Centre de Recherche en Economie et Droit de l'Energie

AN ECONOMETRIC ANALYSIS OF THE MERIT ORDER EFFECT IN ELECTRICITY SPOT PRICE: THE GERMANY CASE

François Benhmad et Jacques Percebois

Cahier de recherche n° 18.01.120

26 janvier 2018

Centre de Recherche en Economie et Droit de l'Energie

CREDEN – Equipe ART Dev – Université Montpellier 1
Faculté d'Economie, Av. Raymond Dugrand, C.S. 79606
34960 Montpellier Cedex 2, France
Tél. : +33 (0)4 34 43 25 04

An econometric analysis of the merit order effect in electricity spot price: the Germany case

François Benhmad [1 *]   Jacques Percebois [2]

Abstract

In this paper, we carry out an econometric analysis for Germany, as a country with high penetration of renewable energy sources (RES), in order to investigate impact of wind energy and Photovoltaic feed-in on electricity spot price level, the so-called merit-order effect.
We have used an ARMA-X- GARCH-X modeling where wind generation and photovoltaic are considered as exogenous variables included in the mean and the variance equation, in order to assess the joint impact of RES on the electricity spot price level as well as on spot price volatility in Germany.
Our main empirical findings suggest that wind power and Photovoltaic feed-in decreases electricity spot price. However, their impact on electricity spot prices volatility are quite different. Indeed, the solar Photovoltaic power has a lowering on impact electricity price volatility whereas the wind feed-in exacerbates it.

Keywords: RES, Electricity spot prices, merit order effect, volatility.

JEL classification: Q41, Q42, Q48

---

[*] Corresponding author

[1] Montpellier University, Site Richter, Avenue Raymond Dugrand , CS79606, 34960 Montpellier Cedex2, France, Tél: +33.4.34.43.25.02, E-mail address : francois.benhmad@umontpellier.fr

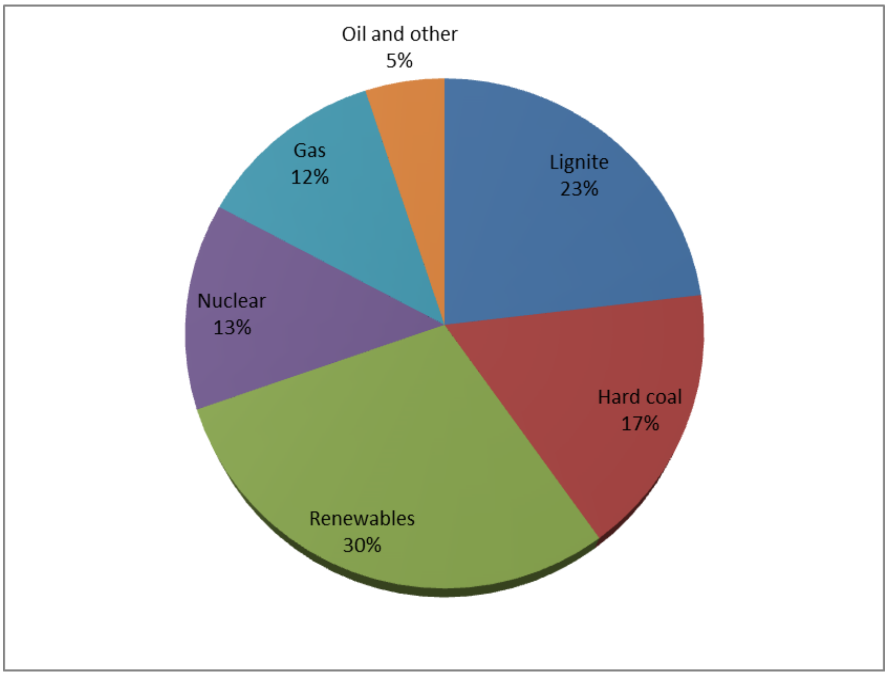
[2] Art-Dev, Montpellier University, Site Richter, Avenue Raymond Dugrand , CS79606, 34960 Montpellier Cedex2, France, Tél: +33.4.34.43.25.04, E-mail address : jacques.percebois@univ-montp1.fr

1. Introduction

Renewable energy is a key component of the EU energy strategy. It started with the adoption of the 1997 White paper and has been driven by the need to decarbonise the energy sector and address growing dependency on fossil fuel imports from politically unstable regions outside the EU. In 2009, the EU released the First Climate and Energy Package, with 2020 targets (compared to 1990 levels): 20% GHG emissions reduction, 20% renewable energy share in primary energy mix, 20% energy efficiency improvement. The Second Climate and Energy Package with targets for 2030 released in 2014 comprised the objectives submitted to the COP21 in 2015: 40% GHG emissions reductions, 27% renewable energy share in primary energy mix, 27% energy efficiency improvement (European Commission, 2015).

Various RES supporting schemes are operating in Europe, mainly feed-in tariffs, fixed premiums, green certificate systems. The German Renewable Energy Act, ”Erneuerbare-Energien-Gesetz” (EEG), a well known support scheme, has provided a favorable feed-in tariff (FIT) for a variety of renewable energy sources (RES) since the year 2000. It also gives priority to electric power in-feed from RES over power in-feed from conventional power plants, i.e., fossil- and nuclear-fuel thermal and already existing hydro-based power plants. Thus, all renewable sources combined made up to 30 per cent of gross electricity production in 2016 and are Germany’s second most important source of electricity generation after coal (BDEW, 2016). Figure 1 summarizes the recent evolution of the electricity mix. Carbon-intensive technologies clearly prevail in Germany, even though the renewable energy sources participation has grown significantly in the last few years.

Figure 1. Share of gross electricity generation (2016).



(Source: AG Energie bilanzen, author)

One of the central empirical finding in the literature on renewable energy is that an increase in RES generation would put a downward pressure on the spot electricity market price by displacing the conventional power plants with higher marginal cost.

In this paper, we carry out an econometric analysis in order to investigate the impact of the RES on electricity prices, the so-called, merit order effect by using a data sample of daily electricity spot prices in Germany for the 2012-2016 period.

There are two main contributions of this study to the literature. Firstly, in contrast to the previous studies in Germany, we take into account the joint impact of wind feed-in and solar photovoltaic on electricity price with a more recent dataset allowing us to assess the learning curve of new technologies integration in the energy-mix of Germany.

Secondly, an ARMA-X-GARCH-X modeling is used with wind and photovoltaic power generation as exogenous variables included in the mean and the variance equation. The goal is to assess the joint impact of intermittent renewable electricity generation on the electricity spot price level as well as on spot price volatility in Germany.

Our main findings suggest that intermittent wind feed-in and solar photovoltaic power generation not only decrease the spot electricity price in Germany but also have an impact on its price volatility. However, photovoltaic has a downward impact whereas the wind feed-in has an opposite impact-upward- on electricity spot price volatility.

The so-called merit order effect has gained increasing attention in the literature both on a theoretical basis and an empirical one. Indeed, Jensen and Skytte (2002) point out that RES generation enters at the base of the merit order function, thus shifting the supply curve to the right and crowding the most expensive marginal plants out from the market, with a reduction of the wholesale clearing electricity price.

Several papers have carried out empirical analysis on the impact of RES in electricity markets, finding evidence of the merit-order effect. Indeed, one of the central empirical findings in the literature on renewable energy sources (RES) is that an increase in intermittent sources generation would put a downward pressure on the spot electricity market price by displacing high fuel-cost marginal generation. RES installations, although they are very capital-intensive, have almost zero marginal generation cost and thus are certainly dispatched to meet demand. More expensive conventional power plants are crowded out, and the electricity price declines.

It is worth noting that several authors have explored this topic. For Germany, Bode and Groscurth (2006) find that renewable power generation lowers the electricity price. Neubarth et al. (2006) show that the daily average value of the market spot price decreases by 1 €/MWh per additional 1,000 MW wind capacity. Sensfuss et al. (2008) show that in 2006, renewables reduced the average market price by 7.83 €/MWh. Weigt (2008) concludes that the price was on average 10 €/MWh lower. Nicolosi and Fürsch (2009) confirm that in the short run, wind power feed-in reduces prices whereas in the long run, wind power affects conventional capacity, which could eventually be substituted. For Denmark, Munksgaard and Morthorst (2008) conclude that if there is little or no wind (<400MW), prices can increase up to around 80 €/MWh (600 DKK/MWh), whilst with strong wind (>1500MW) spot prices can be brought down to around 34 €/MWh (250 DKK/MWh). Jonsson et al. (2010) show that the average spot price is considerably lower at times where wind power production has been predicted to be large. Sáenz de Miera et al. (2008) found that wind power generation in Spain would have led to a drop in the wholesale price amounting to 7.08 €/MWh in 2005, 4.75 €/MWh in 2006, and 12.44 €/MWh during the first half of 2007.

Gelabert el al. (2011) find that an increase of renewable electricity production by 1 GWh reduces the daily average of the Spanish electricity price by 2 €/MWh. Wurzburg et al. (2013) find that additional RES generation by 1 GWh reduces the daily average price by roughly 1 €/MWh in German and Austrian integrated markets. Woo et al. (2011) carry out a empirical analysis for the Texas electricity price market and showed a strong negative effect of wind power generation on Texas balancing electricity prices. Huisman et al. (2013) obtained equivalent results for the Nord Pool market by modeling energy supply and demand. Ketterer (2014) also examined wind power in German electricity markets and found that an additional RES generation by 1GWh led to a reduction of daily spot price by approximatively 1€/MWh.

Benhmad and Percebois (2016 , 2017) also explored German electricity markets for a more recent dataset and found similar results consisting on a reduction of daily spot price by approximatively 1€/MWh for each an additional GWh of wind feed-in.

The paper is organized as follows. Section 2 provides an overview of the merit order effect. In section 3, we carry out an empirical analysis and discuss the main findings. Section 4 provides some concluding remarks.

2. The merit order effect

In order to supply electricity, different power generation technologies compete with each other according to their availability of supply and their marginal cost of production (fossil fuels such as coal or natural gas, nuclear power, renewable energy sources like hydroelectric generators, wind or solar energy).

The electricity market operates according to day-ahead bidding. Indeed, the transmission system operators basically receives the bids from all power producers for the quantity and cost for each hour of the next day and then assigns the dispatch based on the lowest cost producer until demand is met. All producers who dispatch get the marginal price of the last producer that dispatched. As a result even if the last producer only produced theoretically one kWh then that is the price of the system. This conventional approach consists in ranking the power plants of the system in ascending order of their marginal cost of generation. This approach is called the merit order.

Traditionally, the hydroelectric power plants are the first to be dispatched on the grid. They are followed respectively by nuclear plants, coal-fired and/or combined-cycle gas turbines (CCGT), and then open cycle gas turbine (OCGT) plants and oil-fired units with the highest fuel costs.

Although power plants with the highest marginal cost correspond to the oil-fired gas turbines, gas plants are usually the marginal producers and as a result the cost of gas is very relevant to the wholesale pricing setting of electricity. But, due to EU ETS price weaknesses, carbon prices have plunged to record low prices making it more expensive to burn gas than coal. Moreover, The U.S. coal surpluses export due to shale gas revolution has lowered coal prices in Europe whereas oil indexation of gas contracts and geopolitical concerns have made natural gas more expensive. Therefore, the price competitiveness of more polluting coal-fired plants, allow them to be dispatched before the gas turbine and to be the key of electricity price setting.

However, a pricing based on marginal costs could never allow RES to recover their fixed costs. Indeed, the photovoltaic (PV) and wind power plants have a high average cost and their load factor is too low due to intermittency. Therefore, subsidising renewable energy sources by feed-in tariff scheme allowing their average costs to be recovered corresponds to a support mechanism outside the market. By granting an economic return above the market price, these supporting schemes have promoted RES development in several European electricity markets.

As the renewable energy sources (RES) have priority for grid access at zero marginal cost, i.e, have the privilege of priority dispatch, electricity from RES participating in the auction process at zero marginal cost replaces every other energy source with higher marginal cost. The decoupling of spot market prices and RES in-feed due to FIT support scheme results in lower average equilibrium price level on the spot market. This downward pressure on wholesale electricity prices is the so-called merit order effect (Sioshansi, 2013).

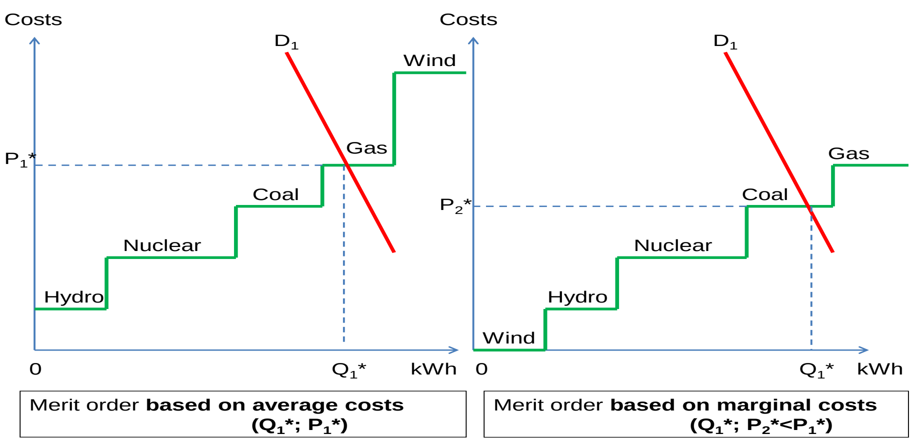
Indeed, during full and peak times, the marginal power plant is logically a combined-cycle gas-fired plant. However, as they have no fuel costs, RES have a zero marginal cost. Thus, electricity from RES makes the coal-fired plant becoming the marginal plant. The electricity market price is thus lower than it would be if there was no RES power in-feed. Lowering electricity spot prices causes a serious distortion to the electricity market.

Indeed, if the wind or solar power plants were not remunerated according to feed-in tariffs scheme they could never be profitable because the spot market price at full and peak periods would not allow them to recovery their fixed costs.

Furthermore, the insufficient dispatching of the flexible gas-fired plants jeopardises their profitability as they cannot be operated profitably because peak spot prices are too often below their marginal operation costs. Thus, the RES, by lowering equilibrium spot price level, will squeeze peak load power plants out of the market due to their comparatively higher variable costs.

The following Figure 2 shows the merit-order curve based respectively on average and on marginal costs.

Figure2. Merit order based on average and marginal costs



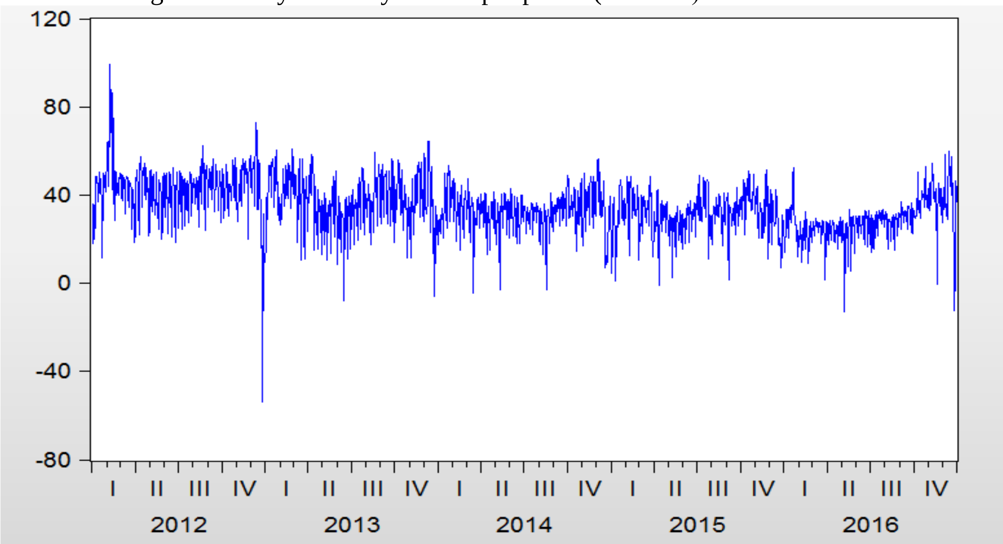
3. Empirical evidence

3.1 Data

The analysis is based on time-series data of the German power system as provided by the platform of the European Energy Exchange (EEX). The spot market is a day-ahead market and the spot price is an hourly contract with physical delivery on the next day. The Phelix day base is then calculated as the average, weighted price over these hourly contracts. The sample data covers the period going from the 1st January 2012 to the 31st December 2016, summing up to 1827 observations.

Figure 3 provides a plot of the data for the whole period. It is easy to see that the data exhibits the typical features of electricity prices and contains several periods of extreme volatility, price spikes and shows a mean-reverting behavior.

Figure 3. Daily EEX day-ahead spot prices (€/ MWh)



The descriptive statistics of German electricity spot prices summarized in Table 1 show that values of sample mean are close to 34.97 and a standard deviation of 11.74.

Table 1 Descriptive statistics of German electricity spot prices.

Observations	1827
Mean	34.97
Std.Dev.	11.74
Skewness	-0.33
Kurtosis	6.86
Jarque-Bera	1171.37
Prob.	0.0000

The sample kurtosis (6.86) is higher than 3, the kurtosis of a normal distribution, implying that price distribution exhibit fat tails. Furthermore, negative skewness indicates a greater probability of large falls in electricity price than large increases. By the Jarque- Bera statistic, the null hypothesis of normal distributions is also rejected.

For the RES generation, we use daily forecasts of wind power and photovoltaic generation for the full period as illustrated in Figure 4 and 5.

Figure 4 .Wind power feed-in (2012-2016)

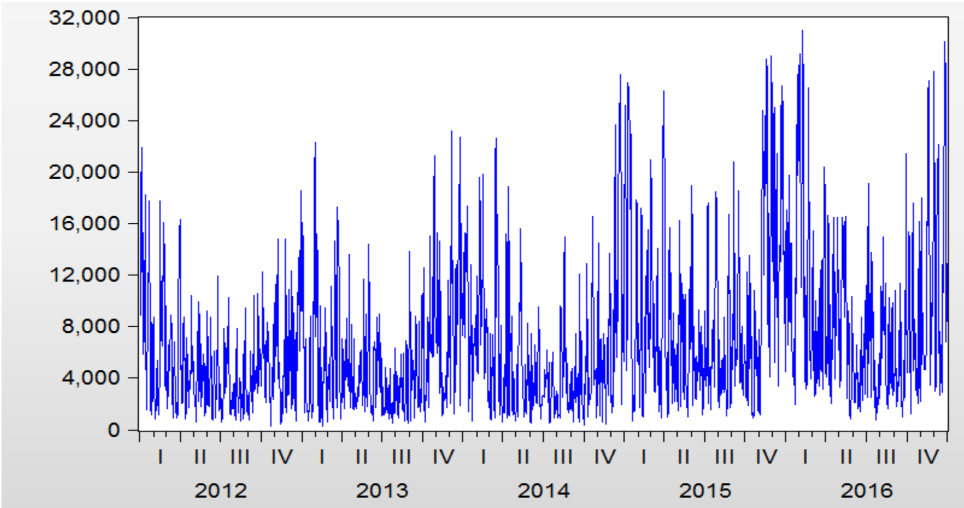
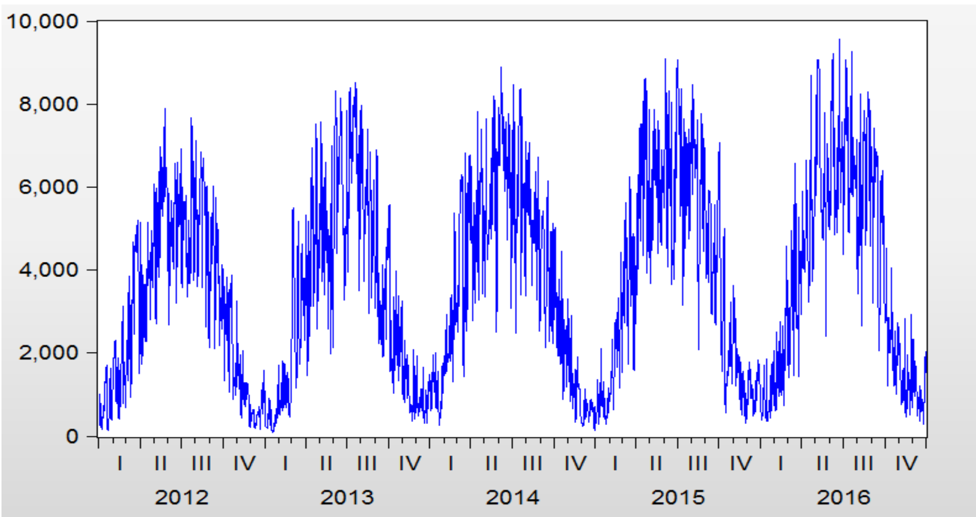


Figure 5.Photovoltaic power generation (2012-2016)



These forecasts are made by the four German transmission system operators (TSO).[1]

[1] The data are available in 15-minute format. For this study, 15-minute MW data are averaged for each hour and again averaged to MWh per day. There is four transmission system operators (TSO) in Germany and one TSO in Austria: *Amprion GmbH*, *TenneT TSO GmbH*, *50hertz Transmission GmbH*, *EnBW Transportnetze*, and *APG-Austrian Power Grid AG*.

The descriptive statistics (Table 2) show that the wind power and photovoltaic forecasts fed into the grid has a respectively a daily mean of 6817 and 3651 MWh per day but a high variability.

Table 2. Descriptive statistics of wind feed-in and photovoltaic

	Wind	PV
Observations	1827	1827
Mean	6817.63	3651
Std.Dev.	5652.75	2380
Skewness	1.54	0.28
Kurtosis	5.32	1.91
Jarque-Bera	1135.58	113.14
Prob.	0.0000	0.0000

3.2 Empirical methodology: ARMA-X-GARCH-X model

In order to explore the link between daily electricity spot price and RES wind in-feed (wind and photovoltaic), we should carry out a linear regression using least squares method.

As electricity spot prices deviates from the normal distribution due to more frequent large outliers, outliers should first be removed before conducting the regression analysis.

In line with the literature, we remove values that exceed three times the standard deviation of the original price series. The outliers are then replaced with the value of three times the standard deviation. Furthermore, the analysis of electricity spot prices correlogram shows a strong autocorrelation in lags 7, 14, 21, 28 indicating a weekly seasonality. Indeed, electricity demand has a typical seasonal pattern as it varies throughout the day and during the week, as well as across the year.

Therefore, models of electricity prices should incorporate seasonality by using dummy variables. For the weekly seasonality, dummy variables coefficients show a progressive lowering of electricity spot prices from the beginning to the end of the week. The lowest value occurs Saturday. For the monthly dummy variables, although some coefficients are not significant, we see a lowering of electricity spot prices during March, April, May, June, July and August.

After outliers removal and seasonal adjustment, we carry out an augmented Dickey-Fuller (ADF) test (Dickey and Fuller,1981) to test for stationarity properties of electricity adjusted spot prices.

Table 3. ADF unit root test on adjusted electricity spot prices

		t-statistic	Prob.
Augmented Dickey-Fuller test statistic		-8.588311	0.0000
Test Critical Values:	1% level	-3.433739	
	5% level	-2.862924	
	10% level	-2.567554	

The ADF t-statistic is -8.85 whereas the 5% critical value is -2.86. The null hypothesis of a unit root is rejected, spot electricity prices are then stationary. As electricity is not storable, the price tends to spike and then revert (mean-reverting behavior) as soon as the divergence of supply and demand is resolved (Escribano et al., 2011).

For the Wind power, the variable shows seasonal dynamics which could be accounted for by using dummy variables. The deseasonnalized time series called (wind_sa) is then tested using the ADF test which reveals their stationary behavior (the ADF t-statistic is -19.17 whereas the 5% critical value is -2.86).

Table 4. ADF unit root test on WIND_SA

		t-statistic	Prob.
Augmented Dickey-Fuller test statistic		-19.173116	0.0000
Test Critical Values:	1% level	-3.433739	
	5% level	-2.862924	
	10% level	-2.567554	

For the photovoltaic power, the variable shows seasonal dynamics which could be accounted for by using dummy variables. The deseasonnalized time series called (pv_sa) is then tested using the ADF test which reveals their stationary behavior (the ADF t-statistic is -23.18 whereas the 5% critical value is -2.86).

Table 5. ADF unit root test on PV_SA

		t-statistic	Prob.
Augmented Dickey-Fuller test statistic		-23.18669	0.0000
Test Critical Values:	1% level	-3.433739	
	5% level	-2.862924	
	10% level	-2.567554	

Even after removing out seasonality and outliers, electricity spot prices still present high order serial correlation in its structure which could be filtered out by an autoregressive moving average(ARMA) filter (Box and Jenkins, 1976) . Therefore, the impact of wind-in feed and photovoltaic on electricity prices is explored according to the following ARMA-X model where the wind feed-in and photovoltaic power considered as exogenous variables X:

$$(spot\_sa)_t = \alpha_0 + \sum_{i=1}^{p} \alpha_1 (spot\_sa)_{t-i} + \sum_{j=1}^{q} \beta_j \varepsilon_{t-j} + \delta wind\_sa_t + \lambda pv\_sa_t + \upsilon_t$$

The selection of autoregressive lag p could depend on AIC minimization, and q is assumed to be 0. According to the Akaike information criterion, the best choice was lag p=7 which corresponds to a weekly seasonality. [2]

The estimation results a reported in Table 6 (Column A) reveal a negative impact of wind power on the electricity price in Germany. Indeed, for each additional GWh of wind feed-in, the electricity price decreases by 1€/MWh at the spot market. Therefore, and given the average wind electricity generation during 2012-2016, the merit-order effect roughly corresponds to an average price decrease, in absolute terms, of approximately 7€/MWh.

---

[2] *The results of 7 autoregressive terms, not reported here, are available upon request.*

Table 6. Wind and Photovoltaic feed-in impact on electricity prices and volatility

Dependant variable : electricity spot prices
Sample : 1.1.2012 31.12.2016

	(A)	(B)
		Mean equation
Constant	-0.46 (0.65)	0.00 (0.99)
Wind	**-0.00099(0.00)**	**-0.0010 (0.00)**
PV		**-0.00098(0.00)**
		Variance equation
Constant	3.59 (0.00)	3.44(0.00)
Alpha	0.31 (0.00)	0.31(0.00)
Beta	0.56 (0.00)	0.56 (0.00)
Wind	**0.00016 (0.00)**	**0.00016 (0.00)**
PV		**-0.0004 (0.00)**
Adj.R squared	0.7467	0.7584
AIC	5.7713	5.6973
BIC	5.8116	5.7426

Note: AIC and BIC stand respectively for Akaike and Bayesian information criterion, p-values are in parentheses.

The residuals of linear regression should then be homoskedastic according to least squares estimator hypothesis. Therefore, an ARCH-effect test following the procedure of Engle (1982) is carried out on residuals data (see, Table 7).

Table 7. ARCH heteroskedasticity test on regression residuals

Heteroskedasticity Test: ARCH			
F-statistic	120.83	Prob. F(1,1816)	0.0000
Obs*R-squared	113.41	Prob.Chi-Square(1)	0.0000

We conclude that the time series of residuals is heteroskedastic and the parsimonious GARCH(1,1) specification (Bolleslev,1986) could be used to take into account the the time-varying volatility feature of spot electricity spot prices.

As our goal consists in exploring the joint impact of wind in-feed on spot electricity price level and also on price volatility dynamics, the wind feed-in should be taken into account as an exogenous variable in the mean equation as well as in the variance equation. Therefore, our empirical analysis is based on ARMA(p,q)-X-GARCH(1,1)-X modeling where the exogenous variable X represents the wind in-feed. The empirical results based on AR(7)-X-GARCH(1,1)-X model are reported in Table 6 (Column A) .

The model parameters are positive and statistically significant at the 1% level. We can conclude that the introduction of wind electricity in Germany has not only reduced the electricity spot prices (-0.001), but also induced an increase of their volatility (positive sign +0.00016 at the conditional variance equation).

Indeed, wind in-feed , due to the merit-order effect, not only reduces the electricity spot price level making them sometimes negative, but induces an increase of electricity price volatility, exacerbating risks in electricity markets.

The estimation results also reported in Table 6 (Column B) reveal not only a negative impact of wind power on the electricity price in Germany but also a negative impact of solar photovoltaic generation on electricity prices of the same magnitude. Indeed, for each additional GWh of photovoltaic feed-in, the electricity price decreases approximatively by 1€/MWh at the spot market. Therefore, and given the average photovoltaic electricity generation during 2012-2016, the merit-order effect induced by photovoltaic roughly corresponds to an average price decrease, in absolute terms, of approximately 3.65€/MWh.

To explore the joint impact of wind in-feed and photovoltaic on spot electricity price level and on price volatility dynamics, the two variables should be taken into account as exogenous variable in the mean equation as well as in the variance equation. The empirical results based on AR(7)-X-GARCH(1,1)-X model are reported in Table 6 (Column B) .The model parameters are positive and statistically significant at the 1% level.

We can conclude that the introduction of wind electricity in Germany has not only reduced the electricity spot prices (-0.001), but also induced an increase of their volatility (positive sign +0.00016 at the conditional variance equation). However, photovoltaic electricity not only reduced electricity spot prices (-0.001), but also induced a downward pressure of their volatility (negative sign - 0.0004 at the conditional variance equation). Therefore, we conclude that wind and solar photovoltaic have the same effect on electricity spot prices (downward effect) of the same magnitude approximatively, but have the opposite impact on its volatility dynamics.

Thus, the full model containing wind feed-in and photovoltaic electricity generation has a clear superiority on the model based only upon wind feed-in as shown by high level of adjusted R squared and information criterions (see table 6).

Indeed, the upward effect on electricity prices volatility induced by highly intermittent wind feed-in is largely offset by the photovoltaic downward effect. Thus, the mixture of installed electricity generation capacities consisting on wind and solar photovoltaic allows German electricity market volatility to be less higher that it would be if Germany had only installed wind generation capacities.

4. Conclusion:

The feed-in tariffs support scheme, consisting in buying intermittent electricity at a fixed price off-market considerably higher than the spot market price, has clearly induced a huge market penetration of RES in Germany.

The fact that this intermittent electricity has statutory priority on the grid and at the same time participates in spot market auctions at a zero marginal cost can have negative effects on the functioning of the spot market as it leads to a downward trend in the equilibrium price: the so-called merit-order effect. Indeed, each additional GWh wind (and RES in general) production of electricity will have a crowding effect on higher marginal cost power plants.

The purpose of the paper consists in quantifying the merit order effect of wind feed-in and photovoltaics in Germany during the 2012-2016 period. One of the major findings is that the day-ahead electricity spot price fell by 1€/MWh for each additional GWh respectively for the two renewable energy sources. Moreover, the wind electricity generation has an increasing effect on the spot prices volatility which is largely offset by photovoltaics with their strong downward impact on volatility.

However, although the volatility is controlled by a mixture of installed capacities of RES, the merit order effect remains a big challenge for Germany. This negative effect of RES could significantly be limited by the interconnections of between Germany and neighbouring countries especially France, allowing it to export its surplus wind power. Therefore, the development of the renewable energy sources should be accompanied by a market coupling in order to address their challenges to European electricity system.

References

Benhmad,F., Percebois, J.,(2016), "Wind power feed-in impact on electricity prices in Germany 2009-2013", *European Journal of comparative economics.* July, Volume13-Issue1

Benhmad,F., Percebois, J.,(2017), On the Impact of Wind Feed-in and Interconnections on Electricity Price in Germany, *Energy Studies Review,* Volume 23, Numero 1,.

BMU (2016), "Renewable Energies Driving Germany's Energiewende", Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, www.bmu.de/english · www.erneuerbare-energien.de (Octobre 2016)

Bode S., Groscurth H.M.(2006), 'The Effect of the German Renewable Energy Act (EEG) on the electricity price', *HWWA Discussion Paper* (**348**).

Bollerslev T.(1986), 'Generalized autoregressive conditional heteroskedasticity', *Journal of Econometrics (***31)**, 307–327.

Box G.E.P., Jenkins G.M. (1970), 'Time Series Analysis Forecasting and Control", Holden-Day, San Francisco.

Dickey,D.A., Fuller,W.A., (1981), 'Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root', *Econometrica* (**49)**, 1057-1072.

Engle,R. (1982), 'Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation', *Econometrica (***50)**, 987-1007.

ENTSO-E (2012), 'Load and consumption data: Specificities of member countries', *Report*, European Network of Transmission System Operators for Electricity, Brussels.

Escribano A., Ignacio Peña J., Villaplana P., (2011), 'Modeling electricity prices: International evidence' *Oxford Bulletin of Economics and Statistics* **(73)**, 622-650.

Gelabert L., Labandeira X., Linares, P., (2011), ' An ex-post analysis of the effect of renewable and cogeneration on Spanish electricity prices' *Energy Economics* **(33)**, S59-S65.

Jensen S.G., Skytte K. (2002), 'Interactions between the power and green certificate markets', *Energy Policy* **(30)**, 425–435.

Jonsson T., Pinson P., Madsen H., (2010), 'On the market impacts of wind energy forecasts", *Energy Economics* (**32)**, 313–320.

Keles D., Genoese M., Most D., Ortlieb S., and Fichtner W., (2013), 'A combined modeling approach for wind power feed-in and electricity spot prices' *Energy Policy* **(59)**, 213-225.

Knittel C.R., Roberts M.R., (2005) 'An empirical examination of restructured electricity prices', *Energy Economics* (**27),** 791-817.

Ketterer J.C., (2014), 'The impact of wind power generation on the electricity price in Germany', *Energy Economics* **(44)**, 270-280

Mugele C., Rachev S.T., Trück S., (2005), 'Stable modeling of different European power markets', *Investment Management and Financial Innovations* (**2),** 65–85.

Munksgaard J., Morthorst P.E., (2008), 'Wind power in the Danish liberalised power market Policy measures, price impact and investor incentives', *Energy Policy* (**36)**, 3940–3947.

Neubarth J., Woll O., et Weber C., Gerecht M., (2006), 'Influence of Wind Electricity Generation on Spot Prices', *Energiewirtschaftliche* (**56)** , 42–45.

Nicolosi M., Fürsch M., (2009), 'The impact of an increasing share of RES-E on the conventional power market - The example of Germany', *Zeitschrift für Energiewirtschaft* (**33)**, 246–254.

Sáenz de Miera *G.*, del Rio Gonzalez P., Vizcaino I., (2008), ' Analysing the impact of renewable electricity support schemes on power prices: The case of wind electricity in Spain', *Energy Policy* (**36)**, 3345–3359.

Sensfuß F., Ragwitz M., and 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.

Sioshansi F., (2013), 'Evolution of global Electricity markets'. Ed.Elsevier, June 2013.

Woo C.-K., Horowitz I., Moore J., and Pacheco A., (2011), ' The impact of wind generation on the electricity spot-market price level and variance: The Texas experience' *Energy Policy,* (**39)**:3939-3944.

Wurzburg K., Labandeira X., and Linares P., (2013), 'Renewable generation and electricity prices:Taking stock and new evidence for Germany and Austria' *Energy Economics*(**40)**, 159-171.