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Effect of stopping hydroelectric power generation on the dynamics of electricity prices: An event study approach

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ABSTRACT

Supply shocks in electricity markets that disrupt energy production cause unexpected spikes in prices, which in turn have economic consequences, such as higher risk and therefore higher costs and losses for producers and consumers of electricity. One relevant shock in this sector is the halting of hydroelectric power generation due to the freezing of water reservoirs after the temperature drops below zero degrees Celsius, and therefore less efficient technologies such as thermal plants must begin to produce electricity. Using an event study approach, this shock in the Nord Pool market is explicitly identified, and the economic importance of expanding the interconnected market and the inclusion of more renewable sources in the generation mix of the system to smooth out price spikes is quantified. When a freezing event occurs, it is found that the average electricity prices increase (between €1 and €6), and that the negative relationship between temperature and prices also increases (for each degree that the temperature decreases, prices increase between €1 and €3). However, as expected, these changes are more pronounced in countries that are most dependent on hydropower generation. By identifying this supply shock, relevant insights are presented for market players, such as policy makers, investors, and consumers and producers, whose decisions are influenced by the effect of temperature, particularly when it causes the stopping of hydroelectric plants.

1. Introduction

Supply shocks in electricity markets that disrupt energy production cause unexpected spikes in the price of electricity. In a market where the electricity generation mix relies mainly on hydroelectric generation, as is the case in the Nord Pool market, supply shocks that negatively affect their production cause the necessity for more expensive technologies, such as thermal plants, to produce electricity to meet demand, and therefore generate unexpected price increases. These price spikes have fundamental economic consequences for producers and consumers of electricity. For instance, unexpected price spikes imply higher risk for market players: more volatile cash flows result in higher costs, and hence in higher losses.

The supply shocks that disrupt electricity production are often caused by weather factors as the role of weather in electricity price formation is indisputable. Water reservoirs depend on the level of precipitation; wind power generation relies on wind speed; temperature affects the demand for electricity as well as its supply. In the specific case of temperature, when the temperature drops below zero degrees Celsius, water reservoirs freeze and hydroelectric plants are not able to use water any more to continue generating power.

When hydroelectric plants stop generating power, thermal plants must be turned on, increasing the price of electricity, unless the market counts on other renewable sources, such as wind power or solar generation to meet demand. Moreover, this shock may be transmitted to different areas from the area where the plant operates. Thus, identifying the supply shock derived from the freezing of water reservoirs allows one to quantify the economic importance of expanding the interconnected market of Nord Pool, the inclusion of more renewable sources in the generation mix of the system and viable storage. Hence, one effect of renewable sources is the smoothing of price spikes.

The objective of this study is to identify this supply shock: the effect of the freezing of water reservoirs when temperature drops below zero degrees in the Nord Pool market on the dynamics of electricity prices. This market has different areas of transactions and countries, which allows us to compare among them to relate the effects of the shock to the generation mix. Although it is straightforward that the dependence upon hydric sources is the main source of unexpected price spikes, we quantify this dependence in Euros, and therefore we show the incentives to diversify the generation mix.

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Not only this supply shock is identified, but also a contribution to understanding the nonlinearities that determine electricity prices is made. While previous studies have found that the relationship between weather and prices is nonlinear [1], this study shows that nonlinearity is caused by the freezing of water reservoirs, which is a novelty in the literature. Therefore, it is possible to create hedging strategies that allow the management of very cold days in a more appropriate manner and the smoothing of this shock through other renewable generation sources.

Previous studies in the literature have used weather factors to model or forecast electricity prices and demand (see [1–19] and Section 2 for an extended literature review). However, none of these studies isolates the effect of stopping hydroelectric plants due to water freezing, as is done here. In this study, an event study approach is followed to explicitly identify the change in the relationship between prices and temperature once hydroelectric plants stop generating power and less efficient technologies, such as thermal plants, must begin to produce electricity. The effect of this supply shock on the dynamics of electricity prices is assessed by means of regressions with indicator variables and threshold regressions that endogenously capture nonlinearities related to price formation in electricity markets.

The days when the temperature drops below zero degrees are considered as the event of interest. The event study methodology has been used extensively in economic and financial literature since its introduction by [20] to examine the effect of certain events on the dynamics of stock prices. Nevertheless, in the energy literature, very few event studies have been conducted (see a discussion of these in the next Section).

Using data from the Nord Pool day-ahead market (Norway, Sweden, Denmark, Finland, and Estonia) to compare the effects across countries that house different power generation mixes, the models proposed are estimated. On the days when the freezing event occurs, that is, when the temperature is zero degrees or less, it is found that the average electricity prices increase and the negative correlation between temperature and prices also increase. However, as expected, these changes are more pronounced in countries that generate power mainly with hydroelectric plants.

These results provide relevant insights about how a higher dependence on hydroelectric production makes an area/country more vulnerable to temperature, particularly when it drops below zero, and other more expensive technologies, such as thermal plants, must be turned on to meet demand. Nevertheless, the integrated market becomes vulnerable to this supply shock as it may be transmitted to other areas.

By explicitly identifying the supply shock of stopping hydroelectric generation on each area of the Nord Pool, relevant insights for market players are given: policy makers interested in expanding the market or increasing its transmission capacities; investors seeking to invest in other renewable power generation sources different from hydroelectric plants; consumers and producers forecasting increment in prices due to freezing events for planning their buying/selling strategies.

The rest of this paper is organized as follows. The literature review is presented in Section 2. In Section 3, the data used in the analysis is presented. Section 4 contains the methodology. In Section 5, the main results are presented, and in Section 6, they are discussed. Finally, in Section 7, the conclusions are presented.

2. Literature review

Weather factors are crucial in the formation of electricity prices as they affect demand and supply. For instance, through demand, lower temperatures trigger a higher consumption of electricity and vice versa. Hence for example, higher temperatures imply lower heating requirements, which translates into lower prices. Owing to supply, temperature affects prices through the freezing of hydro reservoirs, disabling the generation of power with hydroelectric plants, which is the supply shock identified here. Wind speed determines wind power generation and precipitation is expected to affect the level of hydro reservoirs.

Table 1
Literature Review Summary.

Reference	Market	Weather Variables					Effect on		
		Temp	Wind	Preci	Irrad	Other	Demand	Prices	Other
[2]	United States	*					*		
[3]	United States	*					*		
[4]	Spain	*					*		
[5]	California ISO	*					*	*	
[10]	Abu Dhabi	*	*		*	*	*		
[6]	Serbia	*					*		
[7]	Spain	*					*		
[8]	Korea	*					*		
[11]	Canada	*				*	*		
[12]	South Korea	*	*	*	*	*	*		
[9]	Massachusetts	*					*	*	
[13]	Great Britain	*	*		*		*		*
[14]	United States	*	*			*	*		
[18]	Nord Pool	*		*				*	
[19]	NO – DK	*	*	*				*	
[15]	Germany	*						*	*
[16]	EEX	*						*	
[1]	Nord Pool	*	*	*	*			*	
[17]	Italy	*						*	

NO stands for Norway, DK for Denmark, BE for Belgium, FR for France, DE for Germany, and NL for the Netherlands. EEX stands for European Energy Exchange (Germany). The acronym ISO is Independent System Operators. Temp stands for temperature, Wind for wind speed, Preci for precipitation, and Irrad for solar irradiance.

Following the financial literature on asset pricing, portfolios or single assets can be priced in absolute terms, taking reference of their exposure to fundamental sources of risk (risk factors), generally of macroeconomic nature [21]. In the case of electricity markets, weather factors are fundamentals sources of risk, which determine the dynamics of supply and demand. Therefore, resorting to weather variables that directly reflect the electricity supply and demand side was opted, instead of hydropower and wind power generation series.

This approach also has been followed by a branch of the literature that uses weather factors to explain the dynamics of (or to forecast) electricity demand and prices. Table 1 presents a summary of the literature review. It shows the reference of the study, the analyzed market, weather variables employed in each case, and if the study analyzes the effect of weather on electricity demand or prices. In the case of electricity demand, the seminal studies that assess the relationship between temperature and demand in the United States date back to [2,3]. More recently, [4] forecast daily electricity load with cooling and heating-degree days in Spain. [5] find that for the California Independent System Operators (ISO) in the United States, load and prices are sensitive to temperature. [6] analyze the impact of mean daily air temperature in the consumption of electricity in Serbia. [7,8] study the impact of temperature on sectorial electricity demand in Spain and Korea, respectively. [9] assess the effect of climate change on the consumption and price of electricity in Massachusetts, United States. Authors such as [10–14], in addition to evaluating the impact of temperature on electricity demand, also consider variables such as wind speed, precipitation, solar irradiation, and humidity.

Turning the attention to the branch of the literature that models and forecasts electricity prices using weather variables, [15] quantify the effect of heat waves on German electricity market, specifically on market prices, production costs, and consumer and producer surpluses. Furthermore, for Germany, [16] model the European Energy Exchange (EEX) price with temperature as a proxy for electricity demand. [17] determine day-ahead Italian electricity prices using hourly temperature