Is the cannibalization effect of intermittent renewables important for the German wholesale electricity market?

BY Kyriaki Tselika

DISCUSSION PAPER

Institutt for foretaksøkonomi
Department of Business and Management Science

FOR 5/2022
ISSN: 2387-3000
February 2022

Is the cannibalization effect of intermittent renewables important for the German wholesale electricity market?

Kyriaki Tselika*

Department of Business and Management Science, Norwegian School of Economics, Helleveien 30, 5045, Bergen, Norway

Abstract

Employing a quantile regression model, we investigate the impact of renewable sources on their unit revenues (absolute cannibalization) and value factors (relative cannibalization), as well as the cross-effect between technologies. The results indicate that an increase in wind and solar share reduce the technology's own and each other's unit revenues. In the case of value factors, an increase in wind share reduces the wind and solar market value. In contrast, there is no evidence of solar decreasing the wind market value. The findings imply that higher share of renewables may raise market risk and may limit future renewable investments, but these results are not uniform across the unit revenues and value factors distribution.

Keywords: value factor, unit revenues, renewable energy, quantile regression

1. Introduction

The upcoming energy market revolution has rendered renewable sources an essential pillar in the European green deal that seeks to transform the EU into a low carbon economy. Furthermore, renewable energy technologies can be characterized as profit-motivated, which means that their response depends on financial incentives (Steffen, 2020). Thus, renewable energy investors consider risk-return ratios to evaluate long-term investments. When investors are exposed to higher market risks, for instance volatile power prices, they can require higher returns to sustain their investment activity. Risk implications, an important element in electricity market structure, should be acknowledged when designing the market to avoid misleading investment signals. Several countries have applied different support schemes to renewable technologies to facilitate capacity expansion and eventually reach their renewable production objectives. Germany has been a pioneer in the energy transition field and has initially supported renewable sources through Feed-In-Tariffs (FITs). Since then, the support schemes have been modified several times based on the notion that renewable sources can eventually be competitive without governmental support.

Although it has been shown that the levelized cost of energy (LCOE) of renewable producers has been decreasing during the last decades, the question that remains is whether this reduction is higher than the negative effect renewable sources have on their revenues and market value. The literature has revealed that renewable sources can reduce their revenues and market values due to renewable generation patterns and electricity price levels. Clò and D'Adamo investigate the Italian wholesale power market and show that an increase in solar share negatively affects the solar market value. Similarly, Prol et al. (2020) uses an econometric approach to model and test the solar and wind influence on their unit revenues and market values. Their results imply that wind and solar reduce their respective revenues and market value. Conversely, they show

*Corresponding author
e-mail: kyriaki.tselika@nhh.no

that while an increase in wind share decreases the solar market value, a higher solar share in the market increases the wind market value. These phenomena are known as the relative and absolute cannibalization effect (renewables reducing their own unit revenues and values) and cross-cannibalization effect (between renewable technologies).

In this study, we investigate the relationship between renewable energy sources, their revenues and market value through a quantile approach. Previous studies focus only on the median of the revenue and value distribution, while we explore different parts of the revenues and values distribution trying to further characterize and understand the cannibalization and cross-cannibalization effect.

2. Data and Methodology

We use hourly data from the German wholesale electricity market for the period January 1, 2017 to July 31, 2021. The day-ahead electricity prices were retrieved by EPEX (https://www.epexspot.com/) while demand forecasts, power production forecasts differentiated by energy source, and imports-exports (from which we calculated net imports) were obtained by the ENTSO Transparency Platform (https://transparency.entsoe.eu/) We also use daily natural gas prices (converted to euro) provided by the Henry Hub natural gas spot price platform (https://fred.stlouisfed.org/series/DHHNGSP).

We then transform the data into two indices: the wind/solar Unit Revenues (UR) and Value Factors (VF). First, we calculate the specific-generation unit revenues which are defined as the wind/solar generation weighted average price:

$$UR_t^{\{W,S\}} = \frac{\sum_{h=1}^{24} p_h q_h^{\{W,S\}}}{\sum_{h=1}^{24} q_h^{\{W,S\}}} \qquad (1)$$

where $UR_t^{\{W,S\}}$are the daily unit revenues for wind (W) or solar (S) in €/MWh; p_h is the hourly day-ahead electricity prices in €/MWh, and $q_h^{\{W,S\}}$ is the hourly forecasted generation of wind or solar in GWh.

Finally, we determine the Value Factor index (in %), which captures the renewable technology's market value, by dividing the daily unit revenues by the average daily price $\overline{p_t}$.

$$VF_t^{\{S,W\}} = \frac{UR_t^{\{S,W\}}}{\overline{p_t}} = \frac{\sum_{h=1}^{24} p_h q_h^{\{S,W\}} / \sum_{h=1}^{24} q_h^{\{S,W\}}}{\sum_{h=1}^{24} p_h / 24} \qquad (2)$$

As shown in the descriptive statistics (see Appendix A), there is a relative increase in the wind and solar unit revenues in the period 2017-2018, compared to lower numbers in the following years. Concerning the market values, the wind VF is being stable and earns prices lower than the average daily price. On the other hand, looking at solar's VF we notice that it earns prices higher than the average price for 2017-2018, but the pattern is reversed for 2019-2020. Figure 1 illustrates the hourly average renewable generation by source. Wind and solar show diverse seasonal patterns with wind producing more during winter and solar generation peaking in the summer. Their daily generation patterns vary as well: solar is, as expected, concentrated during noon, while wind shows a more stable pattern with a slight decline when solar power starts generating. We also notice (Figure 2) that as solar production increases at noon, electricity prices drop, while the hours that solar is scarce prices spike. The descriptive statistics indicate that as renewable penetration increases over the years, the unit revenues and market value of renewables decrease.

Before proceeding with the empirical analysis, we tested the data for the presence of a unit root (see Appendix B) by performing the Dickey-Fuller (ADF) and Phillips-Perron (PP) test. The number of lags were chosen by the AIC and Schwarz's BIC information criteria. Both tests reject the null hypothesis of a unit root for all the variables in our model.

We consider a linear quantile regression (Koenker and Bassett, 1978) which connects the $\tau = 0.1 \ldots 0.9$ quantile of the unit revenues and value factors with the vector of independent variables. Thus, we model the solar and wind unit revenues and value factors as a function of wind share (W_t), solar share (S_t)[†], net imports (I_t) and gas share (GS_t), electricity consumption (L_t) and gas prices (G_t). Weekend, monthly and yearly effects are included to control for trends and seasonal effects. The model specification takes the following form:

$$Q(\tau)_t^{\{S,W\}} = a_{0,\tau} + \beta_\tau^W W_t + \beta_\tau^S S_t + \beta_\tau^L L_t + \beta_\tau^{GS} GS_t + \beta_\tau^I I_t + \beta_\tau^G G_t + \sum_{i=1}^{3} \theta_{i,t}^D D_{i,t} + \sum_{i=1}^{12} \theta_{i,t}^M M_{i,t} + \sum_{i=1}^{5} \theta_{i,t}^Y Y_{i,t} \quad (3)$$

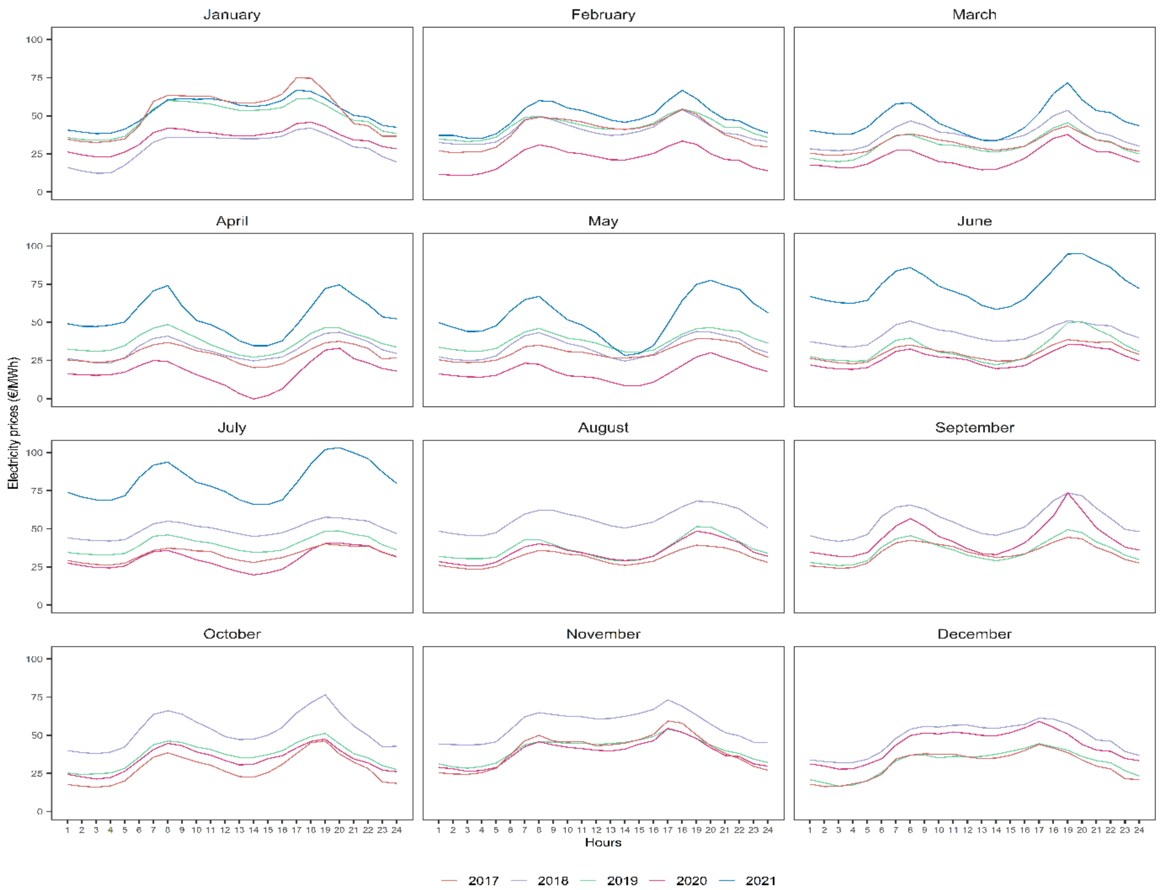

Fig. 1. Hourly average electricity prices per month and year.

† We define the daily solar, wind and gas share as the sum of the hourly forecasted generation by source divided by the daily electricity consumption. In the case of gas, we use realized data due to constrains in data availability.

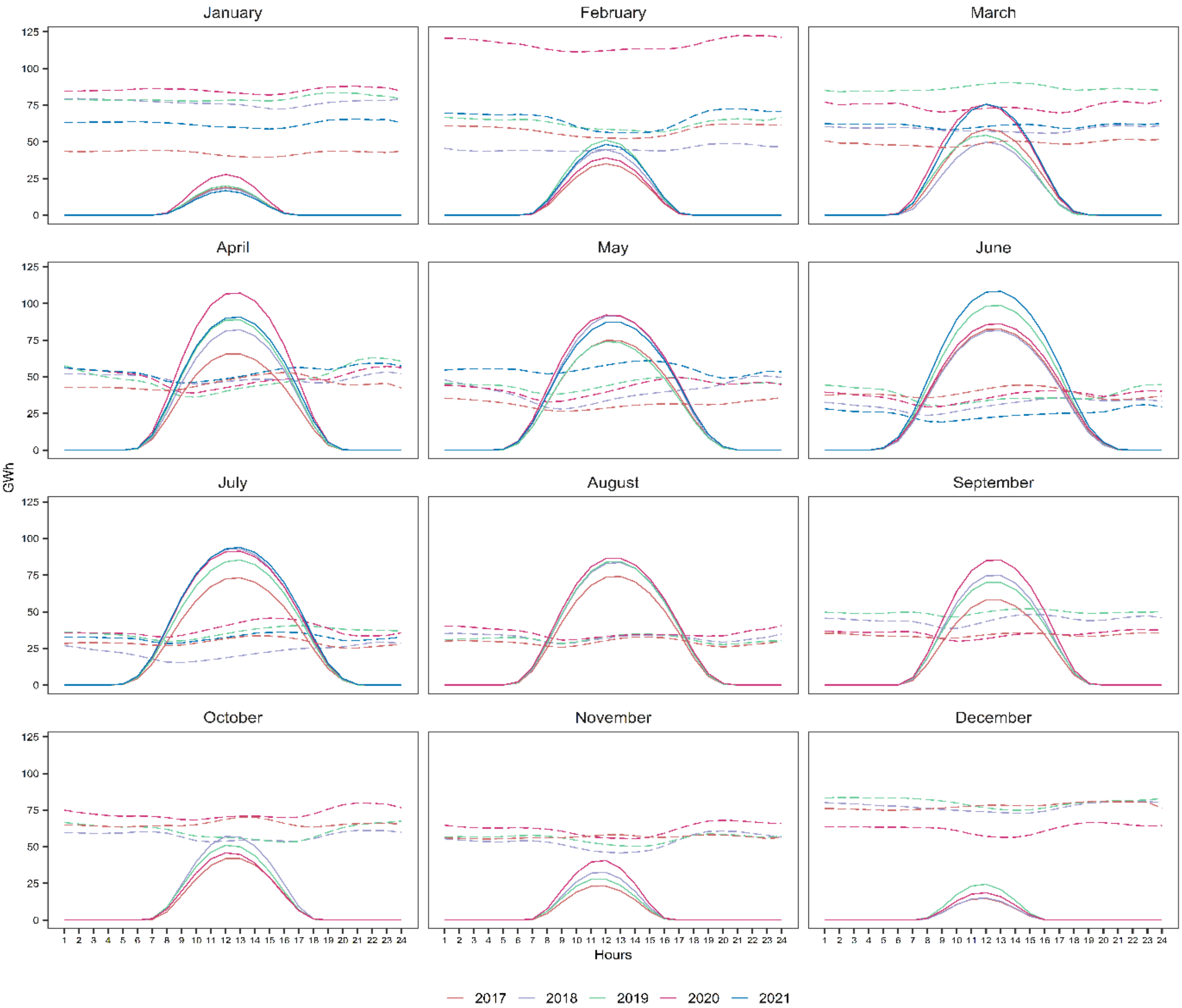

Fig. 2. Hourly average generation of wind (dashed line) and solar per month

3. Empirical results

3.1 Unit revenues (absolute cannibalization)

Fig. 3-4 present the main results for solar and wind unit revenues respectively, shown analytically in Appendix C (Tables C1-C2). As the negative and significant coefficients of the solar share across all solar UR quantiles indicate, higher solar penetration in the generation mix is associated with lower unit revenues received by solar producers. The effect becomes more prominent in the lower quantiles of the unit revenue distribution. In particular, a pp increase in solar share is related to a drop in solar UR ranging from €1.191/MWh to €1.31/MWh. Furthermore, solar UR are also reduced by an increase in wind share, but estimated effect is lower than the solar. Shifting the attention to wind unit revenues, the results follow a similar pattern as in the solar UR, but the effects are weaker. These results further support the cannibalization and cross-cannibalization of renewable producers' revenues in the German market.

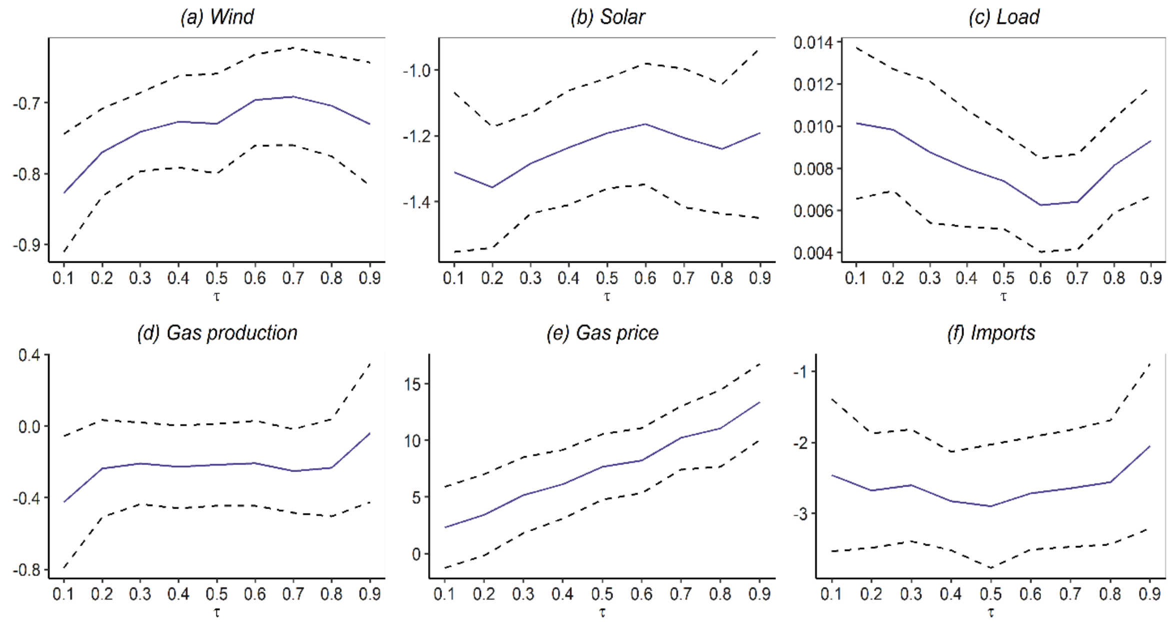

Fig. 3. Estimates of model (1) for solar UR across different quantiles with 95% confidence intervals (dashed lines).

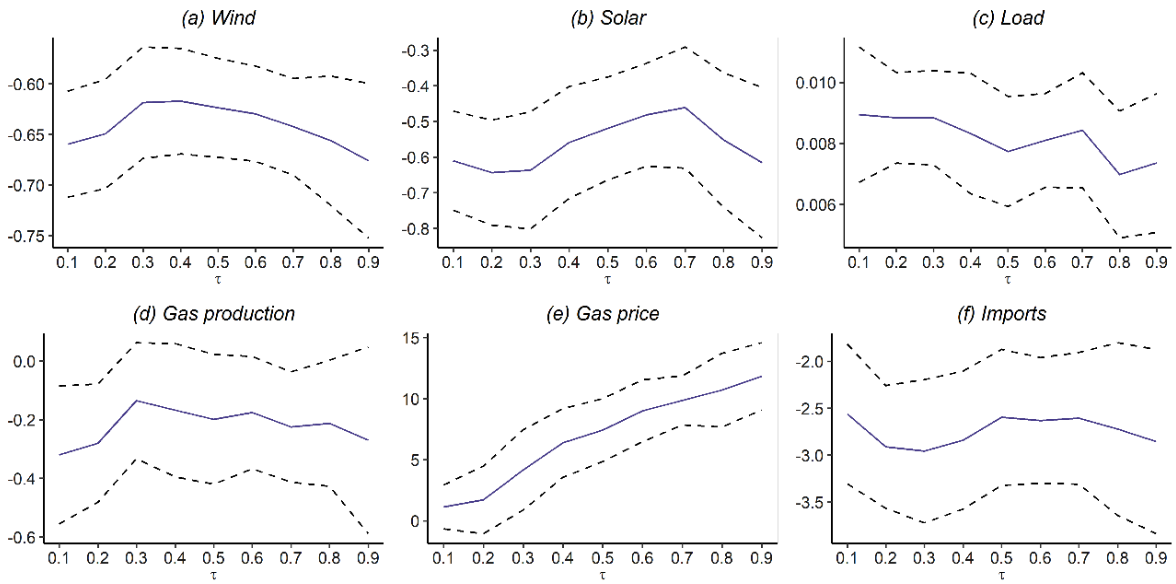

Fig. 4. Estimates of model (1) for wind UR across different quantiles with 95% confidence intervals (dashed lines).

Regarding the control variables, consumption and gas prices have a positive impact on both wind and solar unit revenues. The merit-order effect literature (Cludius et al., 2014) has shown that these two variables raise electricity prices, which is directly reflected on the technology's unit revenues in our results. On the other hand, gas share and net imports have a negative impact on wind and solar UR.

3.2 Value factors (relative cannibalization)

When we investigate the market value of renewable sources (Fig. 5-6), the results suggest that the cannibalization and cross-cannibalization effect appear under specific market conditions. Solar power cannibalizes its market value in all quantiles with the effect ranging across quantiles between €1.313/MWh to €2.575/MWh. The strongest negative effect appears in the lower solar market value quantiles. In contrast, a pp increase in wind share decreases the solar VF when the market value is low, while increases the solar VF when the market value is high. These cross-cannibalization results are significant at 1% level in almost all quantiles in both cases (see Appendix C, Tables C3-C4 for the complete results).

A different image is drawn when we examine the value factor of wind power: a pp increase in wind share reduces the wind market value but only for low wind values. Solar share is negatively associated with the wind VF for low value quantiles, but the only statistically significant results are found in intermediate-upper value quantiles ($\tau = 0.5\ to\ 0.9$) where solar raises the wind value in the market. The cause for this increase may lay in the required flexibility in the market when solar production is scarce and electricity prices spike. Consumption, bearing a negligible impact, is the only significant control variable in the quantile extremes.

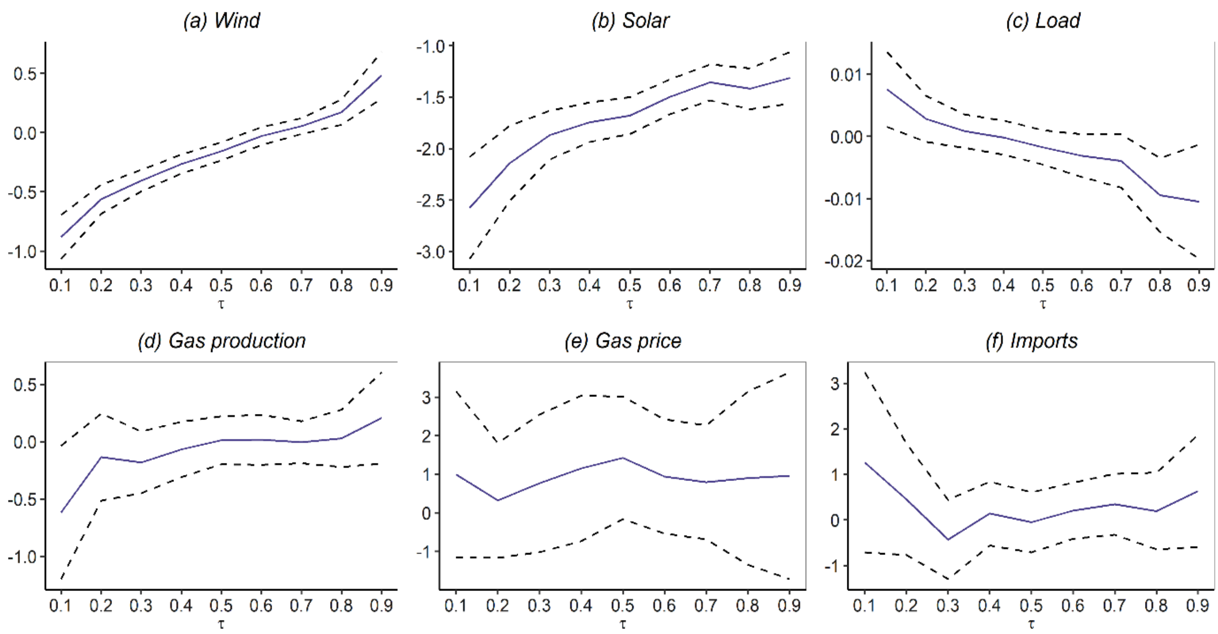

Fig. 5. Estimates of model (1) for solar VFs across different quantiles with 95% confidence intervals (dashed lines).

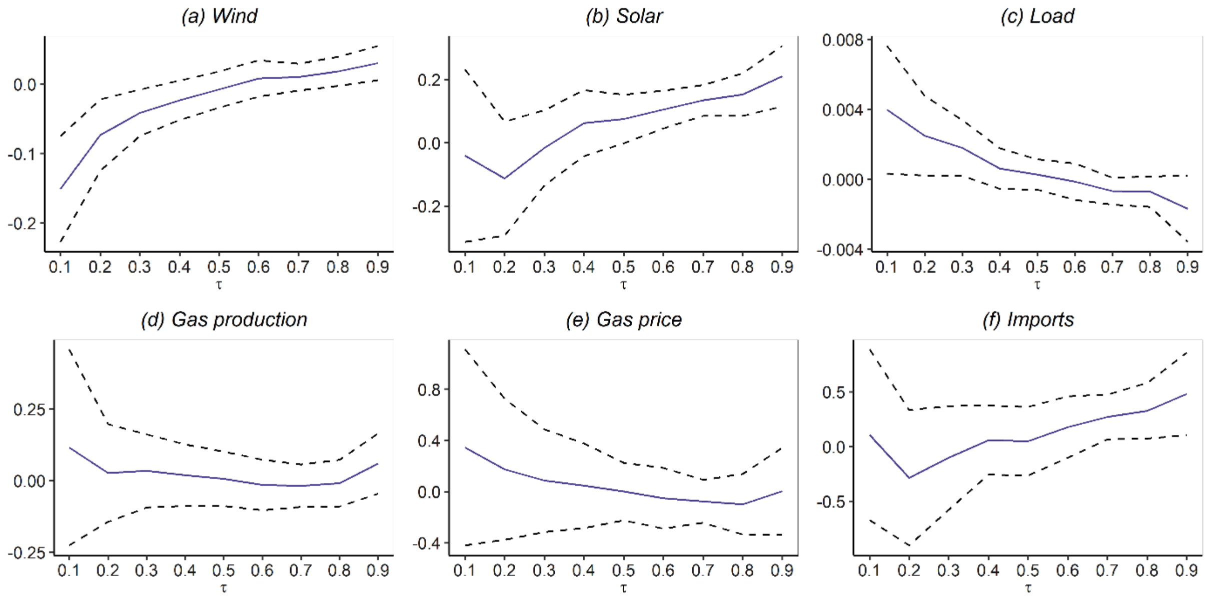

Fig. 6. Estimates of model (1) for wind VFs across different quantiles with 95% confidence intervals (dashed lines).

4. Conclusion

This paper investigates the unit revenues and market value of renewable sources and provides evidence that support the hypothesis that renewable sources reduce their unit revenues and market value. The observed effects, though, are not uniform across the wind and solar unit revenue and value factor distribution. Our results reflect both absolute and relative cannibalization, and thus that market conditions may constrain renewable expansion through profitability and risk. The cannibalization and cross-cannibalization effect are more prominent in lower unit revenues and market value quantiles, so wind and solar reduce their market value when their profit margins are already low. Even if simultaneously the value-adjusted levelized costs of generation continue to fall, it could be that the competitiveness of renewables is compromised in the market if the unit revenue and market value reduction is higher and quicker. This market uncertainty could also jeopardize long-term investments in renewable technologies, which in turn could affect the future German plans for a fully decarbonized sector by 2060. On the contrary, the positive effect of solar power on high wind value factors and the difference in magnitudes of the estimates between these two renewable sources, show that there could be some level of complementarity between them. Policies in Germany have recently been modified to allow renewables enter the market in a more competitive manner. These policies should be sought to account for the cannibalization and complementarity effects of renewable sources.

References

Clò, S. and D'Adamo, G., 2015. The dark side of the sun: How solar power production affects the market value of solar and gas sources. *Energy Economics*, *49*, pp.523-530. https://doi.org/10.1016/j.eneco.2015.03.025

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

Koenker, R. and Bassett Jr, G., 1978. Regression quantiles. *Econometrica: journal of the Econometric Society*, pp.33-50. https://doi.org/10.2307/1913643

Prol, J.L., Steininger, K.W. and Zilberman, D., 2020. The cannibalization effect of wind and solar in the California wholesale electricity market. *Energy Economics*, *85*, p.104552. https://doi.org/10.1016/j.eneco.2019.104552

Steffen, B., 2020. Estimating the cost of capital for renewable energy projects. *Energy Economics*, *88*, p.104783. https://doi.org/10.1016/j.eneco.2020.104783

NHH

NORGES HANDELSHØYSKOLE
Norwegian School of Economics

Helleveien 30
NO-5045 Bergen
Norway

T +47 55 95 90 00
E nhh.postmottak@nhh.no
W www.nhh.no