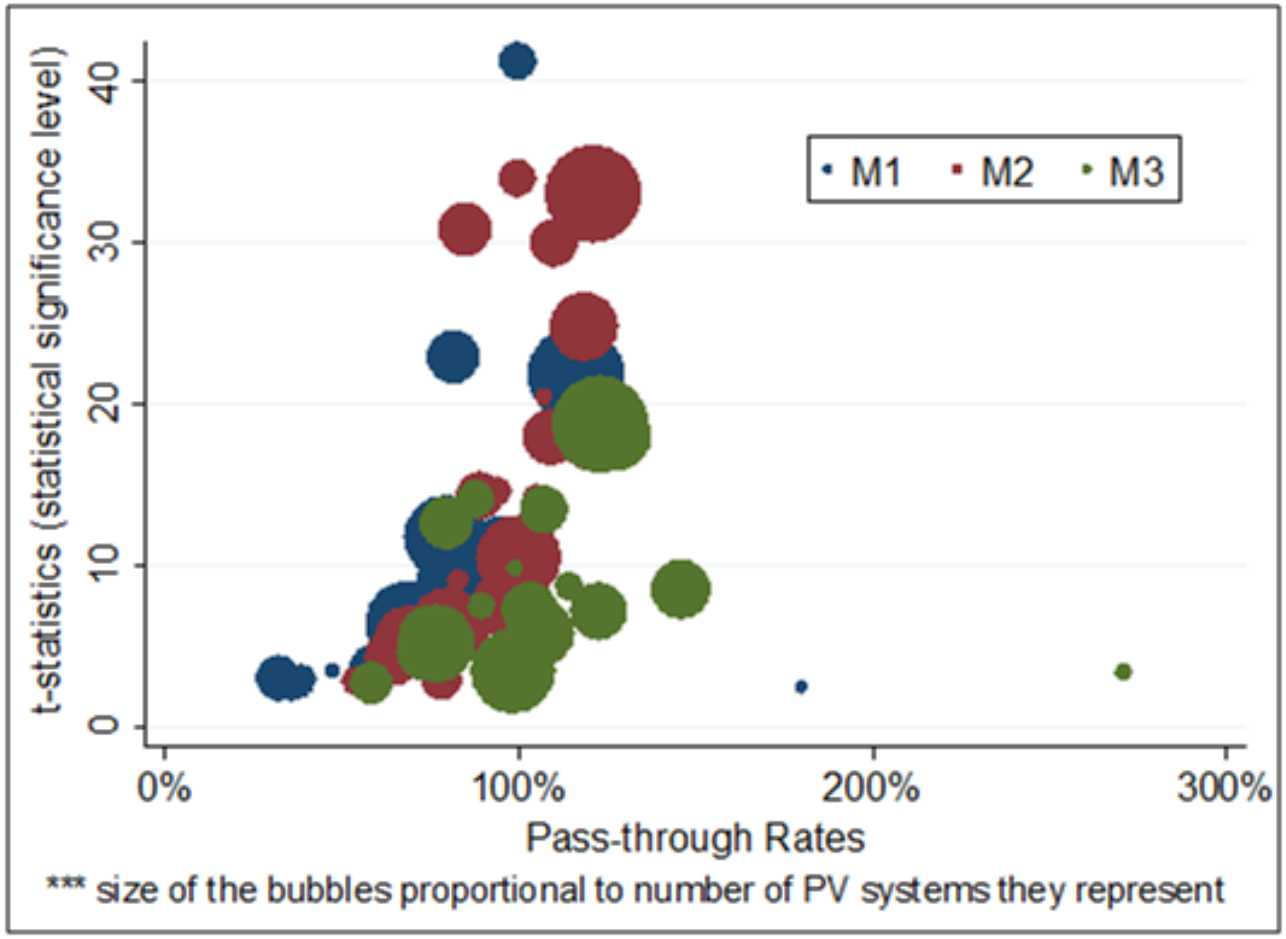
Cost components

Model summary

DV: net price (real $/W)	M1	M2	M3
Rebate	**-0.940*** (0.025)**	**-0.855*** (0.038)**	**-1.033*** (0.037)**
System size	-0.942*** (0.035)	-0.921*** (0.033)	-0.950*** (0.050)
System size squared	0.066*** (0.003)	0.064*** (0.003)	0.066*** (0.004)
Commercial systems	0.038 (0.099)	0.096 (0.099)	0.133 (0.196)
Other customer segments	0.735*** (0.133)	0.706*** (0.133)	0.760*** (0.267)
TPO	-0.323*** (0.029)	-0.299*** (0.036)	-0.267*** (0.044)
China module	-0.546*** (0.022)	-0.532*** (0.027)	-0.634*** (0.035)
Micro-inverter	0.458*** (0.032)	0.516*** (0.035)	0.476*** (0.053)
Thin-film	0.400*** (0.057)	0.225*** (0.057)	0.284*** (0.100)
Building-integrated (BIPV)	0.423*** (0.134)	0.384*** (0.118)	0.352 (0.262)
Tracking system	1.288*** (0.288)	1.234*** (0.306)	1.640*** (0.577)
Installer experience	-0.010*** (0.003)	-0.013*** (0.003)	-0.009* (0.006)
Installer density	-0.197** (853.9)	-0.794*** (661.5)	0.156 (4785.8)
Hardware cost	0.938*** (0.019)		
Labor cost	-0.151*** (0.033)		
Social-demographic variables	Yes	Yes	Yes
Zip code fixed effects	Yes		
Monthly fixed effects		Yes	
Zip code × month fixed effects			Yes
R2	0.322	0.297	0.464
N	92,545	92,545	92,545

Reduced-Form Regression Results: Largest Counties

- Range of 68% to 122% for county-level pass-through, when focusing on inner 10th-90th percentile of results.
- Weighted-average county-level pass-through of 95%.



Conclusions

- We find a high overall historical pass-through rate for the California residential PV rebate programs, though with some level of variation among counties.
  - The structural-modeling approach estimates county-level pass-through rates that vary from 92% to 103%, with a mean value of 99%.
  - The reduced-form regression analysis tends to find consistent results, with average pass-through rates ranging from 86% to 103% at the state level, and with a county-level average pass-through rate of 95%.
- These results suggest that installers in California considered CSI and ERP rebates as outside factors when making pricing decisions, and suggest a reasonably competitive PV installation market and, at least from the perspective of incentive pass-through, a well-functioning subsidy program.

Possible Areas of Future Research

- Companion research will be published in the near future that estimates pass-through rates based on time and geographic discontinuities in rebate levels: results are consistent with those reported here, further demonstrating robustness.

- However, these results do not necessarily apply outside of California, to other customer segments, to other PV incentives such as the federal ITC or utility bill savings (or the aggregation of all incentives, via “value-based pricing”), or to appraised-value TPO systems: further research is warranted along all of these lines.

- Further research is also warranted to better understand any heterogeneity in pass-through rates among different installers.

For more information…

Download the full report, a 2-page fact-sheet, and this briefing:

http://emp.lbl.gov/publications/incentive-pass-through-residential-solar-systems-california

Contact the authors:

C.G. Dong cgdong@lbl.gov
Ryan Wiser rhwiser@lbl.gov
Varun Rai varun.rai@mail.utexas.edu

Thanks to the U.S. DOE's Solar Energy Technologies Office (SunShot Initiative) for their support of this work