CHAIR
Urban New Deal

By
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Poland's solar power surge: a model or misleading success?

With rising concerns about the effects of global warming and climate change, countries introduce policies aimed at greenhouse gas emission reduction. While large transnational instruments are put in place to drive the carbon intensity of the economy down (e.g. EU's Carbon Border Adjustment Mechanism), simultaneous efforts are focused on the general population preferences changing and stimulating the take up of green technologies by households. Among the latter, many governments introduce subsidy and rebate policies to reduce investment costs and increase demand for new environment-friendly products and solutions. Throughout this policy brief, I discuss the solar subsidy policy "*Mój Prąd*" (Eng. "My Electricity") in Poland. This is a very popular subsidy programme that since its beginning in 2019 contributed greatly to the Polish photovoltaic prosumerism boom. During the policy's first five editions running from July 2019 to December 2023, more than three billion PLN (694 million EUR) of subsidies were allocated to almost 600,000 households, that installed 3.5 GW of solar capacities on their roofs. The programme is expected to continue into its sixth edition in 2024.

Studying subsidy policy effects: a brief theoretical overview

Economic analysis often turns to the notion of incidence to evaluate the subsidy effectiveness. The question of who effectively bears the burden of tax or reaps the benefit of a subsidy is of paramount importance in public economics, where studies discuss among others redistributive and equity aspects of incidence (Ito, 2015). The topic is also significant in the industrial organization research. Both streams of literature frequently refer to the concept of pass-through, i.e. the marginal impact of incentive changes on the net (post-incentive) price paid by consumers.

Commonly, the pass-through rates are thought to vary between 0 and 100% and both the theory and the empirics suggest that this is often the case in many existing market structures. A pass-through rate of 100% implies that incentives, subsidies for example, are fully passed through to customers, whereas a rate of less than 100% means that some portion of the incentive is retained by the rebated product/service provider. Nonetheless, the pass-through exceeding unity is theoretically possible.

Although the common sense might suggest that the higher the pass-through of the subsidy the more successful the instrument is in realising its stated objective of lowering the costs of the rebated good, the rates above 100% should warrant caution.

As laid out by Weyl & Fabinger (2013), the theory of incidence tells us that markets characterized by various forms of imperfect competition exhibit over-shifting if demand is sufficiently convex. This imperfect competition suggests the best, socially optimal outcomes are not achieved and there is a space for improvements. Therefore, empirical examination of pass-through is important as it not only informs about the redistributive consequences of the policy but can reveal the presence of market failures if over-shifting is detected. Moreover, this approach might be a more empirically feasible diagnostic test for market power than conducting in-depth structural modelling of market structure that often requires substantial time, data, and resources.

Exploring a case study: residential photovoltaics subsidy in Poland

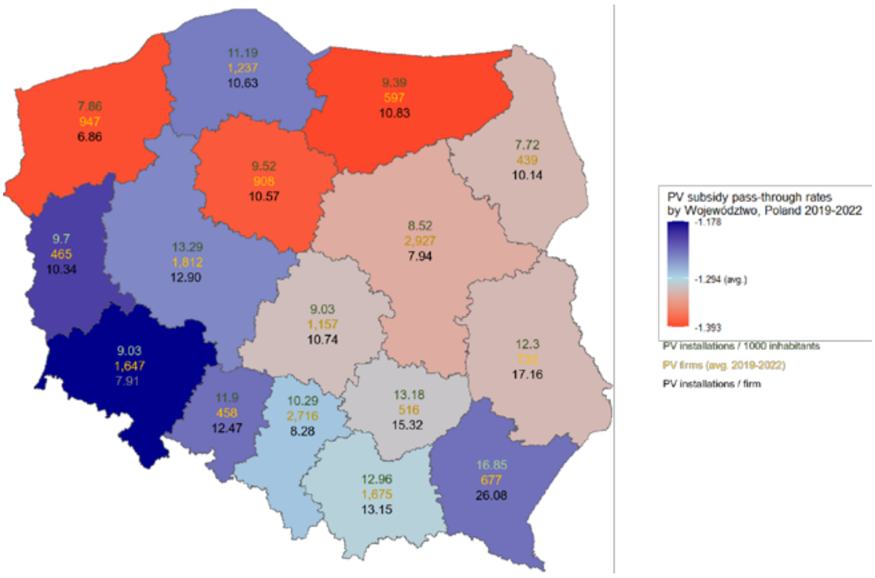
Among the most commonly subsidised technologies are photovoltaic systems, especially residential micro-installations with capacities up to 10 kilowatts (kW) (Iskandarova *et al.*, 2021). In my recent research, I study solar subsidy pass-through consumers face in the context of the very popular *"Mój Prąd"* (Eng. "My Electricity") programme in Poland. The incentive provides households wanting to install a solar rooftop system between 2 to 10 kW of energy generating capacity with financial support to reduce the investment cost.

Table 1.
"Mój Prąd" residential PV subsidy programme's editions summary (in PLN)

Edition	Duration	App. (ths.)	Rejection rate (%)	Total capacity (MW)	Max. subsidy	Total funding	System
1^{st}	30.08.2019 - 20.12.2019	30.48	5.33	149.96	5,000	0.13 bn	net-metering
2^{nd}	13.01.2020 - 06.12.2020	235.93	1.12	1,171.01	5,000	1.13 bn	net-metering
3^{rd}	01.07.2021 - 06.10.2021	178.01	7.10	922.89	3,000	0.48 bn	net-metering
4^{th}	15.04.2022 - 17.03.2023	60.23	3.07	135.99 (31.12.2022)	7,000	0.35 bn	net-billing

Inspired by the Pless & van Benthem (2019) study of the California Solar Initiative rebates programme, I evaluate how the cost net of the allocated subsidy of solar system per kW of installed capacity changes with the size of received financial support in the case of the Polish policy. Using application-level data, I analyse more than 412 thousand unique residential, prosumer PV micro-installations that were eligible to receive a subsidy from the *"Mój Prąd"* programme and were connected to the grid between July 2019 and the end of 2022. I identify subsidy over-shifting – a pass-through rate exceeding 100%. Moreover, having information on the installations' location I detect the regional heterogeneity in pass-through rates across 16 Polish *województwa* (the largest territorial units in Poland). The over-shifting is omnipresent. The subsidy's pass-through to households is about 137% (varying from 118% to 139% when differentiated by *województwa*). In other words, a 1 PLN increase in subsidies translates into a decrease in solar system prices of 1.37 PLN.

Figure 1.
Pass-through rates and local market characteristics by *Województwa*, Poland 2019-2022



Despite limited data on the Polish solar market, I observe that market and PV firm characteristics have a statistically and economically significant impact on PV microinstallation costs (results: *Table 2*). The density of PV installers (PV installers in *województwo* per 100 ths. inhabitants) in a region notably affects costs, with higher density leading to lower prices – a move from the 5th to the 95th percentile of the variable decrease's prices by 241 PLN/kW (55 EUR/kW). This reflects increased price competition and easier access to information. (Nemet *et al.*, 2017). The installers' experience also plays a significant role in reducing the installation costs. Moving from 2 to almost 30 PV installations per firm is associated with a cost reduction of 123 PLN/kW (28 EUR/kW). This result comes as no surprise, as it may be capable of capturing the learning or scale economics mechanisms, where more experienced or larger firms potentially benefit from cost advantages such as greater efficiencies in logistics, lower input costs associated withbulk purchasing or less downtime for installation crews (Gillingham *et al.*, 2016). The higher the average wage in the area, the costlier PV installations are likely to be. Nevertheless, despite its intuitive appeal this relation might be more correlational rather than causal and explained by the regional and temporal specificities (fixed effects controls). This might be due to the lack of direct data on PV services-related earnings and reliance on the general local gross wage indicator. The aggregate number of installations in the region has an imprecise and ambiguous effect on installed costs. Its inclusion among controls should account for potentially important demand effect: the total number of installations is a measure of market size, which may be associated with stronger unobserved preferences for solar PV or over-demand and simultaneous under-supply of service providers and that could therefore raise costs. Alternatively, an increased number of installations in the area could bring down the prices, if there is a neighbour peer-learning effect, where the households exchange information on their PV systems installation experience and can lower their search costs and increase their bargaining power (van Benthem *et al.*, 2008).

Table 2.
Change in the net cost per kW from the 5th to the 95th percentile for selected variables and model specifications

	$5^{th}p.$	$95^{th}p.$	$5^{th}-95^{th}p.$	(3)	(4)	(5)
Net cost (PLN/kW)	2,064.66	5,319.79	3,255.13			
Allocated subsidy	299.77	1,462.50	1,162.73	-1,622.16***	-1,614.31***	-1,592.61***
Capacity installed	3.1	9.9	6.8	-1,864.93***	-1837.19***	-1,828.01***
Avg. gross wage	3,978.05	5,898.52	1,920.47	147.13**	93.29	48.09
PV instal. density	0.65	17.63	16.98	20.69	20.33	-7.6
PV firms density	30.53	68.60	38.07	-211.18***	-224.63***	-241.42***
PV instal./ PV firm	1.75	29.24	27.49	-69.92	-135.09***	-123.15***
PIT inc. per capita	1.04	180.64	179.60	-19.66*	-16.45*	
Turnout in local elect.	39.63%	63.91%	24.28	41.40**	42.42**	
Protected area	0.07%	98.89%	98.82	-13.50	-13.37	
Solar PV potential	1,048.12	1,125.57	77.45	-10.96	-10.38	
Population density	31	1,898	1,867	-27.80**	-25.04*	

An apparent success story or a warning sign? What the findings tell us about the Polish residential PV market

My findings[1] suggest that PV subsidy incidence in Poland falls primarily on the consumer – the to-be prosumer household. It has an important bearing on the assessment of the policy's success and suggests that it achieved its aim of reducing the costs of residential solar systems and stimulating the technology adaptation rate in Poland. However, this finding is also indicative of potential market imperfections appearing in the Polish residential solar market. To further reinforce this prognostic, I estimate the demand elasticities with regard to the net cost levels depending on the varying, available subsidy amounts. My results suggest that demand is convex, which is a necessary condition to apply over-shifting identification as a litmus paper for market power and imperfection detection. Moreover, the alternative circumstances that could explain over-shifting and not entail imperfect competition are also discussed but ruled out as not plausible in the context of the Polish residential solar market. Among those inapplicable different explanations are Giffen's behaviour[2], decreasing marginal costs[3] , or subsidy level manipulation. Whereas the first two are rarely observed in practice, the last one is hardly possible in the context of the *"Mój Prąd"* subsidy as the reported installation costs on which the allocated subsidy amount depends require proof in the form of invoice or receipt.

The importance of the pass-through examination in the Polish context lies primarily in the scale of the studied

[1] In line with the results of Dong *et al.* (2014) and Pless & van Benthem (2019) who identified pass-through rates oscillating and exceeding 100% in the context of the Californian solar market.
[2] The demand for good increases as its price rises, contrary to the basic law of demand.
[3] This rare situation can take place when the economics of scale are so strong that instead of decreasing returns to input in the short-run and more standard elasticity of supply above zero, we observe negative elasticity of supply.

subsidy programme that attracted one-third of all new solar prosumer households between 2019 and the end of 2022. Moreover, in 2021 alone, about 113,000 solar jobs were created in Poland, establishing the country's PV sector as the largest provider of employment across the European Union solar markets (SolarPower Europe, 2022). Therefore, the potential identification of market imperfections has significant consequences as it might indicate reduced welfare resulting from market power presence and should interest and alarm the adequate competition regulation authorities and decision-makers. Especially, the presence of regional, spatial heterogeneity in the pass-through rates further encourages and justifies the economic investigations of the regional variations in the PV market characteristics (e.g. market structure, markups, the experience of firms, etc.) in Poland. Finally, considering Poland's current carbon dependency, this analysis's results have potential relevance in other contexts of high-emitting, green transition-pursuing economies.

The unexpected success of residential photovoltaics adaptation by Polish households

Poland has been developing spectacularly since the political and economic system transformation in 1989 and the European Union accession in 2004. Poland's GDP per capita tripled in real terms between 1999 and 2021. However, its success story is as widely known as the fact that fossil fuels dominate its energy mix. In 2020 they represented 85% of total energy production. While nuclear and off-shore wind sources are expected to replace fossil dependence, the technology that has seen adaption rates far exceeding expectations and projections is solar energy generation.

The installed capacity of photovoltaics in Poland at the end of April 2023 increased to 13.5 GW, reaching 185% of the governmental target for 2030 (Ministry of State Property, 2019). In 2016, Poland had only 0.2 GW of solar capacity. Just between 2021 and 2022, Poland had the second-highest increase in installed PV capacities and added 4.8 GW (67% increase). This growth is well reflected in the overall Polish electricity mix: solar energy covered only 0.5% of the country's final demand for electricity in 2018, in 2022 it was almost 5%.

The increase is driven mainly by the residential PV micro-installations. Between 2019 and December 2023 the number of prosumer micro-installations in Poland increased more than 25 times, from 54 to 1,378 thousand, while their total installed capacity grew 36 times, from 0.3 to 10.9 GW.

Despite growing climate awareness and pro-environmental preferences in Poland, the market probably would not have blossomed as much without the active engagement of the public sector and implemented regulatory framework. The government introduced the net-metering billing system (replaced by the net-billing mechanism in April 2022) and the subsidy programme for micro-installations (2-10 kW) "*Mój Prąd*" (Eng. "My Electricity") to render investing in prosumer photovoltaics more financially attractive to households. Since its first edition in 2019, the subsidy finished the fifth edition of applications in December 2023 and awaits a new, sixth round of applications in 2024. The subsidy policy's results are discussed in this policy brief.

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