THE CANNIBALIZATION EFFECT OF SOLAR PHOTOVOLTAICS IN THE CALIFORNIA ELECTRICITY MARKET

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Overview

Solar photovoltaic technology (PV) has the highest technical and sustainable potential (Jacobson and Delucchi, 2011:1159; WBGU, 2011:119) amongst all renewable technologies. However, increasing amounts of zero marginal cost electricity cause a decline of wholesale electricity prices. There is a rich strand of literature studying the so-called merit order effect (Clò et al., 2015; Cludius et al., 2014; Gelabert et al., 2011; Sensfuß et al., 2008; Woo et al., 2016). Since PV generation is not dispatchable and usually concentrated in a few hours of the day and months of the year, the drop in prices during PV generation is usually stronger than the average. This implies that the higher PV penetration, the lower prices at the generation times and therefore the lower remuneration for PV producers, entailing a fall in the market value of PV electricity (Borenstein, 2008). Consequently, although grid parity has already been achieved in many countries (Breyer and Gerlach, 2013), this *cannibalization effect* could undermine the profitability of PV producers and entail the departure from the grid parity situation as PV penetration increases.

The research question is how PV penetration affects the market value of PV electricity. PV penetration is defined as the share of PV over the total generation, and the solar/wind market value factor is defined as the solar/wind-weighted electricity price (unit revenue of solar/wind producers) over the time-weighted average wholesale electricity price (Hirth, 2015, 2013).

Methods

The methodology is a time series (2011-2016) analysis with data from the CAISO wholesale electricity market. The dependent variable is the PV value factor (V^s), formally defined as

$$V^s = \frac{\bar{p}^s}{\bar{p}} = \frac{[\sum_{t=1}^{T}(S_t * p_t)]/S}{[\sum_{t=1}^{T} p_t]/T}$$

where p represents prices (either daily average or hourly) and S is the solar generation.

The independent variables are solar and wind penetration ($\%solar, \%wind$), gas price, electricity demand, and the shares of other sources of electricity generation (including net imports: $\%NM$) . The data is daily computed from hourly values. The effect of higher penetration can be estimated in relative (value factor, eq. 1) and absolute (unit revenue, eq. 2) terms:

$$(1) \quad V_t^s = \beta_0 + \beta_1 \%solar_t + \beta_2 \%wind_t + \beta_3 gasprice_t + \beta_4 demand_t + \beta_5 \%NM_t + \beta_6 \%others_t + \sum_{i=1}^{n} \beta_i D_i + \varepsilon_t$$

$$(2) \quad \bar{p}^s = \beta_0 + \beta_1 \%solar_t + \beta_2 \%wind_t + \beta_3 gasprice_t + \beta_4 demand_t + \beta_5 \%NM_t + \beta_6 \%others_t + \sum_{i=1}^{n} \beta_i D_i + \varepsilon_t$$

Results

The results show by how much a percentage point increase in PV penetration reduces the value of PV electricity with respect to the average wholesale electricity price on one hand, and the unit (per kWh) revenue of PV generation on the other hand. Since we run the regression for the whole period first, but also for each individual year, we are able to assess wether the cannibalization effect shows a constant trend or if it declines over time.

Conclusions

This analysis goes one step beyond the merit order effect studies to assess not only the effect of higher PV penetration on the wholesale electricity markets, but on the value of PV electricity itself. The results are useful to understand the fluctuations and evolution of the PV market value, which in turn will shed light on the potential departure from the grid parity situation (if the cannibalization effect causes the market value of PV to drop lower than the LCOE), and help us understand the suitability of marginal markets at high penetration of zero marginal cost generation technologies.

References

Borenstein, S., 2008. The market value and cost of solar photovoltaic electricity production. Cent. Study Energy Mark.

Breyer, C., Gerlach, A., 2013. Global overview on grid-parity: Global overview on grid-parity. Prog. Photovolt. Res. Appl. 21, 121–136. doi:10.1002/pip.1254

Clò, S., Cataldi, A., Zoppoli, P., 2015. The merit-order effect in the Italian power market: The impact of solar and wind generation on national wholesale electricity prices. Energy Policy 77, 79–88. doi:10.1016/j.enpol.2014.11.038

Cludius, J., Hermann, H., Matthes, F.C., Graichen, V., 2014. The merit order effect of wind and photovoltaic electricity generation in Germany 2008–2016: Estimation and distributional implications. Energy Econ. 44, 302–313. doi:10.1016/j.eneco.2014.04.020

Gelabert, L., Labandeira, X., Linares, P., 2011. An ex-post analysis of the effect of renewables and cogeneration on Spanish electricity prices. Energy Econ. 33, S59–S65. doi:10.1016/j.eneco.2011.07.027

Hirth, L., 2015. Market value of solar power: Is photovoltaics cost-competitive? IET Renew. Power Gener. 9, 37–45. doi:10.1049/iet-rpg.2014.0101

Hirth, L., 2013. The market value of variable renewables. Energy Econ. 38, 218–236. doi:10.1016/j.eneco.2013.02.004

Jacobson, M.Z., Delucchi, M.A., 2011. Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas of infrastructure, and materials. Energy Policy 39, 1154–1169. doi:10.1016/j.enpol.2010.11.040

Sensfuß, F., Ragwitz, M., Genoese, M., 2008. The merit-order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany. Energy Policy 36, 3086–3094. doi:10.1016/j.enpol.2008.03.035

WBGU - German Advisory Council on Global Change, 2011. World in Transition. A Social Contract for Sustainability.

Woo, C.K., Moore, J., Schneiderman, B., Ho, T., Olson, A., Alagappan, L., Chawla, K., Toyama, N., Zarnikau, J., 2016. Merit-order effects of renewable energy and price divergence in California's day-ahead and real-time electricity markets. Energy Policy 92, 299–312. doi:10.1016/j.enpol.2016.02.023