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The impact of a short-term fuel price cap on market prices after its removal: Evidence from Hungary

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ABSTRACT

In 2022, energy prices in the European Union reached record highs, accompanied by a significant increase in fuel prices. In response, the Hungarian government imposed a price cap on retail fuel prices from November 15, 2021 to December 6, 2022. This study empirically examines the effect of the elimination of the price cap on fuel prices. The aim is to determine whether the removal of the price cap resulted in subsequent price increases. The study employed a synthetic control method, comparing actual observed prices with prices estimated by the synthetic control after the intervention. In the ten-month period following the removal of the price cap (December 2022 to September 2023), the actual price was on average 12 % higher than the price projected by the synthetic control. The largest difference was observed in January 2023, with a price premium of 16 %. There was a moderation in the difference between February and September, but even during these months, the gap remained slightly higher than 11 %. This difference may be attributed to distortions of competition due to the price cap.

1. Introduction

In 2021, energy prices rose globally and reached record levels in the European Union in 2022. Fuel prices also increased. To address this issue and gain public support, the Hungarian government introduced a decree setting a retail (and later also wholesale) price cap of 480 Hungarian Forints (approximately 1.2–1.3 euros) per litre for both euro-super 95 gasoline and diesel, effective from November 15, 2021. Apart from a six-week period at the end of 2021, the market price remained above the price cap. The cap did not affect the tax content of the fuels, but rather reduced the profit margins of the retailers without compensating them. Petrol stations were essentially compelled to sell fuel at the same price they procured it. Although some compensations were introduced during 2022 for small independent petrol stations, it did not cover all their losses. Initially, the price cap was only planned for a three-month period. However, it was extended several times and, with modifications, remained in effect for over a year until it was finally lifted on December 6, 2022. The price cap went through several amendments, including the exclusion of vehicles with foreign license plates from its scope. Later, starting from July 2022, it applied solely to domestically owned private vehicles and taxis. However, the majority of customers were still eligible for the capped price.

The objective of this paper is to empirically examine the short-term price dynamics of the euro-super 95 gasoline market after the removal of the government-imposed price cap. To conduct this analysis, we collected a panel dataset containing the 27 member states of the European Union from 2010 onwards. We analysed the pricing dynamics and the impact of the price cap using the synthetic control method. A synthetic Hungary was created using data preceding the price cap that reflected the Hungarian fuel price movements. The synthetic Hungary was then compared to the observed prices after the elimination of the fuel price cap. This comparison allowed for the measurement of the effect of the intervention, i.e., the price cap, on the outcome variable, i.e., retail fuel prices.

The study's main findings indicate that during the period when the price cap was in effect, the average gasoline price was 21.5 % lower compared to the synthetic control. However, in the ten months following the removal of the cap, the observed price was, on average, 11.6 % higher than the synthetic control, i.e., what it theoretically would have been without the price cap. Therefore, it appears that a price premium emerged for gasoline following the removal of the price cap. Due to the timeliness of the event, only a short-term analysis could be conducted. Therefore, it is uncertain whether the price premium will fade away or remain permanent in the long term. The higher prices can have multiple reasons, one of them is the distortion of competition caused by the price cap. The price cap affected the structure of the fuel market in Hungary as

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several petrol stations went out of business. Tacit collusion on the retail gasoline market, found in several other European countries [1–4] can also be a factor behind the higher prices. These factors also appear to be permanent, suggesting that the price premium may persist in the long term, however, future research should examine and verify it.

This paper presents two main contributions. First, fuel market regulations are not common in developed countries, making their impacts are less well-known. Second, price cap regulations may be politically tempting during periods of high inflation. This paper investigates the impact of price cap regulations on competitive markets after their removal. It aims to contribute to the existing knowledge base on this topic and provide some evidence for future policy considerations.

The paper is structured as follows. Section 2 provides a summary of the prior literature on factors that determine fuel demand and the effects of fuel market regulations. Section 3 introduces the methodology and data used. Section 4 presents the empirical findings and related robustness tests. Finally, Section 5 discusses the results and concludes the paper with policy implications.

2. Theoretical background

The section is divided into two parts. First, the drivers of fuel consumption and prices are investigated from both global and Hungarian perspectives. Second, the most important findings on fuel market regulations are summarised.

2.1. Determinants of fuel demand and prices

The demand for fuel is generally inelastic. Espey [5] conducted a meta-analysis summarising the results of studies published between 1966 and 1997 on fuel demand. These studies analysed the short- and long-term price and income elasticities of fuel using data from 1929 to 1993. The analysis indicated that fuel has a small long-term price elasticity (average: −0.58; median: −0.43) and is highly inelastic in the short term (average: −0.26; median: −0.23). Fuel is a difficult-to-substitute product for consumers, which explains the observed behaviour. Hughes, Knittel and Sperling [6] expanded on Espey's [5] meta-analysis, taking into account changes in travel-related behavioural and structural factors over time. They analysed wholesale fuel prices in the United States from 1975 to 1980 and from 2001 to 2006 using regression models. The study found that short-term price elasticity was significantly lower in the later period, ranging between −0.034 and −0.077. This indicates that fuel is almost entirely price inelastic in the short term. The reason for these results is likely due to the increased importance of cars for transportation purposes since the previous study. Regarding short-term income elasticity, there was no significant difference between the two periods. However, higher income levels were associated with a greater sensitivity of fuel consumption to price fluctuations. This can be explained by the fact that individuals with higher income have more flexibility in reducing their car usage, whereas those with lower incomes have already minimized their car usage, leaving them with little room for further reductions.

Wholesale fuel prices are primarily determined by four main factors: the global market price of crude oil, the exchange rate of the national currency to the US dollar, the level of fuel consumption (which partially determines the quantity of import), and market structure, including the strength of competition [7–11,13]. Deltas [12] investigated the response of retail fuel prices to wholesale price changes. The author used fixed effects regression models to estimate the impact of wholesale prices on retail prices in 48 US states from 1988 to 2002, based on monthly data. The results revealed significant asymmetries, with retail prices responding more quickly to price increases than to price decreases. Furthermore, markets with higher average markups exhibited slower and more asymmetric responses to wholesale price changes. Deltas [12] argued that market power was at least partially responsible for sticky prices and asymmetric reactions. Bumpass, Ginn and Tuttle [13] conducted a study on the long-term relationship between oil prices, and retail and wholesale fuel prices in the United States from 1976 to 2012. The study found that the main factor influencing fuel price changes was the movement of oil prices. Both retail and wholesale fuel prices tended to move in sync with oil prices in the long run. In the short term, however, fuel prices were more responsive to price increases than to price decreases. This pattern was particularly noticeable in markets with weaker competition. However, the long-term results somewhat contradicted Delta's [12] earlier findings. Fuel prices showed a symmetric response to changes in oil prices, suggesting no significant market power.

The results obtained from the Hungarian fuel market are consistent with international findings. Csorba, Farkas and Koltay [14] conducted an empirical study on the relationship between market structure and pricing in the Hungarian fuel market. They used weekly data from October 2006 to December 2008 for 1400 Hungarian petrol stations and found a significantly positive relationship between profit margins and market concentration. However, the practical strength of this relationship was weak. The study found that retail prices were mainly influenced by wholesale prices. However, similar to Bumpass, Ginn and Tuttle [13], no evidence of asymmetric price transmission was found. Farkas [9] conducted a complementary analysis by examining the characteristics of petrol stations and their relationship to retail prices. Additionally, he empirically investigated the relationship between retail prices and market structure. The study found that there is a positive correlation between profit margins and the variety of services offered at petrol stations. Additionally, markets with a denser network of petrol stations had smaller profit margins. Furthermore, prices were found to be positively correlated with the prices of competing petrol stations in the vicinity.

2.2. Fuel market regulations and their impacts

Regarding the fuel market, there are few comparable short-term regulations to the one introduced by the Hungarian government, resulting in a lack of closely related empirical studies. However, there are examples of long-term restrictions and regulations.

It is important to note that government regulations may not always benefit customers. Crompton et al. [15] conducted a study on the long-term regulation of the fuel market in South Africa. The Department of Mineral Resources and Energy regulates petroleum prices on an import parity basis. Various margins, such as wholesale, retail, and secondary storage, are added, along with transport costs and taxes. The government's policy focused on import-substituting industrialization to support industry margins. However, this approach was questioned when the country shifted from being a net exporter of petroleum products to a net importer in 2006. The government prioritized investor profitability over protecting consumers from excessive pricing in the fuel industry. Although this regulation initially increased investments, it also provided support to those who did not need it. Crompton et al. [15] primarily focused on regulated fuel prices. Price regulation failed to keep up with market changes and the intended shift to market pricing in 1998 did not materialize. Regulated profit margins increased in real terms between 2000 and 2019, regardless of market price trends. Overall, the regulations had more drawbacks than benefits for consumers.

Becker, Pfeifer and Schweikert [16] conducted a study on the fuel price regulation implemented in Austria in 2009. The country is heavily dependent on fuel imports to meet its demand, and five major companies control half of the petrol stations, indicating an oligopolistic market structure. The regulation aimed to shield consumers from abrupt price fluctuations. Essentially, the regulation permitted petrol stations to implement only one price change per day and prohibited changes during multi-day holidays. The effects of this intervention were measured using a synthetic control method. The results indicate that the regulation was highly effective in the conventional gasoline market. In the short term, gasoline and diesel prices were 23.4 % and 6.6 % lower, respectively, due to the intervention. The effectiveness of this regulation can be attributed to the increased transparency, which in theory could enhance competition and ultimately lead to lower prices.

In a recent study, Pourkhanali et al. [17] examined the impact of the Australian fuel price cap regulation on electricity prices, given that the majority of electricity in Australia is generated using coal and natural gas. The results of the study are mixed. While the price cap was successful in reducing wholesale electricity prices in one region, it was ineffective in another.

3. Methodology and data

3.1. The logic of the synthetic control method and its previous applications

This study aims to investigate whether fuel prices returned to the pre-regulation level after the elimination of the price cap in Hungary. The difficulty with such analyses is to separate the effect of the intervention from the effects of other market factors. Ideally, a treated group (those affected by the intervention) and a control group (those unaffected by the intervention) should be compared. All other contemporaneous changes and market fluctuations should impact the two groups the same way. The theoretical basis for this lies in the fact that the differences between the two aggregated groups can provide an estimate of the effects of the intervention, with the control group serving as a counterfactual to the treated group. This method relies on the parallel trend assumption, which assumes without the intervention, the treated group would have followed the same path as the control group.

When an intervention affects all observations, finding a suitable control group that closely resembles the characteristics of the treated group before the intervention becomes challenging. This is the case here, as the entire country was exposed to the fuel price cap. To overcome this limitation, the synthetic control method emerged as a reliable alternative. The method aims to construct a synthetic control group by combining potential control (donor) units in a weighted manner. This allows for a more objective approximation of the pre-intervention characteristics of the treated unit. The method does not require the existence of a control group where the parallel trend assumption holds. Instead, it creates this control group using a large set of observations not affected by the intervention. The method is a hybrid of the difference-in-difference and the matching methods. It modifies the difference-in-difference method by not including every control unit in the counterfactual with equal weights. One significant advantage is that it does not require the assumption of parallel trends in any control units. A synthetic control can be constructed objectively by adequately weighting all the available potential donors. This synthetic control approximates the pre-intervention characteristics of the treated unit to a considerable extent [18].

The synthetic control method has become popular due to its ability to address challenges associated with traditional methods and provide reliable impact evaluations of economic or policy interventions. Abadie and Gardeazabal [18] first applied this method to investigate the economic impacts of the Basque terrorist conflicts.

Abadie, Diamond and Hainmueller [19] conducted a seminal study demonstrating the application of this method. They examined the impact of a tobacco tax imposed in California in 1988 by constructing a synthetic California using data from five other US states with different weights. Since then, numerous studies have utilized this method to assess the effects of various policy interventions. Notably, it has been employed to analyse the effects of tax changes [20,21], changes in immigration policies [22] and immigration itself [23,24], minimum wage-related interventions [25–27], climate policies [28–30], organized crime [31], prostitution legalization [32], gun-carrying laws [33], and other important policy issues. It is also commonly used in the field of medical sciences [34,35].

The methodology was also used to analyse interventions in the regional fuel market [16]. Specifically, it was used to examine a nationwide regulation introduced in Austria in 2009. The model used data with annual frequency for all variables, and the pre-intervention period spanned from 2000 to 2008. A total of 11 countries were included as potential donors from which six had non-zero weights in the model for gasoline prices and five for diesel prices.

3.2. Mathematical application of the synthetic control method

The synthetic control method assumes that a combination of untreated units is a better comparison group than any single subject from the control group. The selection of the most appropriate synthetic control is based on a data-driven procedure using the pre-treatment data from potential donor combinations. The applicability of the model relies on the assumption that the treatment did not affect the pre-treatment observed values and did not influence the outcome values of the potential control variables during and after the treatment.

The procedure can be described theoretically as follows [36]. A visual representation of the methodology can be found in Sills et al. [37]. There are $J+1$ units of observations with $j=1$ being the treated unit and the rest being the potential control units not affected by the intervention. Time periods are denoted by t. The outcome variable is represented by Y_{jt} and the k control variables are represented by X_{jt} for unit j at time t.

For each unit j at time t, Y_{jt}^N represents the value of the outcome variable in the absence of intervention. In the case of the treated unit ($j = 1$), in time periods $t > T_0$, Y_{1t}^I denotes the value of the outcome variable after the intervention has occurred.

The effect of the intervention on the treated unit at time t ($t > T_0$) can be described as follows:

$$\tau_{1t} = Y_{1t}^I - Y_{1t}^N \tag{1}$$

Unit $j=1$ is affected by the intervention after the time period T_0. Therefore, Y_{1t}^I has the same value as Y_{1t}, which is known. The challenge lies in obtaining an accurate estimation for Y_{1t}^N, which is the value of the outcome variable of the treated unit in the absence of the intervention. This is that can be achieved using the synthetic control method.

For the synthetic control, we consider a $J \times 1$ vector of weights $W = (w_2, \ldots, w_{J+1})$. The weights cannot be negative and their sum have to equal 1. This gives us the estimations for Y_{1t}^N and τ_{1t} as follows:

$$\widehat{Y}_{1t}^N = \sum_{j=2}^{J+1} w_j Y_{jt}, \tag{2}$$

and

$$\widehat{\tau}_{1t} = Y_{1t} - \widehat{Y}_{1t}^N. \tag{3}$$

The procedure searches for weights for each control unit in a way that minimises the difference in predictor variable values between the combination of the donors and the treated unit during the pre-intervention period (i.e., when $t < T_0$):

$$\min\|X_1 - X_0 W\| = \sqrt{(X_1 - X_0 W)' V (X_1 - X_0 W)}, \tag{4}$$

Where V is a $k \times k$ diagonal matrix containing weights $v_1, \ldots, v_k$ for all predictors, and $X_0 = [X_2, .., X_{J+1}]$. The weights in the V matrix do not indicate the importance of the respective predictors in estimating the outcome variable. Instead, they play a role in the estimation of W.

To obtain the optimal W vector, the following steps need to be taken:

1. Select an arbitrary diagonal matrix V to initialize a preliminary $W(V)$ synthetic control:

$$W(V) = \underset{W}{\operatorname{argmin}} \sqrt{(X_1 - X_0 W)^{'} V (X_1 - X_0 W)}$$
$$\text{s.t.} \sum_{j=2}^{J+1} w_j = 1 \text{ and } w_j \geq 0, j = 2, \ldots, J+1 \tag{5}$$

2. Given $W(V)$, the objective is to find a new V^* that reduces the value of the Root Mean Squared Error (RMSE). The RMSE is the sum of the squared difference between the outcome variable of the treated unit and the synthetic control unit. This process leads to an improved V^*:

$$V^* = \underset{V}{\operatorname{argmin}} \sum_{t<T_0} \left(Y_{1t} - w_2(V) Y_{2t} - \ldots - w_{J+1}(V) Y_{J+1t}\right)^2$$
$$\text{s.t.} \sum_{k=1}^{K} v_k = 1 \text{ and } v_k \geq 0, k = 1, \ldots, K \tag{6}$$

The multi-step process is repeated until the RMSE of the synthetic control cannot be further minimized. This results in obtaining W weights for potential donor units, which are used to create a synthetic control unit that resembles the treated unit before the intervention to the greatest extent possible. The calculations were executed in R using the Synth package (https://cran.r-project.org/web/packages/Synth/Synth.pdf).

3.3. Selection of the control variables and data sources

This section summarizes the data used for this study and introduces the donor countries involved. The data were collected from various sources, including the European Commission, Eurostat, OECD iLibrary, and World Bank Open Data, between 2010 and 2023. The output variable is fuel price. To enhance international comparability, prices without taxes were used. Data on these prices were available on a weekly basis. However, the prices were aggregated into monthly observations due to two distinct considerations. First, weekly data would have exhibited excessive volatility. Second, data concerning control variables were exclusively available at a monthly (or, in certain instances, annual) frequency.

The control variables were selected based on their potential to serve as effective proxies for fuel prices. Fuel prices are influenced by the global market price of crude oil, exchange rates, consumption levels, and market structure, as discussed in the literature review. Furthermore, retail costs can also play a role in forming consumer prices. Although the ideal approach would have been to gauge the import price of crude oil using the global import price per barrel, inadequate data availability prevented its incorporation into the final model. This was due to two factors. First, the lack of available crude oil import prices for Hungary. Second, the limited availability of country-level data for countries where such data were available, extending only until 2019. However, exchange rates were incorporated into the model to account for local price fluctuations caused by exchange rate movements [11]. This factor is of particular importance in Hungary, given that the country relies on imports for the majority of its crude oil requirements.

Passenger vehicles primarily use gasoline, while diesel is commonly used in industrial and agricultural activities. According to statistics published by the Hungarian Petroleum Association, euro-super 95 gasoline accounted for 37 % of total fuel consumption in 2022 and 38 % in 2021 in the Hungarian market. This research utilized price and consumption data for this fuel type. The number of passenger vehicles per 1000 inhabitants is used as a proxy for consumption [38]. To measure market structure, country-specific urbanization was used as a competitive proxy due to the scarcity of easily measurable data. Urban areas generally have more competition than rural areas [39]. Furthermore, in urban settings, shorter road lengths and the availability of alternative transportation modes may affect fuel consumption [40]. To evaluate competition, we also considered road density, measured as km per 100 km^2. Denser road infrastructures are likely to have more petrol stations, increasing competition among them.

Retail fuel prices are also influenced by the costs and profit margins of petrol stations [41]. The discrepancies of these costs across countries and their changes are proxied by the annual inflation rate on a monthly basis of the given country.

Finally, the study utilized variables that describe general economic conditions, including GDP per capita and its growth rate. To ensure comparability across time and location, GDP values are presented in US dollars at 2022 price levels.

Comparable country-specific data was obtained from international sources. Table 1 summarizes the variables utilized.

Data was recorded from 2010, covering a pre-intervention period of over 10 years. This extended timeframe enables the establishment of a more precise synthetic control. Initially, we considered all the European Union member states as potential donor countries, assuming relative economic and geographical similarities between them and Hungary. Furthermore, the European Commission publishes comparable fuel price data for EU member states only. However, it is particularly important to take into account the economic policies of individual countries, as these may potentially impede the comparability of the countries in question. Subsequently, we excluded five countries (Belgium, Luxembourg, Croatia, Malta, and Slovenia) due to state-controlled fuel prices. For Belgium,[1] Luxembourg,[2] and Malta,[3] fuel prices were subject to state regulations. Similarly, following the Russian war against Ukraine, Croatia[4] and Slovenia[5] also implemented state regulations within their fuel markets. As a result, the analysis used 21 potential donor countries with market-based fuel pricing.

4. Results and discussion

4.1. Synthetic Hungary

The first step of the analysis is to construct the synthetic Hungary using the method described above. According to the results, out of the 21 potential donor countries, only four were used to construct the synthetic control unit. Synthetic Hungary was created using Latvia (48.3 %), the Netherlands (40.9 %), Romania (7.4 %), and Lithuania (3.4 %). The weights of the other 17 countries were set to zero, resulting in their exclusion from the model.

The presence of Romania is not surprising due to its proximity to Hungary. Additionally, Romania's average consumption and the GDP per capita values closely resemble those of Hungary, along with a similar number of passenger vehicles (Table 2). Similarly, Latvia's and Lithuania's proportion of urban population, average GDP figures, and, for Latvia, the number of passenger vehicles also closely align with Hungary's data. However, the inclusion of the Netherlands is unexpected, particularly with such a high weight. This can potentially be attributed to the fact that Latvia's small size may be balanced out by the Netherlands' larger consumption and population figures. Furthermore, the Dutch variables that proxy competition and market structure closely mirror the values of Hungary, while the higher road density could potentially compensate for the lower values of the other three donor countries.

The absence of the Visegrad countries (Poland, Czechia, and

[1] https://economie.fgov.be/en/themes/energy/energy-prices/maximum-prices-petroleum.

[2] https://www.oecd.org/fossil-fuels/LUX_v2.pdf.

[3] https://www.imf.org/en/News/Articles/2022/12/12/malta-staff-concluding-statement-of-the-2022-article-iv-mission.

[4] https://vlada.gov.hr/news/plenkovic-government-to-cap-fuel-prices-again/33864.

[5] https://www.iea.org/policies/16539-price-caps-on-fuels.

Table 1
Variables used in the study and their sources.

Variable	Time period covered	Frequency	Unit of measure	Data source
Fuel price without taxes (euro-super 95)	2010.01.04.-2023.09.25.	Weekly, aggregated to monthly	EUR/l	European Commission Weekly Oil Bulletin – Price developments
Fuel consumption (euro-super 95)	2010.01.- 2023.07.	Monthly	1000 tons	Eurostat – Energy Statistics
Fuel import	2010.01.- 2023.07.	Monthly	1000 tons	Eurostat – Energy Statistics
Exchange rate	2010.01.- 2023.12.	Monthly	national currency per EUR	Eurostat
Population	2010–2022	Annual	capita	World Bank – World Development Indicators
Urban population	2010–2022	Annual	% of total population	World Bank – World Development Indicators
Road density	2010–2021	Annual	km/100 km^2	OECD – Transport Performance Indicators
Road motor vehicles	2010–2021*	Annual	vehicles/1000 people	OECD – Transport Performance Indicators
Consumer price index	2010.01.- 2023.12.	Monthly	annual rate of change (%)	Eurostat
GDP per capita	2010–2022	Annual	2022 PPP-adjusted USD	World Bank – World Development Indicators
GDP per capita growth rate	2010–2022	Annual	%	World Bank – World Development Indicators

Notes: * For some donor countries, the 2021 values are OECD estimations.

Slovakia) is somewhat unexpected, given that these countries share numerous similarities and engage in collaborative efforts in economic policy. However, Krawiec, Borkowski and Shachmurove [42] found that fuel prices are largely independent in these countries, which may explain why they were not included in the synthetic control.

The aim of this method is to align the synthetic control as closely as possible to the actual subject when determining the included donor countries and their respective weights. This allows the synthetic control to estimate the post-treatment values of the outcome variable in the absence of the intervention. Table 2 also presents the average predictor variables for the synthetically generated Hungary in the pre-treatment period. Based on the pre-treatment average values of the predictor variables, the synthetic Hungary closely (although not perfectly) approximates the characteristics of the actual Hungary. Therefore, the synthetic control is suitable for conducting the impact analysis.

4.2. *The effect of the price cap on fuel prices during and after the intervention*

This paper employs the synthetic control method to investigate the impact of a short-term fuel price cap on prices. The method compares the observed treated data with a synthetic control unit not affected by the intervention as introduced in the previous subsection. As previously stated, it is a requirement of the analysis that the donor countries included in the synthetic control have not introduced policy interventions that affected their local fuel prices. The Government Energy Spending Tracker published by the International Energy Agency (https://www.iea.org/data-and-statistics/data-tools/government-energy-spending-tracker-policy-database) indicates that among the four donor countries, the Netherlands and Romania introduced financial measures affecting the fuel market. In the Netherlands, the excise tax was reduced. If the tax pass-through is complete, this has no impact on the prices without taxes. Based on the Weekly Oil Bulletin data, the tax reduction was passed on to consumers in full, with no impact on the prices without taxes.[6] This is also corroborated by Drolsbach, Gail and Klotz [43], who discovered that the full extent of temporary fuel tax reductions was reflected in consumer prices in several European countries in 2022.

The Romanian fuel subsidy of 10 euro cents per litre was in force only between July and December 2022. The Hungarian price cap was lifted on December 6, 2022, so the most interesting period, the period after the price cap, is almost unimpacted by the Romanian measure. Therefore, it can be concluded that the Romanian fuel subsidy does not distort the main results of the analysis.

Fig. 1 displays the fuel prices without taxes per litre (in EUR) in Hungary and for the synthetic control unit. The fuel price cap was introduced on November 15, 2021, hence, the last pre-treatment period was October 2021. The fuel price cap was lifted on December 6, 2022, hence, the first period with market prices was December 2022. There were four weekly data points during that month, with the first still showing the price cap data. As a result, the monthly value was predominantly calculated by averaging non-capped prices.

Fig. 1 depicts the alignment of the synthetic control values with the actual values before the intervention. The average fuel price without taxes during this period was 0.573 EUR/litre, while the RMSE of the synthetic control estimation was only 0.012 EUR/litre. This implies that the RMSE is approximately 2 % of the average price. This indicates that the synthetic control unit provides an accurate representation of the Hungarian fuel prices. Furthermore, the exclusion of certain countries due to state-regulated fuel prices did not result in a reduction in the quality of the analysis.

Fig. 2 shows the difference between the estimated fuel price without taxes of the synthetic control and the actual price of Hungary. During the period of the price cap, there was a substantial gap between the estimated price of the control and the actual price, as expected. Fig. 3 displays the percentage difference between the actual and synthetic control prices from the introduction of the price cap until September 2023. During the 13 months when the price cap was in effect, the fuel price without taxes was, on average, 21.5 % cheaper than the estimated price for the synthetic subject in the absence of the price cap. The most significant deviation occurred in June 2022, when the estimated synthetic price reached its peak, resulting in a 40.1 % lower fuel price without taxes compared to the estimated value without the price cap.

The artificially low prices during the price cap period had consequences for later prices. Once the price cap was lifted, the trend reversed. From December 2022 onwards, there was a premium in the actual prices compared to the synthetic control. In the first ten months after the removal of the price cap (December 2022 to September 2023), the actual price was, on average, 11.6 % higher than the estimated price based on the synthetic control. In January 2023, the premium showed the largest discrepancy at 16.4 %. Although there was a reduction in the following months, the difference still stood at approximately 11.3 % from February to September 2023.

The higher prices may be attributed to changes in the market structure, as well as to clear incentives for tacit collusion. Independent petrol stations were unable to compete on price during the price cap regulation. These stations are typically located in less densely populated areas and offer a reduced level of service. However, this is offset by the

[6] The excise tax reduction was 17 cents per litre. This also reduced the value added tax amount, which had to be paid for the amount of the excise tax. Consequently, the overall reduction equalled to 21 cents per litre. Between the last week of March and the first week of April in the Netherlands, net fuel prices decreased by 0.8 cents per litre. In the event of a complete tax pass-through, one can anticipate a reduction in consumer prices by 22 cents per litre. In fact, consumer prices decreased by 22 cents per litre (from EUR 2.33 to EUR 2.11 per litre).

Table 2
Average values of the variables for Hungary and the countries included in the synthetic control between January 2010 and October 2021 (pre-treatment period).

Variable	Hungary	Latvia	Netherlands	Romania	Lithuania	Synthetic Hungary
Euro-super 95 fuel consumption (1000 tons)	110	17	337	114	20	153
Population (capita)	9,843,812	1,975,906	17,028,617	19,727,759	2,901,073	9,475,906
Urban population (% of total population)	71	68	90	54	67	76
GDP per capita (2022 PPP-adjusted USD)	28,203	26,211	53,002	24,991	31,124	37,184
GDP per capita growth rate (%)	3	3	1	3	5	2
Road density (km/1000 km^2)	228	94	415	37	135	222
Road motor vehicles (vehicles/1000 people)	341	343	483	285	515	401
Consumer price index (%)	3	1	2	2	2	2
Exchange rate (national currency per EUR)	310	1	1	5	2	1

fact that fuel prices are lower [9]. The data from the National Tax and Customs Administration of Hungary indicates that the turnover of the independent petrol stations declined significantly as a consequence of the elimination of the price competition resulting from the price cap. Moreover, the price cap regulation also negatively impacted the profitability of petrol stations, with the impact being more pronounced for independent stations, which are typically less financially stable than large networks operated by foreign firms. González and Moral [44] found that independent low-cost stations contribute to lower prices while premium brands exert a softening effect on competition in Spain. The loss of market share by independent low-cost stations in Hungary may have resulted in a reduction in competitive pressure, which could have contributed to the observed higher prices. This is also supported by Csorba, Farkas and Koltay [14] showing that higher market concentration is associated with higher fuel prices in Hungary.

Additionally, some petrol stations stopped operating due to the unpredictability introduced by the legislative changes and the significant losses they had to absorb. The number of petrol stations has decreased more than in previous years. Furthermore, remaining stations may collude tacitly to recoup losses, as it is in the interest of the entire sector. Fuel prices are highly inelastic [5,6], and the market is very transparent making this tacit collusion feasible as it was also found in

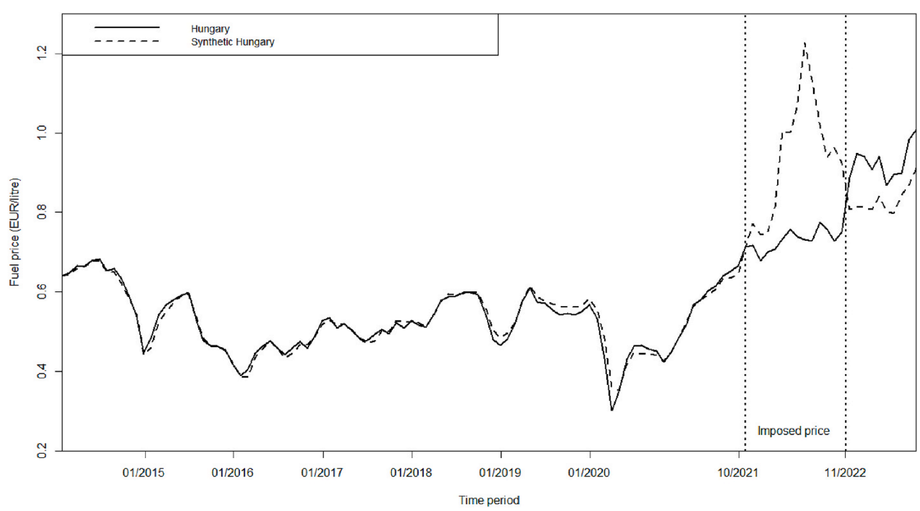

Fig. 1. Fuel prices in Hungary and for the synthetic control unit.

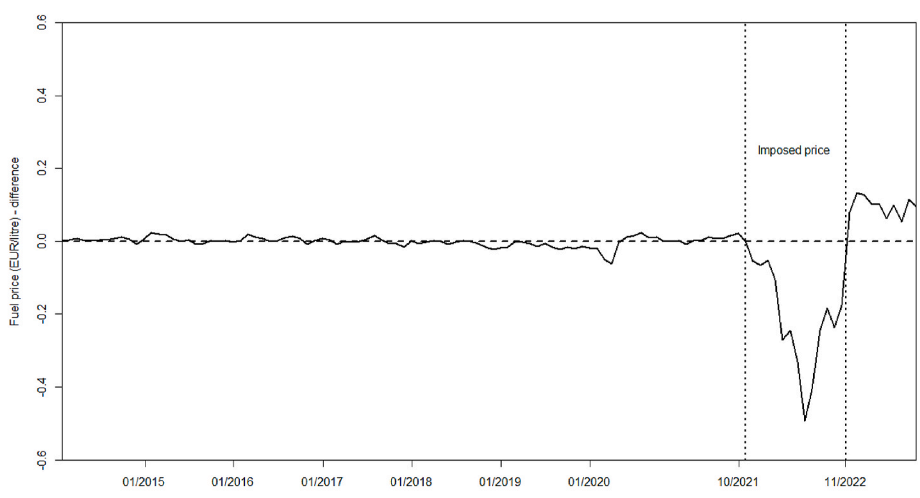

Fig. 2. Difference in fuel prices between Hungary and the synthetic control unit.

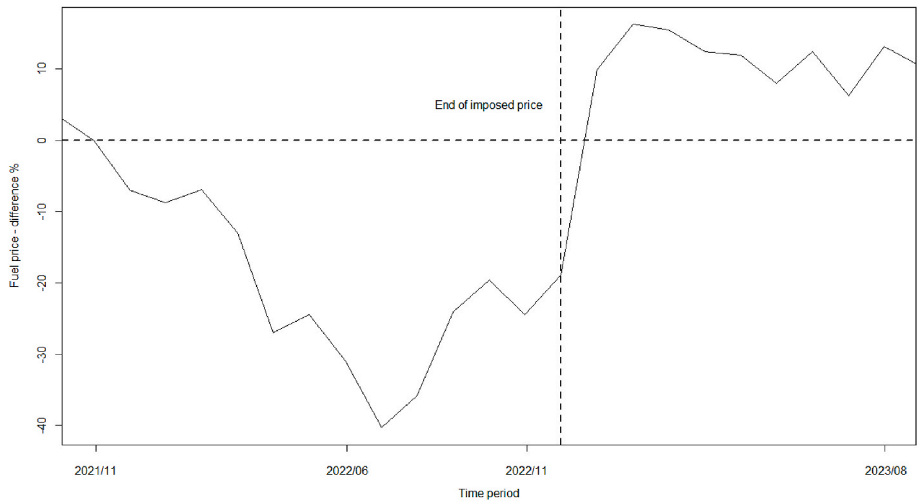

Fig. 3. Difference in fuel prices between Hungary and the synthetic control unit (% of the Hungarian actual price).

other European countries [1–4]. In addition, the fuel market in Hungary is dominated by a single player, which makes tacit collusion manageable, as it was found by García [1] in Spain. This has weakened competition, potentially leading to higher prices.

It is currently unclear whether prices will continue to moderate towards the expected level in the absence of intervention, or if the approximately 11 % price premium observed between February and September 2023 will stabilize over the long term, as the events are recent.

4.3. Placebo tests

Placebo tests can verify whether the constructed synthetic control is suitable for analysis and can inform us about the robustness of the results. The methodology allows for conducting such tests [36]. The placebo tests are conducted in accordance with the methodology outlined in Section 3.2, with the only difference being that the time of intervention or the treated country are modified.

In case of an in-time placebo test, the intervention is performed before the real intervention timing and used as the basis for creating the synthetic control. The estimated values are then compared with those of the treated unit. Fig. 4 shows the results of using August 2016 as the date of the “fake” treatment. The model-building process minimized the difference between the predictor variables of the treated unit and the synthetic control prior to this point in time. During the period between the “fake” and actual interventions, the estimates from the synthetic control closely align with the actual Hungarian prices. A clear observable break occurs at the time of the actual intervention, followed by a movement in the opposite direction after the discontinuation of the price cap. The effects of introducing price caps were observed at the end of 2021, despite the intervention being artificially set in August 2016. This lends credibility to the estimations of the synthetic control.

In the case of an in-subject placebo test, the treated unit is “falsely” changed. As a first step we conducted in-subject placebo tests for the countries used in the construction of the synthetic control, namely Latvia (Fig. 5), the Netherlands (Fig. 6), Romania (Fig. 7), and Lithuania (Fig. 8). To conduct these tests, Hungary was removed from the donor pool. The figures clearly show that there is no treatment effect, which adds further credibility to the estimations of the synthetic control. These results also support our argument that the Dutch and Romanian interventions did not bias our analysis as these interventions had almost no impact on the prices without taxes.

In addition to the individual placebo tests, a permutation test can also be conducted. In this scenario, a synthetic control is created for each country and the estimates of the synthetic controls are compared with their actual values. The results of the permutation test are depicted in Fig. 9, showing the difference between the estimated price (in the absence of the assumed treatment) and the actual price for each country.

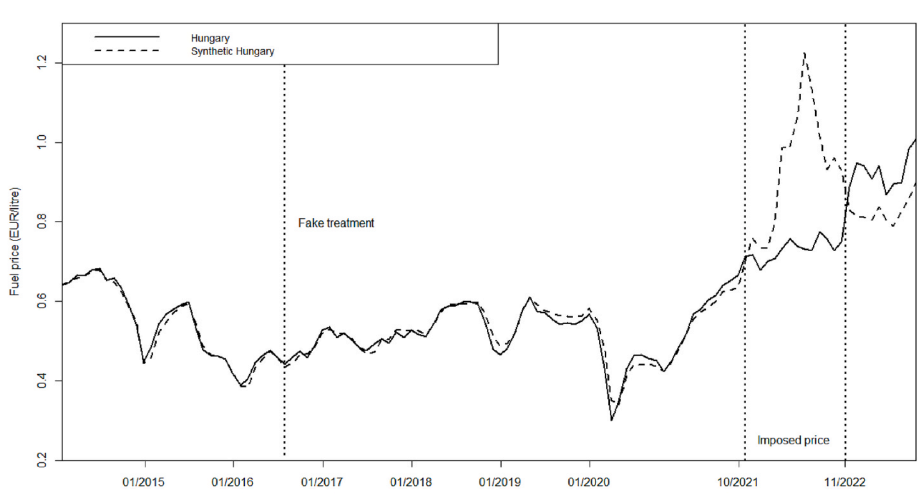

Fig. 4. Results of the in-time placebo test with a “fake” treatment in August 2016.

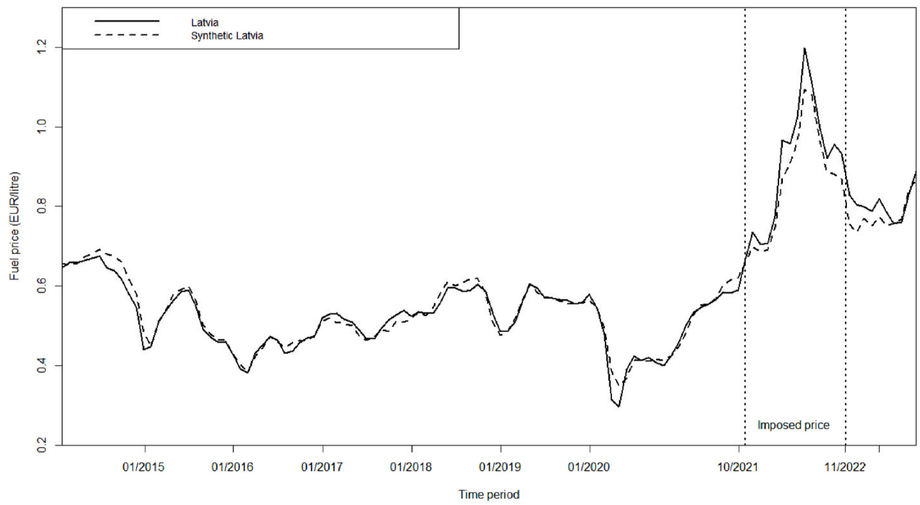

Fig. 5. Results of the in-subject placebo test for Latvia.

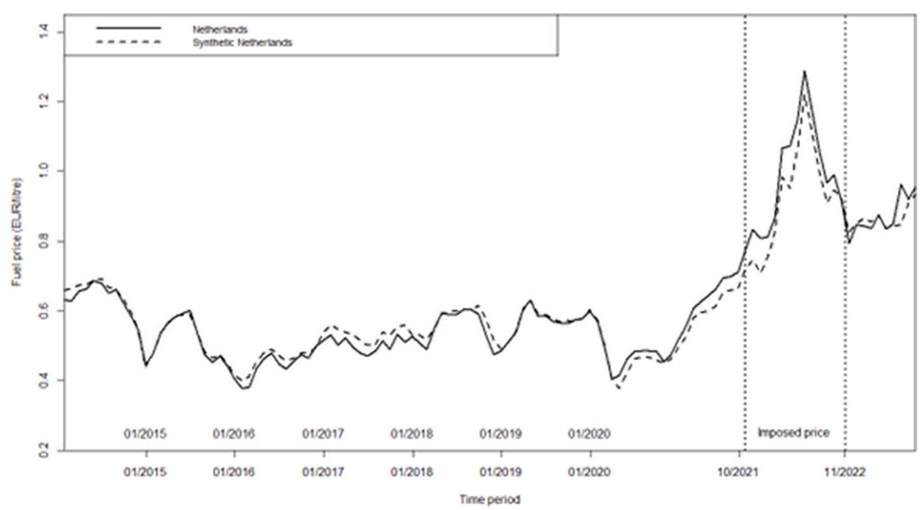

Fig. 6. Results of the in-subject placebo test for the Netherlands.

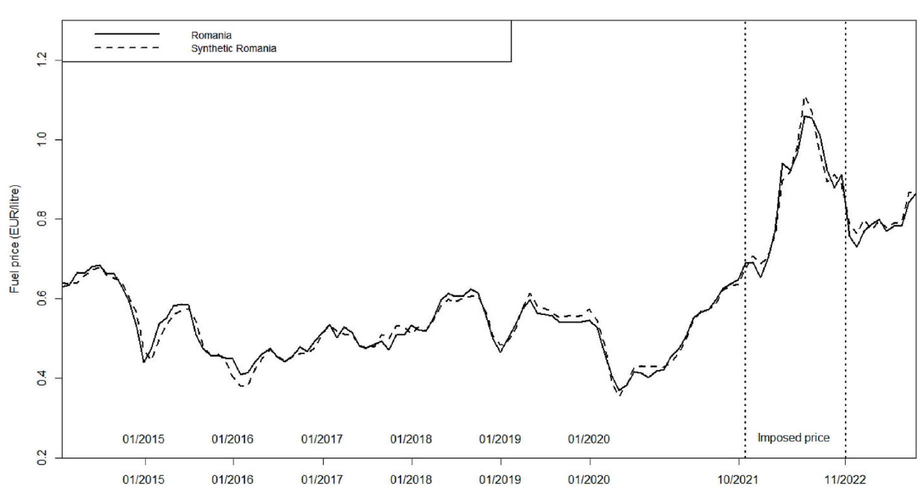

Fig. 7. Results of the in-subject placebo test for Romania.

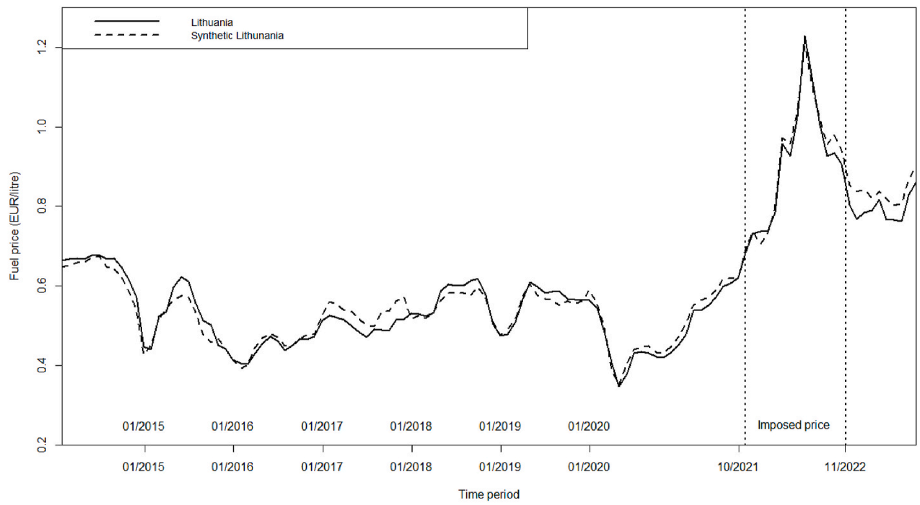

Fig. 8. Results of the in-subject placebo test for Lithuania.

The expectation is that countries without intervention should not show significant deviations. Hungary's values stand out most prominently, indicating that Hungary experienced the most substantial intervention during this period that affected fuel prices. The permutation test further confirms that the impact of the intervention, i.e., the price cap, has been successfully measured.

In summary, the model appears to be appropriate for impact assessment based on the placebo tests.

5. Conclusion and policy implications

This paper examines the price effects of a regulatory fuel price cap that was introduced at the end of 2021 and lifted at the end of 2022 in Hungary. The aim of the price cap was to provide a short-term relief for consumers from rising fuel prices. While it was in force, this measure was able to achieve its goal, leading to, on average, 21.5 % cheaper fuel prices compared to the case of no regulation. The intriguing question is what the long-term effect of this artificial intervention on prices will be after its removal. The aim of this study was to determine whether prices increased following the intervention compared to a scenario without a price cap. To investigate this, a synthetic control method was used.

The results indicate that in December 2022, during the first month of the reintroduced market-based pricing, the intervention resulted in a 9.9 % price premium. Over the first three quarters of 2023, there was an average premium of 11.8 %, with the highest premium occurring in January 2023 at 16.4 %. Following this, there appears to be a trend of moderation between February and September 2023. During this period, the average price of euro-super 95 fuel in Hungary was 11.3 % higher than the estimated price from the synthetic control. The observed increase in prices can be attributed to a number of factors. Potential explanations include the reduction of competition resulting from tacit collusion, the decreasing market share of independent low-cost petrol stations, and the reduction in the number of petrol stations. However, due to the short time frame, it is difficult to conclusively predict how fuel prices will stabilize in the long term, but there are indications that the price premium will be maintained in the long term. Once the long-term impact of the fuel price cap is known, a cost-benefit analysis can be conducted contrasting the positive (price decreasing) and negative (price increasing) effects of the price cap.

Our findings illuminate the negative consequences of politically motivated regulations on free markets. While governments may be tempted to regulate prices during times of high prices, this can result in

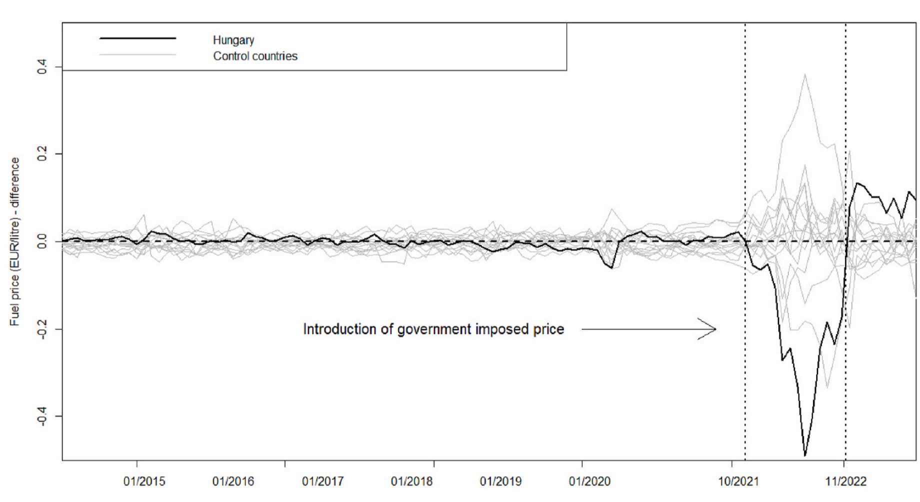

Fig. 9. Results of the permutation test.

temporary shortages and have a long-term detrimental impact on competition. As fuel is an essential input for the economy, fuel shortages during the price cap period can result in a reduction in economic performance. Additionally, the increase in fuel prices following the elimination of the regulation can accelerate inflation. Furthermore, the regulation may also have an adverse effect on consumer behaviour and energy security if it is in effect for an extended period. Therefore, politicians should carefully consider these negative effects before imposing price caps or other regulations on free markets and industries.

The study has some limitations. First, some countries were excluded from the analysis due to regulated fuel prices. Second, some relevant data (e.g., import fuel prices) were not available for all the countries and throughout the entire period. The inclusion of additional countries and the incorporation of the missing variables might have further enhanced the synthetic control. However, the RMSE of the synthetic control was already very low, leaving only a minor scope for further improvement. Another limitation is that the removal of the price cap is a recent event, allowing for only a short-term post-intervention analysis. It would be interesting to revisit the impact assessment from a longer-term perspective, potentially spanning multiple years. However, energy and fuel prices are fluctuating heavily due to the Russian war against Ukraine and other international events. During high price periods, politicians from different countries might be tempted to introduce similar price caps as was done in Hungary. This research aims to draw attention to the potential unintended negative consequences of such interventions.

CRediT authorship contribution statement

Zombor Berezvai: Conceptualization, Validation, Writing – review & editing, Supervision. **Dániel Helfrich:** Conceptualization, Methodology, Software, Formal analysis, Data curation, Writing – original draft, Visualization.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used DeepL in order to improve readability and language of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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