Rooftop PV and Electricity Distributors: Who Wins and Who Loses?

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Introduction and background

The electricity system in Australia is decentralising as consumers increasingly partially self-supply through the installation of rooftop photovoltaics (PV). In Victoria, Australia's second most populous state, a PV system can be found on the roof of every sixth home. Policy promoting rooftop PV has been politically popular and the Victorian Government seeks to more than double the uptake of residential rooftop PV over the coming decade. Rooftop PV is also rapidly expanding amongst larger commercial and industrial customers. Facilitating the connection of distributed generation and providing for two-way power flows have become core activities for Victoria's distributors.

In tandem with the rise of rooftop PV, the extent of cross-subsidies from consumers without rooftop PV to those with rooftop PV has attracted attention. Australian studies (Wood and Blowers, 2015; Simshauser, 2016) suggest consumers with rooftop PV are being subsidised by other customers. These studies reflect their authors' views of what consumers with rooftop PV should be paying for the use of distribution networks compared to what they estimate they are actually paying.

However studies that measure, empirically, the impact of rooftop PV on distributors' charges based on actual bill data, have not yet been published. In addition, while studies and reports (Byrne et al., 2018; Ausnet Services, 2019) recognise that rooftop PV impacts wholesale market prices, this effect also remains hitherto unquantified. The incremental expenditure by consumers and/or distributors needed to resolve localised voltage issues possibly attributed to rooftop PV has become the focus of attention in regulatory applications. But here too, the issues are not yet well understood. It is unsurprising, therefore, that the price impacts of rooftop PV for consumers, producers and distributors remain contested.

In this article we report on econometric studies that seek to fill some of these knowledge gaps, through analysis of the electricity bills of 48 677 households in Victoria, of which 7,212 have installed rooftop PV. Our rich dataset allows us to account for heterogeneity amongst consumers with and without rooftop PV (for example in respect of their actual retail electricity rates, their tariff structures, the size of their PV system and in relation to the volume of their grid purchases, their distributors and their specific network tariffs). We derive statistically robust estimates of the effect of rooftop PV on distributors' revenues and prices, and also on the impact of rooftop PV on wholesale market prices. These findings have important implications for policy affecting distributed generation and the economic regulation of distributors.

Data and Analysis

Our data is obtained from 48 677 residential electricity bills (in their original PDF format) that were provided to us. These bills were originally voluntarily uploaded to the Victorian government's electricity price comparison website over the period from July 2018 to December 2018. Relevant data (such as usage, tariff type and rate, rooftop PV export, feed-in prices, discounts, government concessions, distributor and retailer) are extracted from the PDF files using commercially available software specifically designed to automatically extract information from pdf files (described further in Mountain and Rizio (2019)).

Our research method to estimate the network impacts of rooftop PV is as follows:

- First we estimate the rooftop PV capacity and hence the gross annual PV generation for each of the 7,212 households in our dataset with rooftop PV, using the model in Mountain and Gassem (2020).
- Second, since the annual rooftop PV production exported to the grid is estimated for each customer based on the data in their bills, it is possible to derive the rooftop PV production that is consumed on the premises of those dwellings with rooftop PV.
- Third, we estimate the impact of rooftop solar on the revenues recovered by network service providers through an ordinary least squares regression with annual distributor revenue as the dependent variable and the volume of grid purchases (plus rooftop PV-sourced electricity used on the premises for households with rooftop PV), dummy variables for whether the household had a concession, controlled load or rooftop solar, their distributor and tariff type as independent variables. Model diagnostic tests validate the robustness of the findings

To determine the impact of residential rooftop PV on wholesale electricity markets, in the tradition of "merit order effect" studies (e.g., Würzburg, Labandeira and Linares, 2013; Cludius et al., 2014; Bushnell and Novan, 2018) and specifically following Mountain et al. (2018) we regress the half hourly Settlement Price in the Victorian region of the National Electricity Market against wind generation, solar (large scale and rooftop PV) generation, demand plus inter-regional exports, gas prices, coal generation capacity, and a dummy to account for monthly fixed effects. The wholesale price data used in the model covered half-hourly intervals from 1st April 2016 to 30th October 2018. The coefficient on solar generation establishes the impact of rooftop PV generation on wholesale prices. Model diagnostic tests validate the robustness of the findings.

Results

In our sample, households with rooftop PV on average each export 2.2 MWh per year and our models estimate self-consumption of 1.6 MWh per year per household. In total, for the one in six households that have rooftop PV, this means 0.7 TWh per year of production from large-scale generation that has been substituted by rooftop PV generation and used on-site. The exported rooftop PV generation (worth 0.9 TWh per year) is sold to other customers on the distribution network.

Substituting large scale production for distributed production reduces demand as measured on the transmission system by the distributed production. But the demand reduction from distributed supply measured on the distribution network is only the amount of distributed production used on-site. This is because distributed production that is exported to the grid is sold to other uses on the distribution grid. The decline in annual electrical demand in Victoria, as measured on the transmission system over the decade to 2020, was 7.9 TWh or 29.5% per capita after accounting for population growth. However, when measured on the distribution network, annual demand declined by only 6.3 TWh (25% per capita). When measured at the level of the distribution network, large scale electricity production displaced by residential rooftop PV accounted for 10% of the annual demand reduction between 2010 and 2019. Non-residential rooftop solar accounted for 5% of the annual demand reduction over this period.

Our models estimate that on average households with PV paid $590 less per year for electricity (about 30% of what their bills would be if they did not have rooftop PV). This is likely to explain in part the finding in Best and Burke (2019) that access to rooftop PV is associated with much lower household electricity bill payment stress. However, estimating private benefits from rooftop PV is complicated by the large reductions in PV capital costs, the large increase in electricity prices and big changes in the levels of policy support. Over the decade, policy makers responded to decreasing PV capital costs and increasing grid-supplied electricity prices by sharply reducing subsidies (Mountain & Szuster, 2015) although means-tested capital subsidies have increased again pursuant to the Victorian government's "Solar Homes" policy.

The small impact of residential rooftop PV on the volume of grid-supplied electricity is reflected also in the small impact of foregone network-delivered electricity on network usage prices (network providers in Victoria are subjected to revenue cap regulation and so are not exposed to lower sales volumes within a regulatory control period). Specifically, our model estimates that residential rooftop PV resulted in network access charges $1.3/MWh (about 1 %) higher than they otherwise would be. Households with PV are typically on two-rate time of use tariffs and households without PV are typically on single rate non-time variant tariffs. This effect would be even smaller if households with or without PV had the same tariff structures.

With respect to wholesale market impacts, our model estimates that residential rooftop PV reduced wholesale market prices by $6.4/MWh (about 8%) in 2019.

The net effect of wholesale price reductions and network price increases associated with residential rooftop PV was $217m in 2019. The extent to which this benefit is captured by suppliers (in higher profits) or passed on to consumers (in lower prices) is not knowable with certainty. Assuming it was all passed on to consumers and calculated per MWh supplied, it is worth $5/MWh. If calculated per connection to the grid, it is worth $84 per year. Since the majority of electricity consumed is charged per MWh, we expect that recovery per MWh is likely to provide a more reasonable way to state the shared price benefits of rooftop PV.

Conclusions

Our analysis provides insight into the implications for consumers, distributors and electricity producers of the decentralisation of electricity supply. The main conclusion is that rooftop PV pushes down prices in wholesale markets far more than it raises prices for the provision of network services. This was somewhat unexpected and might be explained by Victoria's extraordinarily high wholesale market prices and also by the fact that despite the high penetration of rooftop solar, the amount of grid-supplied electricity that is displaced by rooftop supply is not large. As we noted earlier, the substitution of grid supply in favour of partial self-supply for the one in six households that have installed rooftop PV accounts for 20% of the decline in grid-supplied electricity (measured at the level of the transmission system). But only 9% of this is displaced grid supply. The remaining 11% is surplus rooftop PV production that is routed through the distribution system and distributors charge for the sale of this electricity just as they would if the electricity had entered distribution networks from the high voltage transmission system.

An additional factor explaining the small impact of distributed supply on distributors' revenues is that distributors have adjusted their pricing structures to increase the fixed proportion of their charges. Over the 8 years to 2019, the distributors' fixed charges increased by 490% while consumption charges only increased by 61% on average. By 2019, on average one third of the revenue that distributors recovered from residential customers was fixed. Such a high proportion of revenue recovery from fixed charges explains in part why rooftop PV production only gives rise to a $1.3/

MWh (about 1%) increase in network prices relative to what they otherwise would have been.

Doubling the uptake of residential rooftop PV (the current government's policy) is likely to lead to less than a 2% increase in network prices (since household consumption is declining and the proportion of distributors' revenues that are recovered through fixed charges is likely to increase.

On the question of the incremental expenditure (by consumers and/or distributors) that is needed to ensure that distributors are able to resolve localised voltage issues possibly associated with greater amounts of rooftop PV, our survey of the Australian evidence suggests much remains to be done to understand the nature of this issue. However in a recent regulatory filing, Victoria's largest distributor, Ausnet Services, is seeking approval for around $12m per year for the next five years to expand distributed supply capacity. It is claimed this will increase charges to residential consumers by AUD0.72 per residential customer per year. Other distributors in Victoria are proposing proportionally similar amounts. Rising distributed generation may present some technical challenges, but distributors' expenditure proposals suggest that meeting these challengers will not be expensive.

Policy implications

Rooftop PV is likely to provide private benefits that exceed private costs since consumers can choose not to install it. However the amount of this benefit is likely to range widely. Households with rooftop PV obtain benefits that households without PV do not obtain. Private benefits of rooftop PV in aggregate may exceed shared benefits in aggregate. However private benefits do not come at the expense of shared costs. The shared benefits for consumers (in the form of lower wholesale prices) far exceed shared costs (higher network prices) although large customers are likely to gain disproportionately more of the shared benefit through their relatively higher exposure to energy rather than distribution charges. Policy makers responding to the politically popular desire for rooftop PV might take comfort from the evidence that rooftop PV also reduces prices for all electricity consumers.

Finally, the results of our study draw attention to the question of the appropriate allocation of the costs and benefits of technology change. Even after one in six homes connected to rooftop PV over the last decade, only 10% of the reduction in demand on distribution networks is attributed to residential rooftop PV, and 5% to non-residential rooftop PV. The remaining 85% of the demand reduction is explained by some combination of lower consumption in response to higher electricity prices, and more efficient appliances. While these outcomes are likely to be somewhat context specific, it is clear in Australia at least that concerns about a "death spiral" in distribution networks associated with ever greater distributed supply are misplaced. If there is a case to reconsider whether distributors should continue to be protected from technology change, this rests not in the expansion of distributed supply but rather in the reduction in consumer demand for grid-supplied electricity.

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