The Effect of Future Financial Benefits on PV Adoption - Evidence from Belgium

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Motivation

- The energy transition requires immense investments from households: around €151-212 billion annually for the next three decades (€-2015) (EC, 2019).
- For a household, the decision of whether and when to invest in an energy-related technology (heat pumps, EVs, solar panels) is complex due to factors such as **future payoffs**, **uncertainty** and **lack of awareness/salience** on benefits.

- Can we say more about the importance of these factors for energy-related investments of households?

→ We take a look at the effect of different incentive schemes for photovoltaic (PV) systems on adoption patterns in Flanders and Wallonia with an econometric model.

→ Comparing the effectiveness of incentive schemes give insight on the importance of factors and optimal design of incentives.

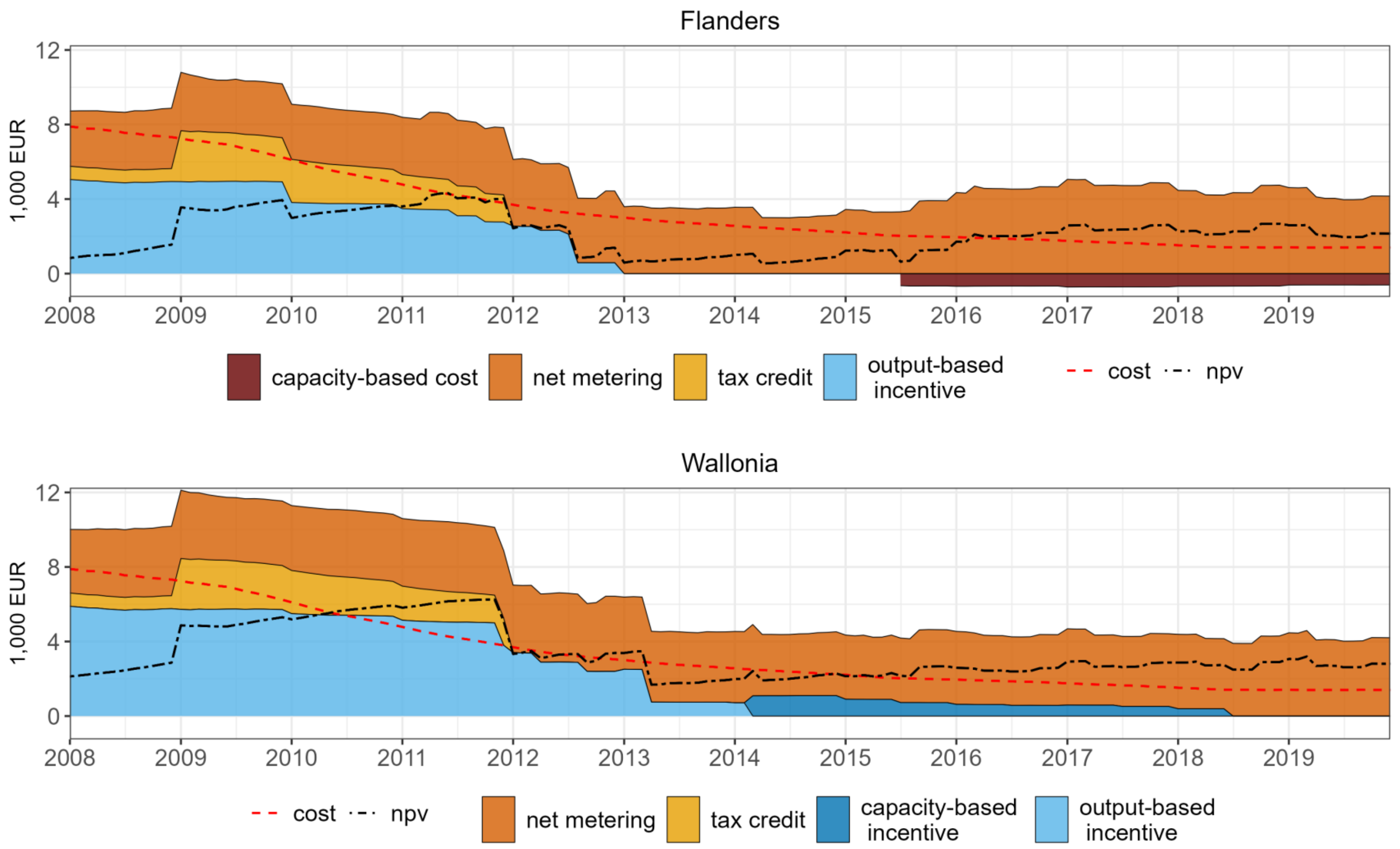
Incentive schemes with Future Financial Benefits in Belgium

- **Output-based (Green certificates)**: Fixed yearly compensation (MWh) of produced electricity for a guaranteed time span (Green certificate scheme) (2006-2014).
- **Net-metering (cost saving):** Grid off-take (excess consumption) and injection (excess production) are netted on an annual basis, varies by regional electricity price (active for the whole sample period).
- **Capacity-based:** Yearly compensation (readjusted, 5 year span) for each kW of installed capacity in Wallonia (up to 3kW; 2014-2018).
- **Capacity-based cost:** yearly fee per kW of capacity in Flanders (since 2015).

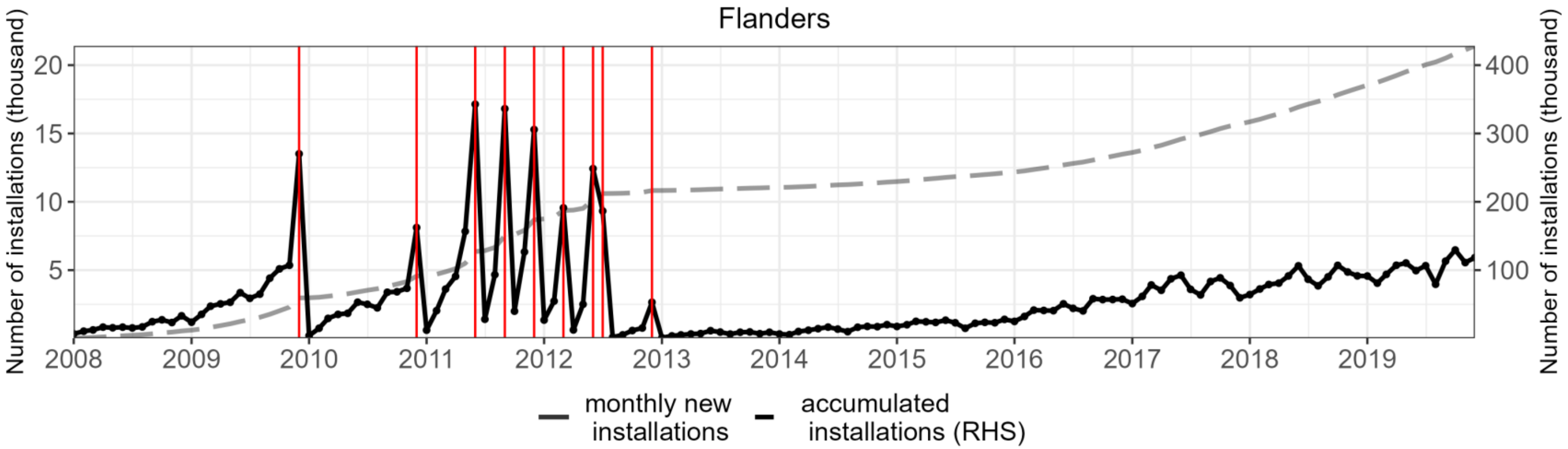
→ We calculate the present value for the separate incentive schemes in each month of investment and ...

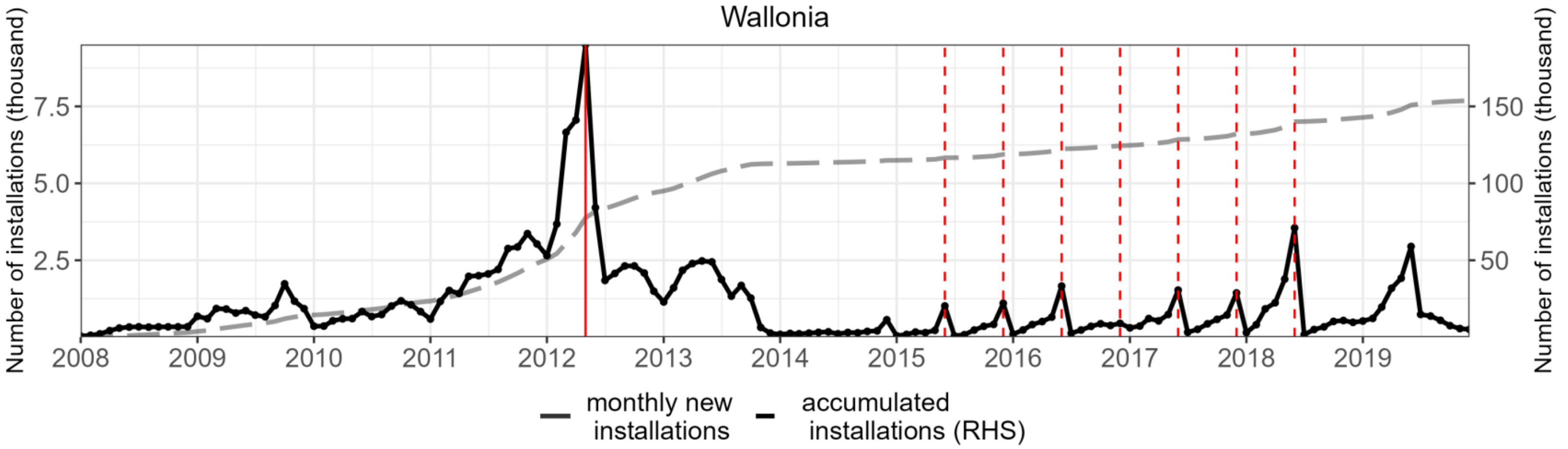
...assess their effectiveness with a statistical model.

Discounted benefits per kW made PV investment worthwhile



PV adoption follows changes in PV incentives





Contribution and research question

- The literature finds a positive effects of (early) adoption patterns to financial benefits for PV in the residential sector:
  - **Effectiveness (reduced-form):** upfront rebates , feed-in-tariffs, electricity prices.
  - **Cost-efficiency (structural models):** capacity-based upfront vs. output-based, optimal incentive design.
- Until now, directly comparing the effectiveness of different incentive schemes with future financial benefits has not been done.
- A comparison is relevant, because it can give insights on the importance of differences in incentive design and decision factors.
- **How effective are different incentive schemes in increasing the number of PV installations and their average size?**

Data

- Monthly data, aggregated at the municipality (zip) level (262 Wallonia, 300 Flanders), 2008-2019: ~580,000 installations and ~80,000 observations.
- **Dependent Variable** *variation by month and zip* : number and average capacity size of new PV installations in the residential sector (≤10kWp) (source: VEKA, SPW)
- **Main explanatory variables** *variation by month and region* : discounted net-benefits and discounted separate benefits per kW (source: market reports VREG & CWaPE).
- **Control variables** *variation by year and zip:* median income deflated (source: statbel), sociodemographics and building characteristics (source: Walstat/provincies.incijfers)

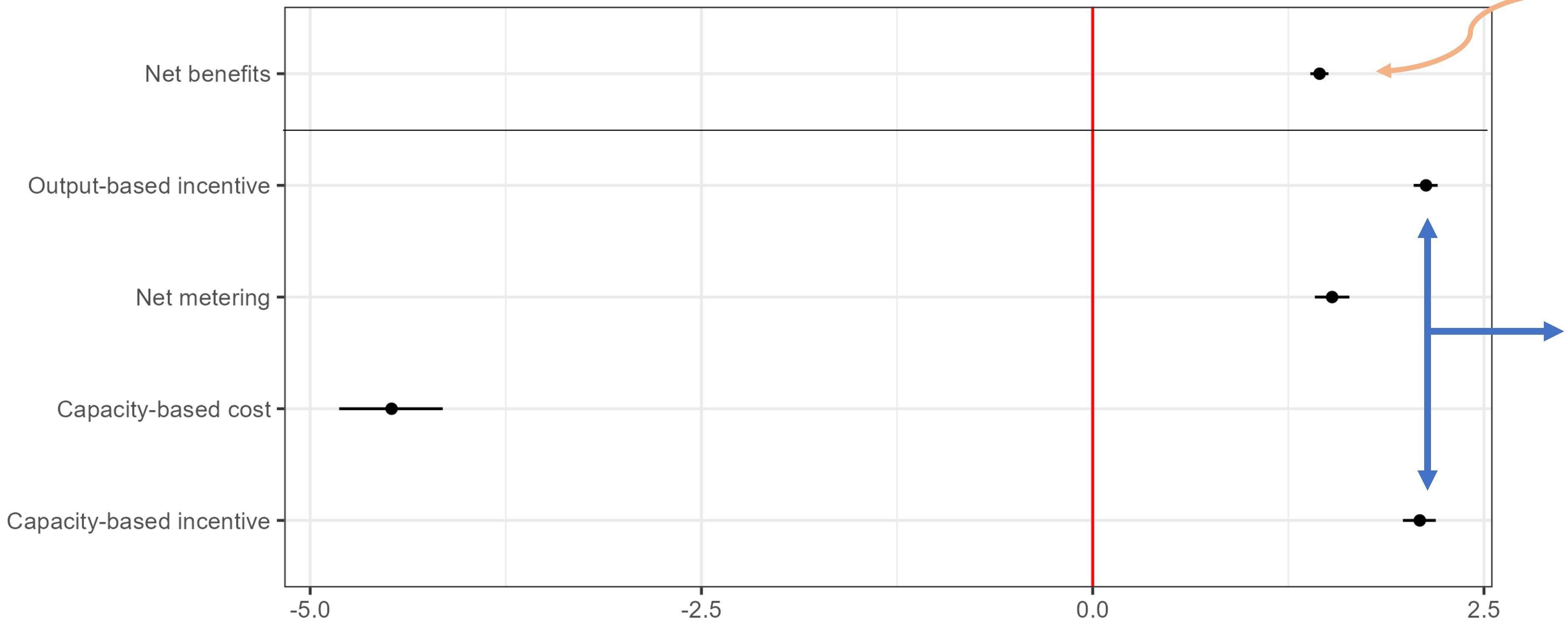
Empirical Methodology

- Regress PV adoption (PV count or average capacity size) on net benefits/each benefit separate, control variables, municipality and time fixed effects.
- Regression equation:

$$PV_{it} = \sum_{j \in J} \beta^{j} \cdot b_{rt}^{j} + \gamma X_{it} + \tau_i + \psi_t + \epsilon_{it} \;, \qquad j \in \{yel, nm, cap, capcost\} \qquad \textbf{(1)}$$

- Identification comes from variation between regions and across time (pre-announced benefit adjustments and price changes).
- Non-linear estimator, because of count-data (Poisson pseudo-maximum likelihood).

Results: Number of PV installations

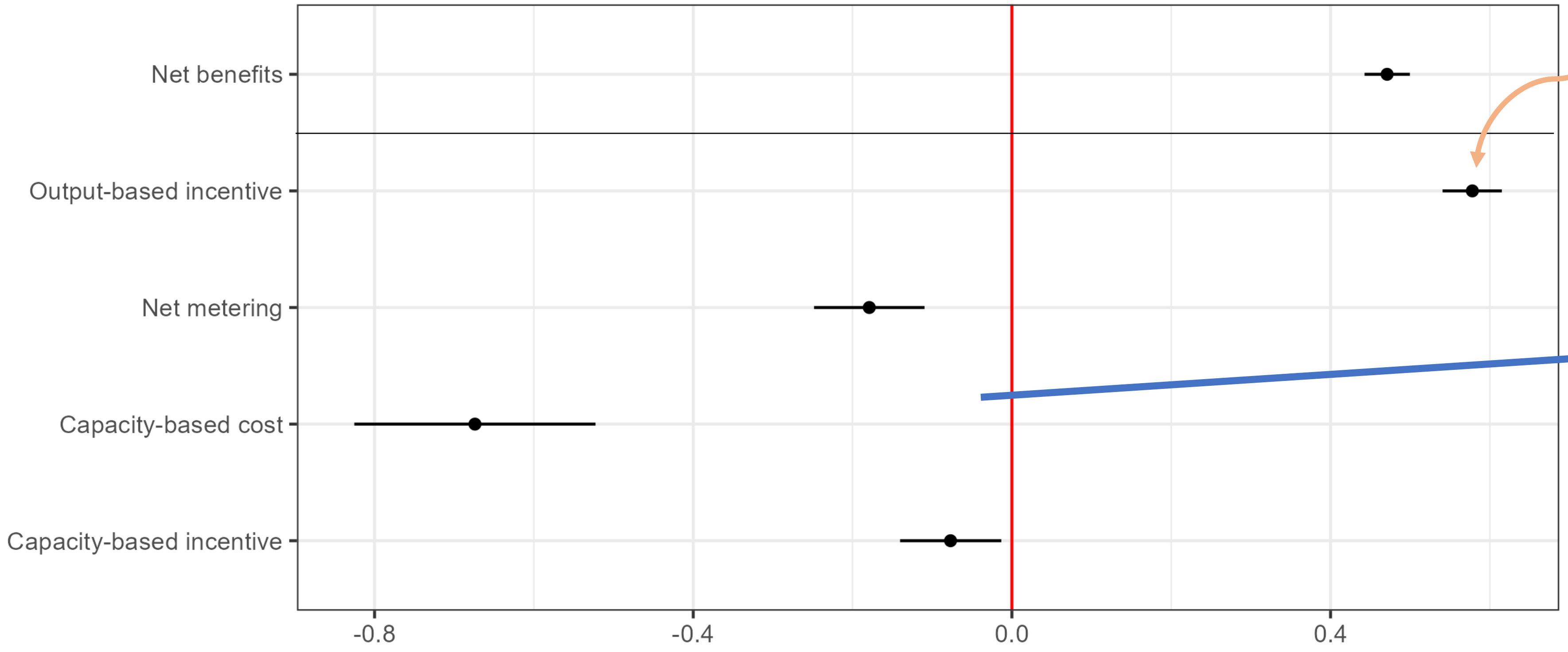


€100 per kW higher net benefits (10% DR) increase the number of residential PV installations by around 14.5% on average.

Output and capacity-based incentives are 6 percentage points larger than net-metering benefits

→ Different effectiveness coincides with differences in the benefit designs: higher uncertainty and lower salience decreases the effectiveness of the same amount of financial benefits.

Results: Sizing of PV installations



€100 per kW higher output-based benefits increase the average size of installations by around 5% on average.

Increasing the remaining incentive schemes decreases the average size of new PV installations

→ Households increase capacity of PV installations when higher capacity is compensated and de-crease it when incentives schemes feature thresholds on compensated capacity.

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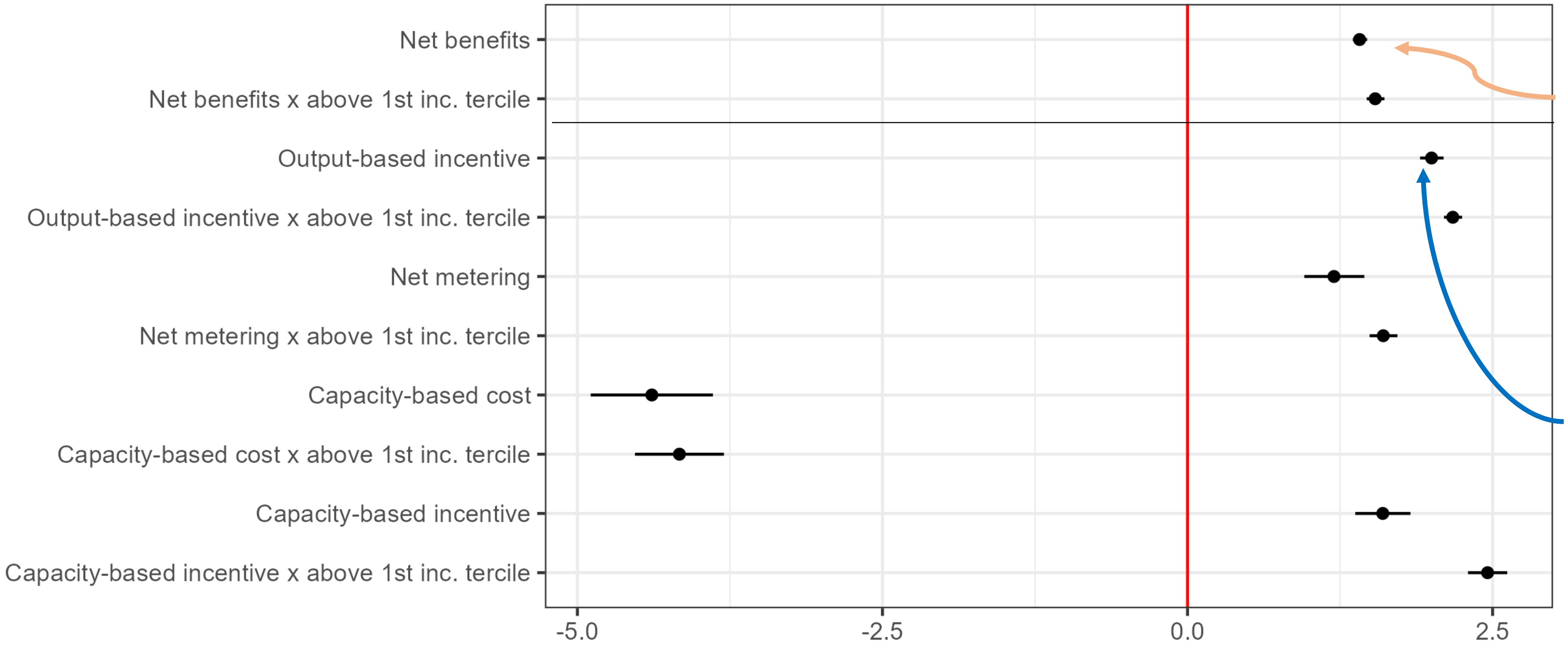
Additional results: different effects by income



€ 100 higher net benefits increase the number of installations by 1.2 p.p. more when municipalities are above low income (15.4 vs. 14.1%).

The gap between low income and the rest is lowest for output-based incentives

→ High-income households are more responsive to benefit increases.

Conclusion

- Main contribution: estimation of future benefits on PV adoption and the direct comparison of the most prominent benefit schemes for the residential sector via reduced-form.
- Households are sensitive to incentive schemes with future financial benefits concerning PV uptake and size.

→ Not all incentive schemes with future financial benefits are similarly effective: The benefit design is an important determinant concerning the overall uptake of energy-related technology adoption.

→ Possible room for improvement for policy makers: more certain, more direct and salient incentive schemes increase energy-related technology uptake.

→ Possibility of improving the modelling of energy related investment decisions and implications for energy system modelling.

Thank you for listening!

Appendix: regression tables

Table 2
The effect of future financial benefits on the number of new PV installations.

Model:	Aggregate benefits			Sep. benefits	Sep. benefits (Poisson CF)
	(1)	(2)	(3)	(4)	(5)
Net benefits (log)	6.02***	6.17***			
	(0.076)	(0.074)			
Net benefits			1.45***		
			(0.030)		
Output-based incentive				2.13***	1.77***
				(0.039)	(0.040)
Net metering				1.53***	1.29***
				(0.056)	(0.077)
Capacity-based cost				–4.48***	–2.74***
				(0.168)	(0.168)
Capacity-based incentive				2.09***	1.78***
				(0.053)	(0.071)
Controls:		Yes	Yes	Yes	Yes
Fixed-effects					
Year	Yes	Yes	Yes	Yes	Yes
Date	Yes	Yes	Yes	Yes	Yes
Zip	Yes	Yes	Yes	Yes	Yes
Fit statistics					
# year	12	12	12	12	12
# date	144	144	144	144	144
# zip	558	557	557	557	557
Observations	80,352	78,048	78,048	78,048	78,048
Squared correlation	0.80353	0.81118	0.77618	0.79363	0.77679

Note: The dependent variable is the number of PV installations. Explanatory variables in 1000 €/kW of installed capacity if not specified otherwise. Monetary values are deflated to 2013-values based on the CPI. Observations are at the municipality-month level. Standard-errors in parentheses, clustered standard errors at the municipality level for specifications (1)–(4), bootstrapped standard errors on second stage for specification (5). For CF-results in column (5) sub-regional variation added for capacity-based incentive and capacity-based cost. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1.

Appendix: regression tables

Table 3
The effect of future financial benefits on average capacity size of new installations.

Model:	Aggregate benefits			Sep. benefits	Sep. benefits (Poisson CF)
	(1)	(2)	(3)	(4)	(5)
Net benefits (log)	1.18***	1.20***			
	(0.040)	(0.043)			
Net benefits			0.471***		
			(0.014)		
Output-based incentive				0.578***	0.539***
				(0.019)	(0.019)
Net metering				–0.179***	–0.124**
				(0.035)	(0.048)
Capacity-based cost				–0.674***	–0.603***
				(0.077)	(0.083)
Capacity-based incentive				–0.077**	–0.136***
				(0.032)	(0.041)
Controls:		Yes	Yes	Yes	Yes
Fixed-effects					
Year	Yes	Yes	Yes	Yes	Yes
Date	Yes	Yes	Yes	Yes	Yes
Zip	Yes	Yes	Yes	Yes	Yes
Fit statistics					
# year	12	12	12	12	12
# date	144	144	144	144	144
# zip	558	557	557	557	557
Observations	80,352	78,048	78,048	78,048	78,048
Squared correlation	0.22619	0.22463	0.23232	0.25136	0.25207

Note: The dependent variable is new average installed capacity (the new installed capacity divided by new installations, in kW). Explanatory variables in 1000 €/kW of installed capacity if not specified otherwise. Monetary values are deflated to 2013-values based on the CPI. Observations are at the municipality-month level. Standard-errors in parentheses, clustered standard errors at the municipality level for specifications (1)–(4), bootstrapped standard errors on second stage for specification (5). For CF-results in column (5) sub-regional variation added for capacity-based incentive and capacity-based cost. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1.

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Appendix: regression tables

Table 4
The additional effect on higher income municipalities.

Model:	Number of installations (1)	(2)	Average new installed capacity (3)	(4)
Net benefits	1.41***		0.467***	
	(0.030)		(0.015)	
Net benefits × above 1st income tercile	0.128***		0.011	
	(0.022)		(0.007)	
Output-based incentive		2.00***		0.554***
		(0.049)		(0.020)
Output-based incentive × above 1st income tercile		0.174***		0.035***
		(0.029)		(0.009)
Net metering		1.20***		−0.159***
		(0.125)		(0.054)
Net metering × above 1st income tercile		0.403***		−0.013
		(0.129)		(0.049)
Capacity-based cost		−4.39***		−0.764***
		(0.255)		(0.106)
Capacity-based cost × above 1st income tercile		0.226		0.142*
		(0.230)		(0.086)
Capacity-based incentive		1.60***		−0.180***
		(0.115)		(0.048)
Capacity-based incentive × above 1st income tercile		0.859***		0.173***
		(0.160)		(0.062)
Controls:	Yes	Yes	Yes	Yes
Fixed-effects				
Year	Yes	Yes	Yes	Yes
Date	Yes	Yes	Yes	Yes
Zip	Yes	Yes	Yes	Yes
Fit statistics				
# year	12	12	12	12
# date	144	144	144	144
# zip	557	557	557	557
Observations	78,048	78,048	78,048	78,048
Squared correlation	0.77692	0.79530	0.23246	0.25209

Note: The dependent variable is the number of PV installations in specification (1)–(2) and new average installed capacity (the new installed capacity divided by new installations, in kW) in (3)–(4). "above 1st income tercile" is an indicator variable equal to one for municipalities above the first tercile in terms of median deflated income by municipality in 2019. Explanatory variables in 1000 €/kW of installed capacity if not specified otherwise. Monetary values are deflated to 2013-values based on the CPI. Observations are at the municipality-month level. Clustered standard-errors at the municipality level in parentheses. Signif. Codes: ***: 0.01, **: 0.05, *: 0.1.

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