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# From Signals to Outcomes: Evidence from Slovakia

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**Abstract**

Dávid Kurjak: **From Signals to Outcomes: Evidence from Slovakia**

This paper analyzes the effects of selected policy decisions and energy supply disruptions on electricity prices from 2015 to 2025. Announcements elicited modest, transitory movements. Realized disruptions such as armed conflict or interruptions to gas pipeline flows generated sharp and persistent price increases. Results indicate that electricity prices are highly sensitive to gas and carbon markets. These findings provide new evidence on the drivers of electricity pricing in integrated European markets.

**Key words**

electricity prices, event study, energy policy, carbon costs, natural gas prices, market integration

**JEL:** C32, G14, Q41, Q48

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## Introduction

Electricity prices in Europe have exhibited increasing volatility over the past decade, reflecting shifts in fuel costs, the integration of renewable energy sources, regulatory interventions, and supply disruptions (Pavlík et al., 2025; Cevik, 2025). The 2021–2022 energy crisis clearly demonstrated this vulnerability: wholesale prices in Central Europe surged more than fourfold even before the outbreak of war in Ukraine, driven by tight gas supply and rising carbon costs (CSIS, 2022). For Slovakia, the nuclear-based generation mix might suggest relative stability. However, these developments underscored the country's degree of exposure to external dynamics via integrated wholesale markets (Janda, 2018).

The EU Emissions Trading System (EU ETS) is a fundamental determinant of electricity price formation in Europe. Carbon allowance prices have been shown to be passed through into wholesale electricity costs (Caporin et al., 2021). Furthermore, the joint effects of renewable expansion and rising carbon prices explain much of the increased volatility observed in European markets after 2015 (Pavlík et al., 2025). Cross-border integration further amplifies this dependence; for example, more than 70 % of price variance across European countries can be traced to spillovers from external markets (Cevik and Zhao, 2025). Notably, crises alter the strength of these linkages: while the COVID-19 pandemic reduced return spillovers, the war in Ukraine intensified them, leading to stronger and more synchronized price spikes (Do et al., 2023)

We contribute in three ways. First, we clarify that price formation in electricity markets is anticipatory by demonstrating how news about supply and policy influences market expectations before disruptions occur. Second, we show that realized shocks, such as wars or gas supply interruptions, have stronger and more persistent effects than announcements, emphasizing the value of examining extended event windows in energy market research. Third, we assemble systematic evidence from Slovakia to illustrate that, even in a smaller and nuclear-based market, electricity prices remain highly exposed to broader European market dynamics.

The paper is structured as follows. Section 1 reviews the related literature. Section 2 describes the data and methodology. Section 3 presents empirical results. Section 4 provides robust checks. Section 5 concludes.

## 1 Literature review

The literature on energy markets has shifted toward analyzing the effects of external events and policy interventions as key drivers of price dynamics in Europe. Initially, earlier research focused primarily on long-term fundamentals, including fuel costs, carbon pricing, and infrastructure integration. However, more recent work highlights event-based analyses that distinguish between announcement effects and realized effects. This distinction has become particularly relevant as electricity markets, regardless of their national generation mix, are deeply integrated into European wholesale trading and thus exposed to external developments.

Recent studies show that energy markets react immediately to political announcements related to supply security. Goodell et al. (2023) find that 24 Nord Stream-related announcements between 2013 and 2022 significantly moved European gas futures, with stronger effects during periods of heightened uncertainty such as the pandemic and the Russia–Ukraine war. This highlights that announcements can shift markets well before any actual disruption occurs. A similar dynamic is evident in carbon markets. Sitarz et al. (2024) demonstrate that the sharp rise in EU ETS prices after 2017 was driven not only by reforms but also by credible policy signals, such as the “Fit for 55” package, which shifted market behavior from short-term to long-term oriented. Here, the announcement effect is closely tied to policy credibility.

Realized events tend to cause stronger and more lasting price effects. For example, the Russia–Ukraine war in 2022 drove euro area electricity prices to record highs, with gas prices increasing by 180 % in just weeks (ECB, 2022). Liu and Lee (2025) estimate an average 9 % rise in OECD energy prices, with the largest impact in Southern Europe. Such evidence confirms that wars and supply cuts have more profound effects than mere announcements. Furthermore, natural gas price shocks have a significant impact on electricity, even in markets with limited gas generation. Zhu et al. (2024) demonstrate significant pass-through in the Nordics after 2022, indicating that integrated markets effectively spread supply disruptions. Related evidence at the city level is provided by Ingoglia, Horký, and Fidrmuc (2024), who demonstrate that energy variables, particularly heating needs and gas prices, significantly increase living costs across European cities. These findings highlight how energy shocks extend beyond wholesale markets, affecting broader inflation dynamics and urban cost-of-living disparities.

Carbon pricing is another key driver. Bai and Okullo (2023) demonstrate that ETS costs are fully or more than fully passed through to electricity prices in several countries. This indicates that carbon prices, shaped by both fundamentals and policy, directly increase power costs and reinforce the electricity link. Market integration further spreads such effects across borders. Cevik and Zhao (2025) find that over 70 % of price variance in 24 European countries is attributed to cross-border spillovers. Kłopecka and Bonar (2025) demonstrate that convergence is limited and influenced more by national energy mixes than by interconnections.

The literature also documents how governments respond to realized energy price shocks with direct interventions. Enerdata (2024) reports that some countries have extended electricity price caps well below market levels to protect households, such as the €61/MWh ceiling introduced until 2025. While announcements may briefly unsettle markets, actual supply disruptions or escalations often compel governments to intervene, with long-term fiscal and market implications. Beyond direct policy interventions, financial structures also play a crucial role in shaping energy outcomes. Horký and Fidrmuc (2024) demonstrate that while banks tend to support carbon-intensive industries, well-developed capital markets promote the adoption of renewable energy, underscoring the systemic channels through which financial development influences the energy transition.

## 2 Data and methods

The dataset covers the period from January 1, 2015, to January 1, 2025. It is constructed as a daily time series (excluding weekends) and includes 61,290 observations. Prices are reported as closing values from day-ahead market sessions, consistent with standard market valuation practices. The ten-year horizon ensures that the data captures several episodes of heightened energy market stress, including the implementation of the European Green Deal, the Russia–Ukraine war, and the shutdown of gas pipelines in 2022.

The dataset was chosen to reflect the main fundamentals of electricity price formation, as identified in the literature, which includes fuel costs, carbon prices, demand conditions, and cross-border integration (Bunn & Gianfreda, 2010; Weron, 2014). These factors jointly capture both the cost-side and demand-side pressures shaping wholesale electricity markets, making them a suitable basis for analyzing the impact of major external events.

To reflect domestic market fundamentals, the dataset includes the day-ahead wholesale electricity price, electricity demand, and electricity supply obtained from OKTE.sk, the national market operator. To account for external drivers, additional variables include natural gas, coal, and oil prices, EU ETS allowance prices, and average daily temperature in the European Union. This data was collected from established providers, including Montel, Investing.com, and Power Statistics. Together, they represent both national market characteristics and broader European developments that shape electricity pricing.

For empirical analysis, all variables were transformed into first differences to remove deterministic trends and ensure stationarity, thereby reducing the risk of spurious regression. This preprocessing step is standard in electricity price modeling, where persistence and seasonality are well documented (Weron, 2014).

Table 1 presents descriptive statistics of the dataset. Most variables fluctuate around their mean, with skewness and kurtosis within an acceptable range. Coal prices show high kurtosis (156.13), reflecting extreme fluctuations, while EU temperature displays negative skewness, indicating more frequent elevated temperatures during the period.

Table 2 reports the correlation matrix. As expected, electricity prices are most closely correlated with neighboring markets: the Czech price (0.813), the German price (0.654), and the French price (0.503). These strong relationships confirm the high level of cross-border market integration in Europe. Correlations among explanatory variables remain moderate, minimizing the risk of multicollinearity. A variance inflation factor (VIF) analysis further supports this conclusion. None of the variables exceeded the critical threshold of VIF> 5. The highest values were observed for the German price (4.76) and the Czech price (4.71), while the average VIF of 1.89 confirms the appropriateness of the selected variables.

The event study methodology has been increasingly applied in energy economics to assess how markets respond to major disruptions (Du, Li, & Wang, 2022). It is particularly suitable for electricity markets, where both announcements and realized shocks influence price dynamics.

Abnormal returns (ARs) capture the difference between actual returns and the expected returns that would have occurred in the absence of the event:

$$AR_{i,t} = R_{i,t} - \hat{R}_{i,t} \tag{1}$$

where $R_{i,t}$ denotes the observed daily return and $\hat{R}_{i,t}$is the expected return.

Expected returns are derived from a multivariate regression model that accounts for the main fundamentals of electricity price formation. The specification is:

$$\begin{aligned}\hat{R}_{i,t} = \alpha + \beta_1 \Delta Demand_t^{SK} + \beta_2 \Delta Supply_t^{SK} + \beta_3 \Delta Temp_t + \beta_4 \Delta EUA_t + \beta_5 \Delta Oil_t \\ + \beta_6 \Delta Coal_t + \beta_7 \Delta Gas_t^{TTF} + \beta_8 R_t^{DE} + \beta_9 R_t^{FR} + \beta_{10} R_t^{NO} + \beta_{11} R_t^{CZ}\end{aligned} \tag{2}$$

The explanatory variables include Slovak demand and supply, average EU temperature, EU ETS allowance prices, international fuel prices (oil, coal, natural gas), and returns from neighboring electricity markets (Germany, France, Norway, Czech Republic). This setup ensures that normal returns account for both domestic fundamentals and cross-border spillovers, capturing the economic reality of integrated European power markets (Bunn & Gianfreda, 2010; Mosquera-López et al., 2017).

The parameters are estimated using ordinary least squares (OLS) within an estimation window of 60 trading days prior to each event. This window length is a standard compromise, and it provides sufficient observations for reliable estimation while minimizing the risk of structural breaks caused by distant shocks. The event window is defined as ±15 trading days around the event date, thus covering both anticipatory effects and delayed market responses.

To capture the overall impact of an event, daily abnormal returns are aggregated into cumulative abnormal returns:

$$CAR_i(t_1, t_2) = \sum_{t=t_1}^{t_2} AR_{i,t} \tag{3}$$

For multiple events of the same type, cumulative average abnormal returns (CAARs) are computed as:

$$CAAR(t_1, t_2) = \frac{1}{N}\sum_{i=1}^{N} CAR_i(t_1, t_2). \tag{4}$$

where N is the number of events. CAARs allow for generalization of findings across events of a similar nature (Du, Li, & Wang, 2022; Mosquera-López et al., 2017).

## 3 Results

The results are presented using descriptive graphs, regression tables, and event study outputs. Figure 1 gives an overview of wholesale electricity prices from 2015 to 2025, highlighting key events. Table 1 presents regression estimates that identify the primary drivers of electricity price dynamics, including fuel costs, carbon pricing, and cross-border market linkages. Table 2 summarizes the effects of individual events, distinguishing between announcements and realizations, and quantifies their impact through cumulative abnormal returns (CARs). Figure 2 shows the response of abnormal returns (AR) and CAR around the Nord Stream 1 announcement and shutdown. Together, these results provide a robust picture of how market fundamentals and external shocks shaped electricity prices over the past decade.

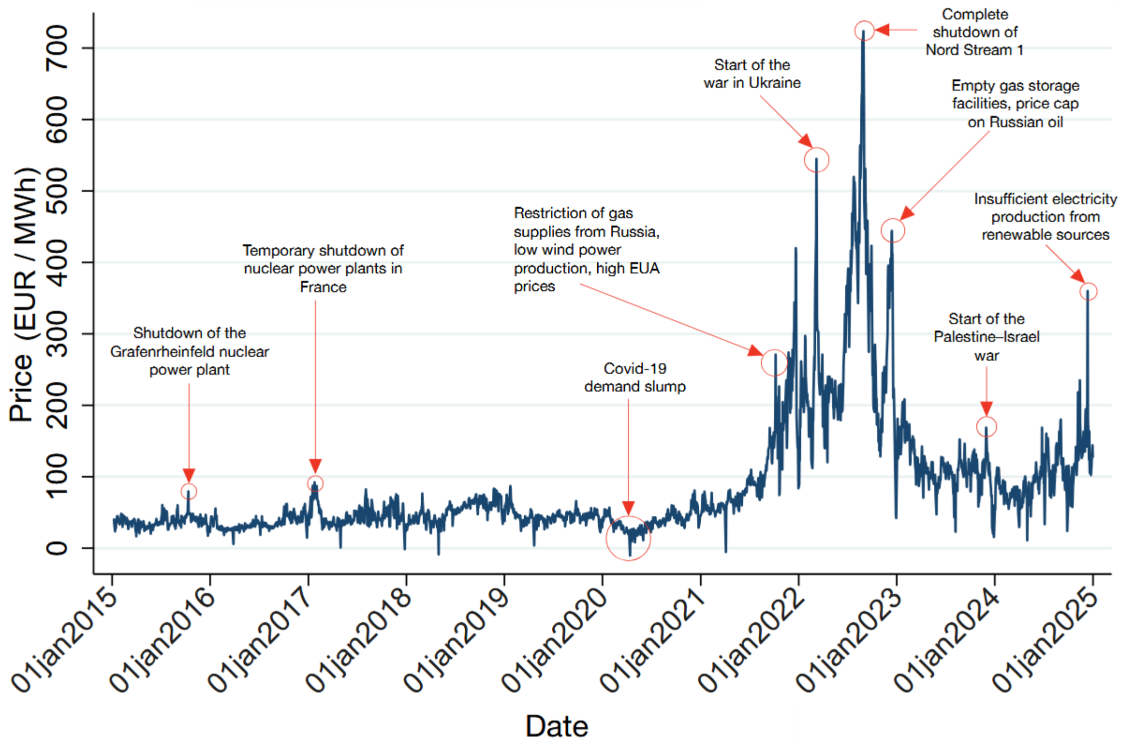
Figure 1 documents several cleanly identified effects. Early events such as the Grafenrheinfeld nuclear shutdown (2015) or the temporary outage of French nuclear plants (2016) generated only limited price responses, reflecting the relative stability of European fuel markets at that time. By contrast, the COVID-19 crisis (2020) is associated with a clear temporary slump in demand and prices, underscoring the sensitivity of electricity markets to macroeconomic shocks.

The most dramatic surge occurred during the Russia–Ukraine war (2022) and the complete shutdown of Nord Stream 1 (2022), when wholesale electricity prices spiked to unprecedented levels of over EUR 600/MWh. These events provide robust evidence of the dependence of electricity price formation on natural gas availability, despite the prevalence of nuclear generation. The rapid pass-through of gas and carbon costs confirms that marginal cost pricing at the European level governs domestic outcomes.

Subsequent events, including the EU price cap on Russian oil (2022) or renewable underproduction (2023–2024), also coincided with heightened volatility. However, their effects were less extreme compared to the initial gas supply shock, suggesting that markets had already internalized the structural shift toward higher and more uncertain energy costs.

Overall, the results confirm that electricity price dynamics are shaped not only by domestic supply and demand fundamentals but also by broader European market conditions. Importantly, the clustering of major spikes around realized shocks, rather than announcements, provides clear evidence that electricity markets react most strongly when uncertainty materializes into actual supply disruptions.

Figure 1 Slovak wholesale electricity prices, 2015–2025




*Note: The figure displays the daily Slovak wholesale electricity price (in EUR/MWh) from January 2015 to January 2025. Red markers indicate selected geopolitical and policy-related events that significantly affected European energy markets, including nuclear plant shutdowns, the COVID-19 demand slump, the Russia–Ukraine war, and disruptions in natural gas supplies. Data source: author's calculations*

The regression estimates in Table 1 provide evidence on the main determinants of Slovak electricity prices. Columns (1) – (5) gradually extend the specification by including additional explanatory variables. The results show that most domestic demand and supply factors are not statistically significant, suggesting that Slovak electricity prices are primarily driven by external influences.

Among the market fundamentals, the EU average temperature displays a weak but significant negative effect in early specifications, consistent with the expectation that higher temperatures reduce heating demand. However, the coefficient becomes insignificant once additional controls are included.

By contrast, the price of emission allowances (EUA) is highly significant and positively associated with Slovak electricity prices across all models, confirming that carbon costs are effectively transmitted into wholesale electricity markets. Similarly, the natural gas price (TTF hub) shows a strong positive effect in column (3), underlining the importance of gas-fired generation in shaping marginal electricity prices.

In the extended models, cross-border electricity prices emerge as the most powerful determinants. Prices in neighboring countries, particularly the Czech Republic (coefficient 0.98, significant at the 1% level), exert a near one-to-one impact on Slovak prices. German and French prices also play a significant role, albeit with smaller coefficients. These findings reflect the high level of market integration within Central Europe, where Slovak prices closely follow regional benchmarks.

Overall, the regression analysis confirms that Slovak electricity prices are strongly dependent on European market conditions, particularly carbon and gas prices, as well as cross-border electricity flows. Domestic demand and supply factors, in contrast, play only a marginal role.

Table 1 Determinants of Slovak day-ahead electricity price – OLS estimates

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| Electricity Demand in Slovakia [MWh] | 0.000<br>(0.000) | 0.000<br>(0.000) | 0.000<br>(0.000) | 0.000<br>(0.000) | 0.000<br>(0.000) |
| Electricity Supply in Slovakia [MWh] | 0.000<br>(0.001) | 0.000<br>(0.000) | 0.000<br>(0.001) | 0.000<br>(0.001) | 0.001*<br>(0.000) |
| Average Temperature in the EU [°C] | | -0.299*<br>(0.144) | -0.325*<br>(0.143) | -0.326*<br>(0.140) | 0.014<br>(0.83) |
| EUA Carbon Allowance Price [€/t$CO_2$] | | | 1.130***<br>(0.179) | 1.136***<br>(0.175) | 0.419***<br>(0.103) |
| Brent Crude Oil Price [€/bbl] | | | | 0.431<br>(0.238) | 0.480***<br>(0.138) |
| Coal Price [€/tonne] | | | | 0.029<br>(0.067) | 0.001<br>(0.039) |
| Natural Gas Price (TTF hub) [€/MWh] | | | | 0.843***<br>(0.091) | 0.075<br>(0.054) |
| Electricity Price - Germany [€/MWh] | | | | | -0.202***<br>(0.019) |
| Electricity Price - Norway [€/MWh] | | | | | 0.052*<br>(0.022) |
| Electricity Price - France [€MWh] | | | | | 0.037**<br>(0.014) |
| Electricity Price - Czech Republic [€/MWh] | | | | | 0.980***<br>(0.024) |
| Constant | 0.035<br>(0.379) | 0.036<br>(0.379) | 0.007<br>(0.376) | -0.007<br>(0.368) | -0.011<br>(0.214) |
| No of Observations | 2580 | 2580 | 2580 | 2580 | 2580 |
| Adjusted $R^2$ | 0.002 | 0.004 | 0.019 | 0.058 | 0.683 |

*** p<0,01, ** p<0,05, * p<0,1

*Note: The table presents regression estimates that explain Slovak wholesale electricity prices using demand, supply, weather conditions, fuel prices, and foreign electricity prices as explanatory variables. The dependent variable is the Slovak day-ahead electricity price (EUR/MWh). Coefficients are reported with robust standard errors in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Data source: author's calculations.*

Table 2 summarizes the effects of major events on wholesale electricity prices, distinguishing between the announcement and realization phases. The reported values are based on an event window of [−15, +15] trading days around each event and an estimation window of 60 trading days prior to the event. Across all cases, the results confirm that while announcements shape expectations, realized events tend to generate much stronger and more persistent price adjustments.

The temporary outage of French nuclear plants in late 2016 provides a clear example of how uncertainty about supply capacity immediately feeds into electricity prices. At the announcement stage, markets reacted strongly, anticipating tighter nuclear availability in a system where France is a key exporter. Once the outages materialized, the shock deepened, driving prices further upwards. This pattern illustrates the high dependence of the Central European market on French baseload nuclear power.

A similar mechanism is visible for the German nuclear shutdowns. When the closure of Gundremmingen B was announced in 2017, prices increased moderately, reflecting the anticipation of reduced future capacity. The realization, however, translated this expectation into concrete scarcity, producing a sharper negative market response. These findings confirm that nuclear availability remains a central anchor for price stability in Europe, and any reduction in capacity, whether temporary or permanent, transmits directly into higher wholesale prices in Slovakia.

Policy-related events show a different channel of transmission. The Green Deal announcement in 2019 initially led to only a modest decline in prices, consistent with markets interpreting the policy as a long-term signal rather than an immediate supply shock. Yet, when the package began to be implemented in the middle of 2021, the effect became more pronounced. This suggests that credible policy commitments can shift expectations gradually, but only concrete regulatory changes alter actual bidding behavior and price formation.

The Russian gas supply shocks stand out in magnitude. The announcement of the Nord Stream 1 shutdown in July 2022 triggered a dramatic repricing of electricity, as markets immediately reassessed the security of European gas supply. Electricity prices reacted strongly despite Slovakia's nuclear dominance, highlighting the extent of gas power coupling through the marginal pricing system. By the time the shutdown was realized in August, much of the adjustment had already occurred, resulting in a smaller but still significant reaction. This sequence demonstrates the forward-looking nature of electricity markets; expectations about gas flows were priced in as soon as information became available, leaving less room for further adjustment when the disruption materialized.

Finally, the EU price cap on Russian oil illustrates the limits of announcement effects when credibility or market relevance is weaker. The initial announcement generated some negative reaction, but the realization did not produce a statistically significant effect. This outcome reflects the fact that oil is less directly linked to power generation in Europe, and that markets may have doubted the effectiveness of the measure.

Table 2 Market Reactions to Selected Announcements and Realized Events

Estimation window [60]
Event window [15,15]

| Event | Date of Announcement | Announcement CAR | Announcement Percentage change (%) | Date of the realization | Event CAR | Event Percentage change (%) |
|---|---|---|---|---|---|---|
| Shutdown of a nuclear power plant in Germany - Grafenrheinfeld | 28.3.2014 | -4,269 (7,254) | 196,253% | 29.6.2015 | -6,329*** (1,592) | 1 757,384%*** |
| Temporary outage of French nuclear plants | 30.12.2016 | -13,153*** (3,094) | 106,071%*** | 9.1.2017 | -26,954*** (4,866) | 1 866,014%*** |
| Shutdown of a nuclear power plant in Germany - Gundremmingen B | 13.12.2017 | 2,671 (1,377) | 700,018% | 2.1.2018 | -4,822*** (1,078) | 120,171%*** |
| Green Deal policy | 11.12.2019 | -5,244* (2,271) | 32,555%* | 21.6.2021 | -6,741*** (1,188) | 1 022,233%*** |
| Shutdown of Nord Stream 1 | 10.7.2022 | -88,431*** (12,406) | 568,382%*** | 31.8.2022 | -24,264*** (6,334) | 81,572%*** |
| EU price cap on Russian oil | 2.9.2022 | -14,824 (7,555) | 5,731% | 5.12.2022 | -6,664 (8,700) | 117,675% |

*** p < 0.01, ** p < 0.05, * p < 0.1

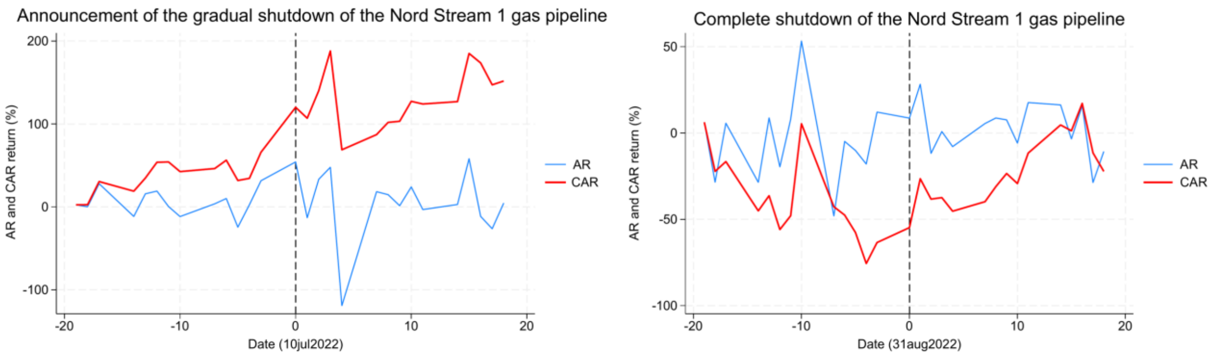
*Note: The table reports cumulative abnormal returns (CAR) and percentage changes in Slovak wholesale electricity prices around selected announcements and realized events. Announcement CARs capture market reactions within a short window following the release of information, while event CARs reflect adjustments at the time of actual implementation. Coefficients are reported with robust standard errors in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Data source: author's calculations.*

A graph was created to illustrate the impact of both the announcement and the event. Figure 2 displays abnormal returns (AR, blue line) and cumulative abnormal returns (CAR, red line) around the announcement of the gradual shutdown of Nord Stream 1 (left graph) and its complete shutdown (right graph). Abnormal returns (AR) show the deviation of actual electricity price returns from model-predicted values, measuring the immediate market response beyond expected conditions. Cumulative abnormal returns (CAR) aggregate these deviations over the event window, reflecting the lasting effect of the event on market pricing.

In the case of the announcement (July 10, 2022), the AR line shows a downward trend around the event date, suggesting that the market initially interpreted the gradual reduction in Russian gas flows as moderating wholesale electricity prices. However, the CAR reveals a strikingly different picture; cumulative effects increased sharply after the announcement, reaching nearly 200% of the original level. This divergence indicates that while daily adjustments were mixed and sometimes negative, the market repriced electricity upwards as expectations of long-term gas scarcity became embedded in price formation. The CAR thus emphasizes that the announcement alone was sufficient to trigger a structural reassessment of fundamental market factors, particularly given the central role of natural gas as a marginal fuel in European electricity markets.

For the complete shutdown (31 August 2022), the dynamics differ. Here, AR fluctuates around zero with occasional spikes, reflecting short-term uncertainty and mixed intraday reactions. In contrast, CAR turns sharply negative in the days immediately following the shutdown, reaching lows of around –80%. This suggests that much of the anticipated effect had already been priced in at the time of the July announcement, leaving the realized event to confirm expectations and even temporarily relieve uncertainty once flows were fully cut. The rebound of CAR after day +10 supports this interpretation, as markets adjusted to the “new normal” of absent Russian gas flows.

Figure 2 Abnormal and cumulative abnormal returns around Nord Stream 1 shutdown events




*Note: The figure displays abnormal returns (AR, blue line) and cumulative abnormal returns (CAR, red line) for Slovak wholesale electricity prices around two key events related to the Nord Stream 1 pipeline. The left panel displays the announcement of the gradual shutdown on July 10, 2022, while the right panel depicts the complete shutdown on August 31, 2022. Data source: author’s calculations*

## 4 Robustness analysis

To ensure the robustness of the results, the analysis is extended by varying the length of the event window. While the baseline specification employed an event window of ±15 trading days, alternative specifications with event windows of ±10, ±5, and ±2 trading days are also considered. This procedure follows recommendations from the event study literature, where robustness checks are necessary to confirm that the identified effects are not artifacts of a specific modeling choice (Sorokina et al., 2013). The rationale for using a longer event window in the baseline is that energy markets differ from financial markets in their adjustment dynamics. Anticipatory behavior is common, as traders and utilities react to information signals before the actual event, while the materialization of shocks often unfolds gradually (Weron, 2014; Goodell et al., 2023). Thus, capturing the full adjustment requires an extended time frame.

Table 3 presents results for the ±10 trading day window. The estimates remain broadly consistent with the baseline findings. Nuclear-related events continue to have a strong and significant impact, particularly the temporary outage of French nuclear plants, which generated both substantial announcement and realization effects. The shutdown of Nord Stream 1 in 2022 also remains highly significant, though the magnitude of cumulative abnormal returns (CARs) is somewhat reduced compared to the ±15 specification. Policy-driven events such as the Green Deal continue to exhibit measurable but less pronounced effects, suggesting that market participants treated them as gradual, long-term signals rather than immediate disruptions.

Table 3 Event study results with event window [10,10] and estimation window [60]

Estimation window [60]
Event window [10,10]

| Event | Date of Announcement | Announcement CAR | Announcement Percentage change (%) | Date of the realization | Event CAR | Event Percentage change (%) |
|---|---|---|---|---|---|---|
| Shutdown of a nuclear power plant in Germany - Grafenrheinfeld | 28.3.2014 | -6,492 (2,675) | 80,562% | 29.6.2015 | -7,408** (2,081) | 375,837%*** |
| Temporary outage of French nuclear plants | 30.12.2016 | -9,848* (3,370) | 68,859%* | 9.1.2017 | -18,195*** (4,959) | 1 864,823%*** |
| Shutdown of a nuclear power plant in Germany - Gundremmingen B | 13.12.2017 | 1,568 (1,031) | 619,997% | 2.1.2018 | -1,970 (0,970) | 60,001% |
| Green Deal policy | 11.12.2019 | 8,238* (2,311) | 57,387%* | 21.6.2021 | 6,174*** (1,598) | 768,933%*** |
| Shutdown of Nord Stream 1 | 10.7.2022 | -9,118 (24,479) | 60,421% | 31.8.2022 | -26,929*** (8,019) | 62,601%*** |
| EU price cap on Russian oil | 2.9.2022 | -13,939 (8,443) | 15,945% | 5.12.2022 | -8,327 (9,935) | 34,349% |

*** p < 0.01, ** p < 0.05, * p < 0.1

*Note: The table reports cumulative abnormal returns (CAR) and percentage changes in Slovak wholesale electricity prices around selected announcements and realized events. Results are estimated using an estimation window of 60 trading days and an event window of ±10 trading days. Announcement CARs capture market reactions immediately following the release of information, while event CARs reflect adjustments at the time of realization. Robust standard errors are in parentheses. ***, *, and * denote significance at the 1%, 5%, and 10% levels, respectively. Data source: author's calculations.*

Table 4 reports the results for the ±5 trading day window. Here, many of the reactions weaken substantially. For instance, the German and French nuclear events remain statistically significant, albeit at lower magnitudes, while the Nord Stream 1 shutdown produces a smaller CAR compared to the longer windows. Policy-related announcements largely lose significance within this short horizon. These results suggest that a short event window may not fully capture the adjustment process in electricity markets. Price effects in energy markets often unfold gradually, with part of the reaction occurring in anticipation and the remainder following the disruption's materialization. As a result, restricting the event window to a few days risks underestimating the true impact of major shocks.

Table 4 Event study results with event window [5,5] and estimation window [60]

Estimation window [60]
Event window [5,5]

| Event | Date of Announcement | Announcement CAR | Announcement Percentage change (%) | Date of the realization | Event CAR | Event Percentage change (%) |
|---|---|---|---|---|---|---|
| Shutdown of a nuclear power plant in Germany - Grafenrheinfeld | 28.3.2014 | -3,873<br>(5,783) | 170,651% | 29.6.2015 | -3,503***<br>(0,593) | 1 361,913%*** |
| Temporary outage of French nuclear plants | 30.12.2016 | -4,769<br>(3,321) | 34,675% | 9.1.2017 | -8,297<br>(7,606) | 1 404,706% |
| Shutdown of a nuclear power plant in Germany - Gundremmingen B | 13.12.2017 | 1,230<br>(0,895) | 2596,408% | 2.1.2018 | -1,464<br>(0,991) | 9,033% |
| Green Deal policy | 11.12.2019 | 4,632<br>(3,034) | 458,379% | 21.6.2021 | -2,253<br>(1,309) | 747,083% |
| Shutdown of Nord Stream 1 | 10.7.2022 | 45,252<br>(34,359) | 29,365% | 31.8.2022 | -6,994<br>(9,809) | 60,541% |
| EU price cap on Russian oil | 2.9.2022 | -9,705<br>(9,169) | 2,296% | 5.12.2022 | 12,168<br>(10,971) | 88,848% |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

*Note: The table shows cumulative abnormal returns (CAR) and percentage changes in Slovak wholesale electricity prices around selected announcements and realized events. Estimates are based on an estimation window of 60 trading days and an event window of ±5 trading days. Announcement CARs capture immediate market reactions to new information, while event CARs measure adjustments when the event is realized. Robust standard errors are reported in parentheses. ***, *, and * indicate significance at the 1%, 5%, and 10% levels, respectively. Data source: author's calculations.*

Table 5 presents the most restrictive specification, which includes an event window of ±2 trading days. Under this setting, most events lose statistical significance, and the estimated CARs fluctuate strongly. While some physical disruptions, such as nuclear outages and the shutdown of Nord Stream 1, still exhibit directional effects, the estimates are less stable and fail to capture the full extent of market adjustments. This outcome further demonstrates that short windows, although common in financial market studies, are unsuitable for energy markets where adjustment dynamics extend beyond a few days.

Table 5 Event study results with event window [2,2] and estimation window [60]

Estimation window [60]
Event window [2,2]

| Event | Date of Announcement | Announcement CAR | Announcement Percentage change (%) | Date of the realization | Event CAR | Event Percentage change (%) |
|---|---|---|---|---|---|---|
| Shutdown of a nuclear power plant in Germany - Grafenrheinfeld | 28.3.2014 | 2,412 (5,254) | 56,387% | 29.6.2015 | 1,615 (1,798) | 271,568% |
| Temporary outage of French nuclear plants | 30.12.2016 | -5,018 (4,354) | 5,099% | 9.1.2017 | -0,853 (6,742) | 742,037% |
| Shutdown of a nuclear power plant in Germany - Gundremmingen B | 13.12.2017 | 0,506 (0,574) | 889,939% | 2.1.2018 | 0,499 (2,342) | 33,466% |
| Green Deal policy | 11.12.2019 | 2,303 (3,502) | 333,196% | 21.6.2021 | -2,253 (1,309) | 57,214% |
| Shutdown of Nord Stream 1 | 10.7.2022 | -1,382 (37,471) | 312,351% | 31.8.2022 | 4,264 (9,354) | 39,781% |
| EU price cap on Russian oil | 2.9.2022 | 6,761 (12,746) | 6,826% | 5.12.2022 | 17,431 (16,238) | 55,162% |

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

*Note: The table reports cumulative abnormal returns (CAR) and percentage changes in Slovak wholesale electricity prices for selected announcements and realized events. Results are based on an estimation window of 60 trading days and an event window of ±2 trading days. Shorter windows primarily capture immediate reactions, while longer-term adjustments are less visible. Robust standard errors are shown in parentheses. ***, *, and * indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Data source: author's calculations*

Taking together, the robustness analysis confirms the comprehensive and stable nature of the main findings. Physical supply shocks, nuclear outages, and gas pipeline disruptions consistently generate the largest and most persistent effects across all specifications, even when the magnitude varies with the event window. Policy announcements, by contrast, display weaker and less robust effects, consistent with their gradual implementation and limited immediate market relevance. Importantly, the comparison across windows highlights that only longer horizons enable a clear identification of the full adjustment process in energy markets. This result aligns with prior research emphasizing the anticipatory and multi-stage nature of price formation under uncertainty (Weron, 2014; Goodell et al., 2023).

Overall, the robustness checks reinforce the reliability of the baseline results and provide additional insights into the temporal dynamics of electricity price responses. The evidence demonstrates that while financial markets may react within days or even hours, energy markets require a broader lens to properly capture the unfolding of shocks.

## 5 Conclusion

This paper examined the announcement and realized effects of major geopolitical and policy events on Slovak electricity prices between 2015 and 2025. The analysis contributes to the growing literature on energy market integration by providing the first systematic evidence for Slovakia. Using an event study, the study highlights the asymmetric way in which electricity markets process new information.

The results demonstrate that announcements primarily shape expectations but rarely generate lasting price adjustments. Events such as the European Green Deal or sanctions on Russian energy exports triggered only modest and short-term responses. Markets appear to weigh credibility and relevance when processing announcements. Policy signals influence prices only if backed by strong institutional commitment, while oil-related announcements have little effect given the limited role of oil in European power generation.

In contrast, realized events such as the war in Ukraine or the shutdown of Nord Stream 1 produced dramatic and persistent price increases. These shocks revealed the deep dependence of Slovak electricity prices on European market conditions, despite the dominance of domestic nuclear generation. The strong pass-through of gas and carbon costs confirms the marginal pricing logic of European markets. Electricity prices are determined by the cost of the most expensive unit needed to meet demand. When natural gas became scarce, even countries with little gas-fired generation experienced unprecedented price spikes.

The robustness analysis confirms that short event windows underestimate the true impact of shocks, while longer windows capture the gradual adjustment typical of energy markets. Across all specifications, physical supply disruptions remained the most influential and consistent drivers of price volatility, whereas policy-related events showed weaker effects.

Our findings underscore several implications for policymakers. Credible communication alone is insufficient to stabilize markets during crises; resolving uncertainty once supply conditions are realized is essential. For energy-intensive firms, the results underscore the importance of hedging against fuel and carbon costs, as well as geopolitical risk, given that prices react sharply to actual disruptions in cross-border supply. For Slovakia, the evidence confirms that insulation from European shocks is not feasible within the integrated electricity market.

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## Appendix

Table A1 Univariate Descriptive Statistics

| Variable | Mean | Standard Deviation | Min | 25% | Median | 75% | Max | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|---|
| (1) Electricity Price - SK | 0,03 | 19,28 | -202,29 | -5,22 | 0,01 | 5,20 | 111,22 | -0,93 | 21,66 |
| (2) Electricity Demand in SK | 6,82 | 4776,17 | -22000,00 | -1558,80 | 15,00 | 1534,05 | 27098,00 | 0,04 | 8,76 |
| (3) Electricity Supply in SK | 6,26 | 4250,40 | -21000,00 | -2027,55 | -78,05 | 1937,95 | 24749,00 | 0,21 | 6,74 |
| (4) Average Temp. in the EU | 0,00 | 2,63 | -14,10 | -1,50 | 0,10 | 1,60 | 11,10 | -0,18 | 4,58 |
| (5) EUA Price | 0,03 | 2,11 | -58,77 | -0,31 | 0,01 | 0,37 | 59,00 | -0,18 | 473,47 |
| (6) Natural Gas Price (TTF) | 0,01 | 4,26 | -66,59 | -0,35 | 0,00 | 0,37 | 45,42 | -1,65 | 67,36 |
| (7) Brent Crude Oil Price | 0,01 | 1,59 | -16,84 | -0,72 | 0,09 | 0,84 | 8,80 | -0,96 | 13,12 |
| (8)Coal Price | 0,02 | 5,86 | -96,65 | -0,40 | 0,00 | 0,50 | 121,50 | 0,94 | 156,13 |
| (9) Electricity Price - DEU | 0,01 | 24,55 | -250,87 | -5,47 | -0,09 | 5,49 | 175,81 | 0,76 | 18,77 |
| (10) Electricity Price - NO | 0,00 | 12,44 | -141,50 | -1,70 | 0,00 | 5,68 | 160,65 | 0,17 | 41,27 |
| (11) Electricity Price - FRA | 0,02 | 19,70 | -240,88 | -4,31 | -0,05 | 4,51 | 227,84 | -0,83 | 32,82 |
| (12) Electricity Price - CZ | 0,03 | 19,44 | -206,52 | -5,02 | -0,13 | 4,93 | 111,10 | -0,87 | 21,51 |

Table A2 Cross-correlation matrix

| Variable | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | VIF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) Electricity Price - SK | 1.000 | | | | | | | | | | | | NaN |
| (2) Electricity Demand in SK | -0.047 | 1.000 | | | | | | | | | | | 1,330 |
| (3) Electricity Supply in SK | 0.038 | -0.493 | 1.000 | | | | | | | | | | 1,330 |
| (4) Average Temp. in the EU | -0.041 | -0.010 | -0.010 | 1.000 | | | | | | | | | 1,030 |
| (5) EUA Price | 0.125 | -0.057 | 0.037 | 0.029 | 1.000 | | | | | | | | 1,020 |
| (6) Natural Gas Price (TTF) | 0.194 | -0.009 | 0.017 | 0.000 | -0.001 | 1.000 | | | | | | | 1,160 |
| (7) Brent Crude Oil Price | 0.061 | -0.041 | 0.018 | 0.006 | -0.007 | 0.125 | 1.000 | | | | | | 1,050 |
| (8) Coal Price | 0.075 | -0.030 | 0.009 | -0.013 | 0.005 | 0.304 | 0.195 | 1.000 | | | | | 1,140 |
| (9) Electricity Price - DEU | 0.654 | 0.003 | -0.029 | -0.122 | 0.074 | 0.150 | 0.026 | 0.087 | 1.000 | | | | 4,760 |
| (10) Electricity Price - NO | 0.475 | 0.024 | -0.016 | -0.070 | 0.098 | 0.127 | 0.015 | 0.036 | 0.626 | 1.000 | | | 1,690 |
| (11) Electricity Price - FRA | 0.503 | -0.015 | 0.006 | -0.127 | 0.102 | 0.167 | 0.032 | 0.025 | 0.558 | 0.424 | 1.000 | | 1,600 |
| (12) Electricity Price - CZ | 0.813 | -0.009 | 0.001 | -0.069 | 0.090 | 0.203 | 0.023 | 0.082 | 0.874 | 0.587 | 0.593 | 1.000 | 4,710 |