Subsidies and time discounting in new technology adoption: Evidence from solar photovoltaic systems.

De Groote & Verboven (2019), AER

Environmental Reading Group session 20

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Research Question

- Compare two subsidy program to incentivize residential solar PV installation:
    - **one-off investment cost subsidy (US)** v.s. **future production subsidy up tp 20 years (EU)**
- Why important?
    - Public expenditure savings.
    - Households's welfare (as public cost will be transmitted to consumers).
    - Effect of subsidy policy (whether it motivates green technology adoption as wished)

Background

- This paper uses data from Green Current Certificate Program (GCC), almost through subsidies on future electricity production, running in Belgium from 2006-2012.
  - Upfront investment subsidy (10%).
  - Tax credit (40%) and tax cut (VAT21%6%).
  - GCC subsidy, pay fixed price to power generation.
  - savings on your own electricity purchase.
- The purpose of this generous program is to motivate household to install rooftop solar PV.

Datasets

Household-level data in Flanders of Belgium from May 2009 to December 2012 (44 months):

- Time of adoption.
- Location.
- Types of solar PV: 2kw,4kw,6kw,8kw,10kw.
- Household characteristics (9182 local markets and 295 households per).

Dynamic Choice Model

- In period t, household i may choose $j \in \{0, 1, 2, ...J\}$
  - $j = 0$: no installment.
  - $j = 1, ..., J$: PV with different capacities. selection means termination.
- In period t, household i obtains i.i.d. random taste shock $\varepsilon_{i,j,t}$, following type I extreme value distribution.
- Condition value of alternative j in period t is:

$$v_{i,j,t} = \delta_{j,t} + \underbrace{\mu_{i,j,t}}_{heterogenity} \tag{1}$$

Dynamic Choice Model (Cont.)

- Objective Function: $\max_j v_{i,j,t} + \varepsilon_{i,j,t}$.
- $j > 0$. Decomposition of $v_{i,j,t}$ (first assume no heterogeneity $\mu_{i,j,t} = 0$):

$$v_{i,j,t} = \delta_{j,t} = x_{j,t}\gamma - \alpha p_{j,t} + \xi_{j,t} \tag{2}$$

$x_{j,t}$: fixed effect of alternative j, $p_{j,t}$: price, $\xi_{j,t}$: unobserved quality.

Dynamic Choice Model (Cont.)

Decomposition of price $p_{j,t}$,

$$p_{j,t} \equiv p_{j,t}^{IVV}(\beta) - \frac{1-(\beta^G)^{R_t^G}}{1-\beta^G} p_{j,t}^{GCC} - \frac{1-(\beta^e)^{R^E}}{1-\beta^E} p_{j,t}^{EL} \tag{3}$$

$$p_{j,t}^{IVV}(\beta) = p_{j,t}^{GROSS} - \sum_{\tau=1}^{4} \beta^{12\tau} taxcut_{j,t}^{\tau}$$

$$\beta^G = (1-\lambda)(1-\pi)\beta$$

$$\beta^E = (1-\lambda)(1+\theta)\beta$$

β monthly discount factor; λ depreciate rate; θ real electricity price; π inflation rate.

Dynamic Choice Model (Cont.)

$j = 0$.

$$v_{i,o,t} = u_{0,t} + \beta E_t \underbrace{\bar{V}_{t+1}}_{\text{Real Option of Waiting}} \tag{4}$$

as $\varepsilon_{i,j,t}$ follows type I extreme value distribution,

$$\bar{V}_{t+1} = 0.577 + \ln \sum_{j=0}^{J} exp(\delta_{j,t+1}) \tag{5}$$

Dynamic Choice Model (Cont.)

Choice Probability = Market Share

$$S_{j,t} = s_{j,t}(\delta) = \frac{exp(\delta_{j,t})}{\sum_{j=0}^{J} exp(\delta_{j,t})} \tag{6}$$

Two tricks

1. No assumption of household's expectation. Rewrite expected value as true value minus a bias.

$$E_t \bar{V}_{t+1} = \bar{V}_{t+1} - \eta_t \tag{7}$$

2. Berry Approach: market share inversion. For $j = 1, \dots, J$

$$\begin{aligned} \ln(S_{j,t}/S_{0,t}) &= \delta_{j,t} - \delta_{0,t} \\ &= (x_{j,t} - \beta x_{1,t+1})\gamma - \alpha(p_{j,t} - \beta p_{1,t+1}) + \beta \ln S_{1,t+1} + e_{j,t} \end{aligned} \tag{8}$$

where $e_{j,t} = \xi_{j,t} - \beta(\xi_{1,t+1}) - \eta_t$. The part in red is estimating equation.

Heterogeneity

$\mu_{i,j,t} \neq 0 \Rightarrow \mu_{m,j,t} = w_{j,t}\Lambda D_m.$

$$s_{j,t}(\delta) = \frac{exp(\delta_{j,t})}{\sum_{j=0}^{J} exp(\delta_{j,t})} \tag{9}$$

$$\Rightarrow s_{m,j,t}(\delta) = \frac{exp(v_{m,j,t})}{\sum_{j=0}^{J} exp(v_{m,j,t})} \tag{10}$$

then to include micro-moments indicate local market heterogeneity.

Regression Results (aggregate)

	Static (1)		Dynamic (2)		+ Micro-moments (3)	
Price sensitivity in 10^3 EUR $(-\alpha)$	-0.318	(0.074)	-0.470	(0.098)	-0.604	(0.100)
Monthly discount factor (β)	0.9886	(0.0016)	0.9884	(0.0025)	0.9884	(0.0024)
Annual interest rate in % $(r = \beta^{-12} - 1)$	14.82	(2.28)	15.09	(3.43)	15.00	(3.42)

Regression Results (micro-moments)

			Local market fixed effects included	
Local market variables (Λ)				
Interactions with constant				
Interactions with capacity difference				
Pop. density (10^4 inhab/m^2)			−0.689	(0.029)
Average house size			0.057	(0.009)
Average household size			0.124	(0.016)
Average house age (decades)			0.011	(0.002)
Median income (10^4 EUR)			−0.066	(0.030)
Percentage homeowners			−0.075	(0.038)
Percentage higher education			−0.128	(0.041)
Percentage foreign			0.383	(0.040)
Interaction with price				
Median income (10^4 EUR)			0.049	(0.007)
Observed macro-moments ($J \times T$)	220	220	220	
Observed macro-moments ($M \times J \times T$)	0	0	935,440	

Counterfactual (PV life expectancy)

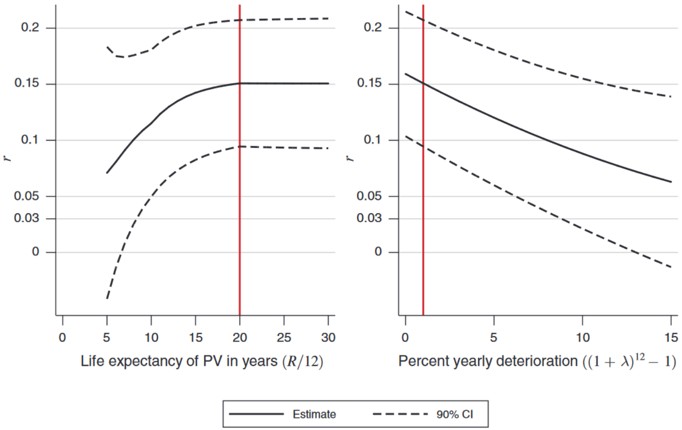


FIGURE 6. ESTIMATED IMPLICIT INTEREST RATE UNDER DIFFERENT INVESTMENT ASSUMPTIONS

Counterfactual (Commitment Period)

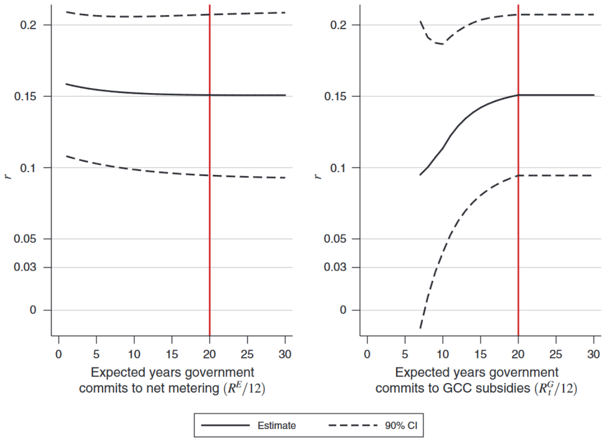
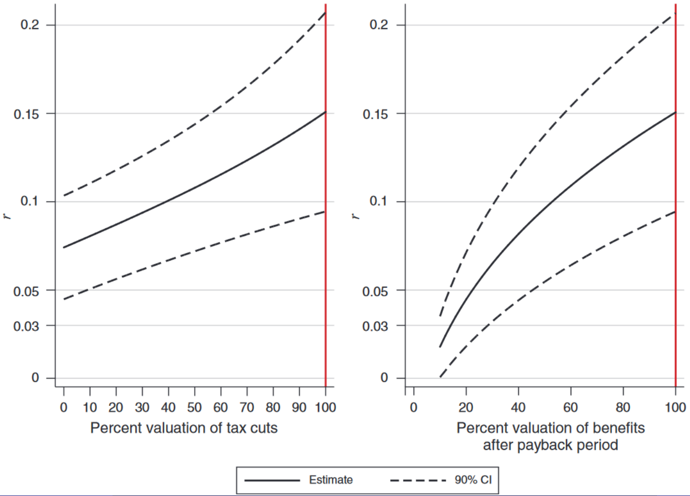


Figure 7. Estimated Implicit Interest Rate under Different Beliefs for the Duration of Goverment's Commitments

Counterfactual (Myopia)



Counterfactual (Upfront Investment)

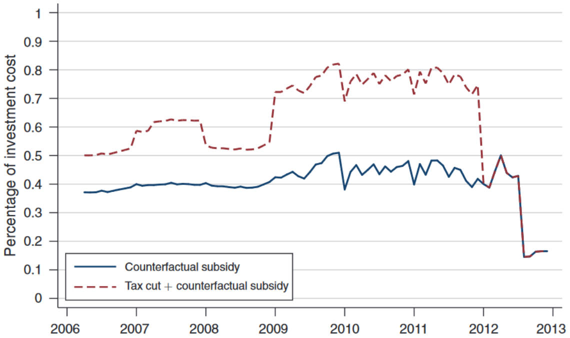


Figure 10. Counterfactual Investment Subsidy

Take-away

To incentivize household PV installment, production subsidy is much more expensive than upfront investment subsidy (almost **double the cost**) as consumers discount futures' revenue at a real discount rate (15%) much more than interest rate (around 3%).

Reference

De Groote, O., & Verboven, F. (2019). Subsidies and time discounting in new technology adoption: Evidence from solar photovoltaic systems. American Economic Review, 109(6), 2137-2172.