HOW IS WIND ENERGY CHANGING THE PRICE DYNAMICS IN TURKISH POWER MARKET?

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Abstract - The purpose of this paper is to investigate the price dynamics in Turkish power market, and discuss the effects of intermittent renewable energy technologies on electricity power market. For this purpose, long-run and short-run relations between electricity prices, fossil fuel prices and wind power generation output are investigated by using monthly data between 2012 and 2018. The results show that the wind power has statistically significant impact on wholesale market prices as expected. On the other hand, this effect is smaller relative to other major fuel sources, since the share of wind technologies is still low compared to other technologies.

I. INTRODUCTION

Turkey has significant renewable energy potential; however, its power supply is still dominated by fossil fuels to a significant extent. With the recent regulations, significant investments are made in renewable energy technologies, and the installed capacity in wind power has exceeded 7 GW by the end of 2018. Projections show that investments in intermittent renewable energy technologies (wind and solar) are expected to continue, and total installed capacity in renewable technologies will reach to 61 GW by 2023.

Experiences of other economies have shown that renewable energy technologies are changing the dynamics of electricity markets, and new challenges and problems have emerged as the share of new – intermittent - technologies are increasing in the power supply [1,2]. One notable effect has been observed in electricity markets, and high diffusion of new technologies are causing changes in temporal and geographic patterns of wholesale peak prices, changes in the locational marginal cost, and increase uncertainty in prices [3,4]. Prices in wholesale electricity markets are determined by the total load and seasonal patterns of demand, fuel costs, variable costs of power plants and other factors such as transmission capacity constraints, environmental regulations and market-specific factors [5–7]. Intermittent renewable energy technologies have different operational characteristics than conventional thermal plants, and new technologies are replacing natural gas plants (and coal plants in some cases) in the dispatch merit-order, known as the "merit-order effect" [3,8]. Many studies have shown that these technologies cause negative merit-order effect, and the average day-ahead prices have declined in many markets [1,9].
Understanding the impacts on electricity markets is crucial to develop consistent regulations and renewable energy policies, and there has been a growing literature on both the US and European electricity markets. Yet, the literature on developing economies is limited, and there is almost no analysis on some economies which have a functioning electricity market. In this respect, this study aims to contribute to the literature by looking at the price dynamics in Turkish power market, and discuss the effects of intermittent renewable energy technologies on electricity power market by using empirical methods.

II. AN OVERVIEW OF TURKISH ELECTRICITY MARKET

After the economic crisis in 2001, Turkey initiated major economic reforms to increase competitiveness of the economy, strengthen the financial sector and restructure the government sector. One major pillar of these reforms was restructuring the energy sector which was heavily controlled by the state, and restrictions on private investment in the electricity market were removed, state-owned generation and distribution utilities were privatized and day-ahead/ intra-day electricity markets were established [10]. Similar to European counterparts, transactions in the Turkish wholesale electricity market are made through bilateral contracts and electricity exchange which consists of day-ahead, intra-day and balancing markets. Day-ahead market (GOP), which functions through a uniform price auction for each delivery hour of the following day, became operational in December 2011. In this market, the quoted prices for each of the 24 hours are determined simultaneously through the daily auction, with the physical delivery arranged at each specific hour on the next day. Market participants submit their bids at a minimum volume of 0.1 MW for individual hours or blocks, and demand and supply bids are matched by the Turkish Energy Exchange (EXIST). The bids cannot be negative or higher than 2000 TL/MWh, and uniform market-clearing price (Piyasa Takas Fiyatı-PTF) which is the price that maximizes the total surplus (consumer surplus plus producer surplus) is established for the delivery hour of the next day.

Figure 1 presents hourly day-ahead market prices (capped at 500 TL/MWh) in selected years. The figure shows some features of TEM. Firstly, seasonal patterns can be observed, and during the spring period there is a decline in prices –mostly caused by hydropower plants. Secondly, prices increase during winter which is caused by gas shortages. Finally, there was a significant increase in prices in the second half of 2018. Following the turmoil in financial markets, Turkish gas operator, BOTAS, changed its pricing formula from quarter tariff to monthly tariff in 2018. As Turkish lira depreciated significantly during the period, gas prices increased causing jump in wholesale market prices.

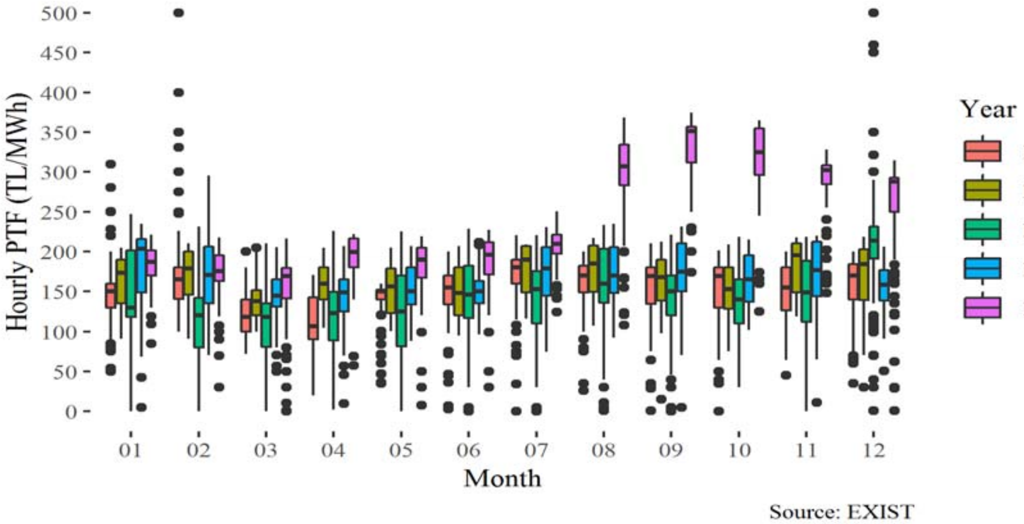

Figure 1 Hourly day-ahead market prices

Renewable energy investments are supported by YEKDEM mechanism, and technology specific feed-in tariffs are provided to investors [10,11]. Additional payments are also given for domestically manufactured equipment use in renewable energy power plants. Table 1 presents installed capacity in Turkey by the end of 2018. The system is still dominated by fossil fuels, but the share of renewable technologies is increasing. Renewable technologies are prioritized in power supply, hence the share of renewable technologies is daily or hourly generation may be higher than the average generation.

Table 1. Installed capacity by technology in Turkey by 2018

	Installed Capacity		Generation	
Type	MW	Share	GWh	Share
Domestic Coal	10247	11,5%	3800	16,3%
Imported Coal	8939	10,0%	5326	22,8%
Natural Gas / LNG	25625	28,8%	3564	15,3%
Geothermal	1302	1,5%	660	2,8%
Hydro - Dam	20538	23,1%	5032	21,6%
Hydro - River	7832	8,8%	2133	9,2%
Wind	6968	7,8%	1868	8,0%
Solar	81,7	0,1%	10	0,0%
Thermal (Unlicensed)	327	0,4%	19	0,1%
Wind (Unlicensed)	63	0,1%	11	0,0%
Hydro (Unlicensed)	7,6	0,0%	3	0,0%
Solar (Unlicensed)	5157	5,8%	534	2,3%
Other	1958,7	2,2%	349	1,5%
Total	89046		23309	
Source	TEIAS,EXIST [12,13]			

III. METHODOLOGY AND DATA

We focus on Turkish electricity market and the market's major fuel sources as well as renewable energy sources. In this manner, our data consists of monthly averages of PTF, coal, natural gas and oil prices in US dollars as well as wind power generation output between 2012 and 2018. Turkish electricity market data is taken from Energy Exchange Istanbul and other data is taken from the World Bank Data used in the study is summarized in Table 2. All variables are transformed into natural logarithms for the analysis to stabilize the variance.

Table 2. Summary of the Data

Data	Description	Resolution
Turkish Electricity Price (PTF)	Market clearing price	monthly, average spot price in US dollars
Oil Price (OIL)		monthly, average spot price in US dollars (Brent)
Natural Gas Price (NGAS)		monthly, average spot price in US dollars (Europe)
Coal Price (COAL)		monthly, average spot price in US dollars (South Africa)
Wind Power Generation (WIND)		monthly, average power generation in GWh

In time series modelling, testing stationarity is a very important concept to prevent invalid inferences. In addition, the stationarity test is needed to determine the order of integration. In order to check stationarity of the data, widely used Augmented Dickey Fuller (ADF) test is employed. The test is conducted for all variables on the model including the intercept, intercept and trend and results are summarized in Table 3. According to the test results, variables are non-stationary in level but stationary in their first differences at 1% and 5%significance level. Therefore, we conclude that all variables are integrated of order 1.This means cointegration order for our models is one.

Table 3 Augmented Dickey-Fuller Unit Root Test Results

		Unit Root Tests (Levels)		Unit Root Test (First Differences)	
		ADF		ADF	
		Statistics	Prob	Statistics	Prob
LPTF	Intercept	-2.4029	0.1441	-11.8103	0.0001
LWIND		-1.9211	0.3212	-10.5426	0.0001
LCOAL		-1.4305	0.5635	-7.8150	0.0000
LNGAS		-1.2054	0.6689	-7.4782	0.0000
LOIL		-1.6493	0.4530	-6.4695	0.0000
LPTF	Intercept and Trend	-4.0440	0.0109	-11.7999	0.0000
LWIND		-3.0674	0.1210	-10.4734	0.0000
LCOAL		-1.5092	0.8187	-8.1162	0.0000
LNGAS		-0.5865	0.9771	-7.5134	0.0000
LOIL		-1.8601	0.6660	-6.4473	0.0000

When the variables are not stationary in their level standard Vector Auto Regression (VAR) model cannot be applied to analyze the relations between variables. For this case, cointegration analysis is needed to shows us the long-run comovement of the variables. A set of variables is defined as cointegrated if a linear combination of them is stationary although some of them or even all of them are nonstationary. Hence, we employed Johansen Cointegation Test to check the existence of long-run relationship between the variables. Since, cointegration analysis and causality analysis are sensitive to lag lengths optimum lag length is determined as 2 according to LR, FPE and AIC criterions.Table 4 summarizes the Trace statistics of Johansen Cointegration Test, which means there are 2 cointegrating equations at 5% significance level.

Table 4 Trace Statistics Results

Hypothesized No. of CE(s)	Trace Statistic	0.05 Critical Value	Prob
None*	64.91037	47.85613	0.0006
At Most 1*	29.85484	29.79707	0.0492
At Most 2	12.84820	15.49471	0.1205
At Most 3	0.324482	3.841466	0.5689

Since the variables have long run relationship, Vector Error Correction Model (VECM) and VECM based Granger-Causality Tests can be applied in order to estimate the causality relationships. VECM results and residual diagnostics tests are summarized in Table 5. Wind power is selected as exogenous variable, since wind power is intermittent and wind power generation is not affected by other variables. Moreover, wind power investments are driven by the government feed-in tariff scheme. Solar power is not included because almost all generated solar output is from unlicensed investments, and these technologies can participate in wholesale market (except for aggregation).

Accordingly, there is a long run causality running from natural gas and oil to electricity prices (PTF). Furthermore, there is also long run causality from oil prices and natural gas to coal prices. Also, residual diagnostic tests show that there is no serial correlation, no heteroskedasticity in the residuals and residuals are normally distributed at 10% significance level.

Table 5. VECM Results

	Dependent Variable: LPTF
$LPTF_{t-1}$	-0.435862(0.08727)
$LOIL_{t-1}$	0.065252 (0.06624)
$LWIND_{t-1}$	0.000826 (0.02093)
$LNGAS_{t-1}$ $LCOAL_{t-1}$	-0.023136 0.04840) -0.032698 (0.04455)
Breusch-Godfrey Serrial Correlation LM Test	5.602910 (0.0607)
Heteroskedasticity Test: Breusch-Pagan-Godfrey	11.74156 (0.5489)
Jarque-Bera Normality Test	0.3221 (0.8512)

After VECM model, we employed VECM based Granger Causality test. Test results are represented in Table 6. LCOAL Granger causes LPTF at 10% significance level where LNGAS and LOIL Granger cause LPTF at 5% significance level. In other words, there is a unidirectional causality from coal, natural gas and oil prices to electricity prices.

Table 6 Granger-Causality Results

	Dependent Variable: LPTF
LCOAL	4.729250 (0.0940)
LNGAS	6.856970 (0.0324)
LOIL	12.96460 (0.0015)
ALL	22.26169 (0.0011)

CONCLUSION

In this study, Turkish market price dynamics and how wind energy is affecting market dynamics is analyzed. Using monthly average data, a VECM model is established to include correlations between major fuel prices. Given the results of VECM model, wind power has statistically significant impact on wholesale market prices as expected. On the other hand, this effect is smaller relative to other major fuel sources, since the share of wind technologies is still low compared to other technologies. As more intermittent technologies are projected to be operational in the coming years, Turkish market will likely to see growing impact of renewable technologies on prices. Further studies may examine the effect of intermittent technologies using hourly or daily data.

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