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FEAR OR PRICE? VULNERABILITY OF THE INTEREST IN GREEN TRANSPORT TO COVID DYNAMICS AND FUEL PRICES IN V4 ECONOMIES

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ABSTRACT. The article seeks to verify the possible impact of the COVID-19 and the increase in fuel prices related to the Russian invasion of Ukraine on the consumers' interest in sustainable transportation. In order to achieve this objective, the conducted analysis focused on the search intensity in Google for the phrases related to public transport (e.g., "timetable") and non-oil vehicles (e.g., "bicycle", "electric bicycle", "electric scooter", "electric car") in Czechia, Slovakia, Hungary, and Poland since the outbreak of the COVID-19 pandemic (January 2020 - end of February 2023). Non-linear ARDL models were constructed for these search intensities. Two explanatory variables were employed: the COVID-19 case intensity and the consumer prices of fuels in the selected countries during the specified research period. The findings indicate that the popularity of public transport was most affected by fuel prices and COVID intensity. However, in most cases, increasing petrol prices contributed to the growing popularity of electric cars, but not of electric scooters and bikes.

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Introduction

The escalating severity of climate change and the ongoing discourse on reducing fossil fuel consumption culminated in the drafting of the Paris Agreement and the European Commission's recommendations. A set of policy initiatives aimed at making the European Union (EU) climate-neutral by 2050, known as the European Green Deal and the Sustainable

and Smart Mobility Strategy adopted in December 2020, promote, among others, widely accessible sustainable transport. However, for the average consumer, the problem of choosing a means of transport for commuting, educational pursuits or recreational activities is influenced by transportation costs more so than the imperative to protect the environment (Mussone and Changizi, 2023a; Mussone and Changizi, 2023b). Rapid increases in crude oil prices and, consequently, petrol or diesel prices may prompt consumers to consider alternative transportation options that are less dependent on the oil price fluctuations.

In 2020-2023, consumers' choice of transportation mode was additionally influenced by the pandemic, related travel restrictions, and the fear of using public transport. The growing popularity of bicycles, electric bicycles, and scooters, could be attibuted to a number of factors. Firstly, commuters avoided airplanes, buses, trains, and subways in the initial period of the pandemic, when the fear of infection was the greatest and the passenger limits were the strictest (Mussone and Changizi, 2023a; Mussone and Changizi, 2023b). Secondly, oil and fuel prices surged after the Russian invasion of Ukraine. Finally, the fashion factor (Lin et al., 2017; Javaid et al., 2020) results from the promotion of a sustainable, low-emission lifestyle.

This article investigates the time-varying interest of consumers in sustainable transportation modes. The objective of the study is to determine the conditions under which consumers seek out information on the possibility of using public transport. The secondary aim of the research is to reveal the circumstances in which consumers consider buying or renting various alternative means of transport, such as bicycles, electric scooters, or electirc cars, and therefore look for information about them online. In order to ascertain whether consumers express an interest in sustainable transportation, we approximated such interest with the Google search intensity for the keywords related to public transport and non-oil vehicles since the outbreak of the COVID-19 pandemic (January 2020 - end of February 2023).

We concentrate on V4 (the Visegrád Group also known as the Visegrád Four) countries, Czechia, Slovakia, Hungary and Poland, and compare the results obtained for the group with those for Germany and Sweden. The V4 group constitutes a special subset of post-communist economies. It differs from Western Europe concerning the quality and access to public transport and the attitude towards possessing private cars. Namely, the generation of people born after 1980 in Western countries is less keen on car ownership and driving than the previous generation (Pojani et al., 2018; Kuhnimhof et al., 2012). They also show a greater preference for utilising alternative modes of transportation. Contrariwise, in Central and Eastern Europe, the situation is the opposite, since cars not only guarantee unrestricted mobility (there are many places that public transport does not reach) but are also a synonym of higher socioeconomic status (Pojani et al., 2018; Pucher and Buehler, 2005). On the other hand, the availability and quality of public transport and transportation policy are diverse within the V4 group.

Within the V4 group, Hungary is the leader in urban public transport usage, followed by the Czech Republic, Poland and finally the Slovak Republic. It is worth stressing that the usage of public transport in Czechia and Hungary, exceeding 3,000 km/year, is the highest - as compared not only to the rest of V4 but also to the EU average of around 2,200 km/year (Enerdata, 2023). On the other hand, the level of satisfaction associated with travelling by urban public transport was the highest in the Czech Republic while the lowest in Hungary (Minelgaitė et al., 2020). Satisfaction with urban public transport is mainly affected by the availability of transport, fare price, transport time and its quality (comfort, cleanliness). Data shows that the portion of public transportation in overall passenger movement has been decreasing rapidly in most Central and Eastern European countries (except Czechia), i.e. the countries where public transport used to be dominant (especially in Estonia, Poland and Bulgaria) (Enerdata, 2023).

Nowadays, one observes the growth of interest in electric cars as an alternative to traditional ones. The tendency is worldwide, particularly noted in Europe. According to a European Parliament regulation, starting from 2035, all newly sold passenger cars and vans in the EU must be emission-free. Emission limits for clean light commercial vehicles are 50 g CO2/km until 31 December 2025 and 0 g CO2/km from 1 January 2026. In the V4 countries, the highest shares are set for the Czech Republic at 29.7%, followed by Hungary at 23.1%, Poland and Slovakia at 22%.

Of the 27 EU countries, 20 provide incentives for purchasing electric vehicles (further: EVs). Seven do not offer any incentives for buying EVs, but the majority of these offer tax deductions. These incentives have impacted the increasing numbers and shares of electric vehicle registrations in EU countries. In the first half of 2023, approximately one in five new passenger cars registered was electric with external charging, with the share of battery electric vehicles (BEVs) reaching 12.9% and plug-in hybrids (PHEVs) 7.4%. The Scandinavian countries and the Netherlands are the leaders in the uptake of electromobility (in 2023, in Sweden, the share of new passenger electric vehicles with external charging was 37.3% BEV and 20.7% PHEV, in Finland 32.6/18.8%, in the Netherlands 28.8/13.1% and in Denmark 30.0/10.9%). In the case of the V4 countries, the share of BEVs and PHEVs was 3.4% and 2.9%, respectively (Hungary: 5.1/4.9%, Poland 3.6/2.8%, Slovakia 2.4/2.8%, Czech Republic 2.6/2.2%) - see: ACEA (2023).

The degree of development of the electric cars market in European countries also varies due to other factors, such as the maturity of EV infrastructure or the total cost of ownership. According to the LeasePlan (2023) report referenced to 22 countries[1] the best-adapted countries are Norway, Netherlands, United Kingdom, Austria, and Sweden. The situation is slightly worse in Germany (10th position in the ranking) and Hungary (15th position). However, countries such as Slovakia, Czechia and Poland are performing much poorer in terms of preparedness for the electric vehicle transition. Therefore, what Poland, Czechia, Slovakia, and partly Hungary have in common is that they need a well-developed infrastructure allowing their citizens to use electric cars conveniently. Moreover, the EV market share is still relatively small, and the total cost of electric cars' ownership is high so far.

Moreover, the V4 countries differ in terms of the popularity of two-wheelers and the quality of infrastructure devoted to cyclists. European Cyclists' Federation compared 28 European countries, taking into account various aspects of cycling (bicycle modal share, road safety, cycling tourism, number of cycling advocates, and bicycle sales) and published ECF Cycling Barometer (ECF, 2015). Sweden took third place in the ranking, ahead of Germany (fifth place), Hungary (eighth position), Slovakia (10th place), Czechia (14th place) and Poland (20th place).

Regarding electric micromobility, the usage of electric scooters has greatly increased in Europe since 2015. According to the Innovation Centre for Mobility and Societal Change (InnoZ) GmbH, during the period spanning 2016 to 2017, the number of scooters increased fourfold (with 350,000 registered users in 2017). Between 2017 and 2018, it almost tripled (after: (Zagorskas and Burinskiene,˙ 2020)). The most rapid expansion of private e-scooters in 2019 took place in Poland (1151% growth per year), Taiwan (925%), Spain (498%) and

[1] The situation in the following countries was analysed: Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Spain, Sweden, Switzerland and the United Kingdom. The maturity of EV infrastructure was assessed based on data on public charge points relative to the population, EV registration market, and availability of fast chargers relative to the size of available highways. The maturity of the EV market measures the actual uptake of EV registrations in a country. Total cost of ownership was evaluated based on data on government incentives, energy prices and monthly rental of lease vehicles.

Belgium (415%) (Howe and Bock, 2018). Thus, we could treat Poland as a leader in V4 in electric scooters adoption.

This analysis aims to investigate the possibility of the V4 economies fulfilling sustainable development goals, particularly the reduction in the usage of combustion cars. We examine which form of transport can be perceived as a possible replacement: public transport, micromobility or electric vehicles, and which factors are crucial to speed up the change. We concentrate on such factors as safety preference and cost. We hypothesise that (H1) the cost factor (petrol price) should significantly affect at least the interest in electric vehicles (see e.g. Du et al., 2024). In contrast, (H2) safety should be crucial for the choice of public transport. Based on the results of the study, we formulate policy implications.

Our results show that the popularity of public transport was most affected by COVID intensity and fuel prices. Moreover, we numerically corroborate the differences between the V4 countries regarding the reaction of the end-user interest to growing fuel prices. For instance, the changes in fuel prices did not affect the interest in public transport in Hungary, where its usage rate is the highest and the satisfaction - the lowest. The high usage rate of this kind of transport may thus not result from choice but from no other choice and thus - is not affected by the price of the alternative transport mode. Also, the reaction of interest in electric cars to the changes in fuel prices differed across the V4 countries. In Hungary, which has the best-developed infrastructure for EVs adoption, the interest in this kind of cars was independent of fuel prices. The results suggest the need for special policies to enhance the usage of the latter in countries with lower GDP per capita, as well as investment in infrastructure supporting the usage of alternative transport modes.

The article's structure is as follows: the review of scientific literature, the research methodology and description of the data, main results, and discussion with conclusions and policy implications.

1. Literature review

1.1. Factors determining the choice of transport mode

Regarding the literature on transport choice, Javaid et al. (2020) point out three types of factors that determine the urban mode choice: individual, social, and infrastructure level factors. Based on the review of 75 papers, the authors conclude that the infrastructure-related aspects provide a rationale for substantial discrepancies in preferences for the transport mode. Thus, investment in the latter is crucial for the transition to sustainable mobility. The study also reveals that price- and time-elasticities play important roles in choosing the travel mode.

Minelgaite et al. (2020) concluded that the availability of a stop from the place of residence is the most decisive motivating factor for using public transport. Other studies (Efthymiou and Antoniou, 2017) demonstrate that enhanced contentment with the quality of service, environmental awareness, high car use and upkeep expenses result in a rise in public transportation demand. On the other hand, an increase in ticket prices, as well as preference to use other modes (car, bike and walk), have led to a decrease in the use of public transport.

Many researchers document, however, that the influence of the factors and the preferences themselves changed after COVID-19 (Mussone and Changizi, 2023b; Abduljabbar et al., 2022; Zhu et al., 2023; Nadimi et al., 2022). In the pre-COVID period, the most important were travel duration and distance, combined with socio-demographic characteristics such as gender, age, income, and access or having a particular transport mode (after Mussone and Changizi (2023b)). For instance, Wójcik (2019), who studied the determinants of travel mode choice in one of the biggest cities in Poland, Lodz, showed that from all analysed factors, the

most decisive were the individual characteristics of respondents and whether they had access to a car. Nevertheless, the fuel cost affected car usage as well.

According to (Mussone and Changizi, 2023a, 2003b), factors like residency, trip time, and movement area played an influential role in determining the selection of transport mode before the first lockdown in Italy. On the contrary, during and after the lockdown, socio-demographic factors (gender and age), as well as day-to-day travel priorities and worries about the safety of public transport, affected the transport mode choice the most. In another study, Osorio et al. (2022) found that the decline in passenger numbers choosing buses and trains was mainly caused by remote learning and working, along with socio-demographic factors.

COVID-related measures had also a positive influence on the environment and travel safety. Mobility restrictions contributed, inter alia, to the decline in car-accidents rate (Bucsuházy et al., 2023). However, through an examination of the factors influencing telecommuting frequency, choice of transportation for commuting, and the environmental pollutants produced by these journeys, Ceccato et al. (2022) demonstrated that the positive environmental impact of on-line work during the COVID-19 pandemic may be reduced soon. Although the number of trips may decrease, there is a notable shift towards unsustainable modes of travel. Hence, post-pandemic longer trips may predominantly involve car travelling. Łącka and Suproń (2021), who analysed the Polish road freight transport, reached similar conclusions, showing that once the mobility restrictions had been removed, the number of kilometres covered by cars increased more substantially than in previous years.

Regarding the choice of "traditional car" as a transport mode, Alberini et al. (2022) studied data from the German Mobility Panel, covering the years 2004 - 2019. The authors investigated the impact of fluctuating fuel prices (in time and over regions) on the so-called Vehicle Kilometers Traveled (VKT). The study revealed that VKTs are vulnerable to petrol prices and significantly fall in response to the increase in gasoline prices. The cost of travel was also one factor contributing to the increased usage of electric bicycles in China (Bai et al., 2020). Among other factors affecting the choice, the authors name low cost, comfort, flexibility, accessibility and the possibility of omitting traffic jams. Similar results were documented for Italy by Di Gangi et al. (2022). However, when it comes to shared micromobility, trip distance, precipitation, and access distance determine this mode choice (Reck et al., 2022).

There is also a strand in the literature that concentrates explicitly on the motivation for electric car usage. Although electric cars are perceived as luxury goods, concerns about the possible increase in gas and oil prices were the primary incentives of EV producers (Khazaei, 2019). Moreover, as documented by Gerpott and Mahmudova (2010), electricity prices are one of the factors (apart from environmental awareness) that motivate people to purchase green energy. Thus, we can suppose that the energy cost - or the possibility of using low-cost energy - is a crucial factor in determining EV usage (see also Priessner and Hampl (2020), Du et al. (2024)). Infrastructure also plays a crucial role here: the electric car is the superior choice compared to the gasoline car depending on the location of the charging point and the possibility for fast recharging (Armenio et al., 2022). According to Abbasi et al. (2021), this is the perceived level of convenience and ease associated with using an electric car. Individuals fascinated by new technologies (technophiles) are convinced that these technologies will work well and be seamless (Osiceanu, 2015). Another motivating factor is the social influence and environmental awareness (Mau et al., 2008; Axsen et al., 2013; Khazaei, 2019).

1.2. Using Internet data to measure sentiment and approximate consumers' demand

Internet data, especially Google Trends or Twitter, have been gaining attention as a valuable resource of the market and consumers' sentiment. Scholars have successfully used this

tool in numerous studies devoted to predicting demand, modelling sentiment, and forecasting prices of stocks and commodities.

For instance, Pani et al. (2023) used Twitter data to approximate consumers' sentiment towards electric vehicles. The authors documented the decline of positive attitudes to such vehicles after the pandemic. Strictly related to our study is the work of Afkhami et al. (2021). The authors predicted demand for retail gasoline in the United States. The research shows that the accuracy of the prediction can be improved when one includes Google Search Volume Index data for buses and trains to approximate consumers' readiness to use public transport services.

Search engines' data have been successfully used to forecast demand in the tourist sector, too. For instance, Pan et al. (2012) used search query volume to predict demand for hotel rooms. The authors concluded that such data could serve as a preliminary signal of visitors' interest and that managers could use them to predict occupancy of hotel rooms, event attendance and respective spending. Yang et al. (2015) used search data from two different search engines, Google and Baidu, to accurately forecast the number of visitors to the most visited tourist spots in China, and Bangwayo-Skeete and Skeete (2015) successfully applied the MIDAS (Mixed-Data Sampling) model with Google data to predict tourists' arrivals to the Caribbean. Moreover, an index developed by Yang et al. (2021), constructed to monitor recovery in the tourism sector after the COVID-19 pandemic, is also based on information from Google searches.

Regarding other types of demand, Hand and Judge (2012) demonstrated that information about the number of Google inquiries related to cinema visits could increase the accuracy of forecasting cinema admissions. Wu and Brynjolfsson (2015) examined the real estate market and proved that data on Internet queries could help to predict market price changes and sales volumes reliably. The authors concluded that consumers' digital traces reveal their likely underlying economic intentions and activities. Kim and Shin (2016) showed that one could successfully use data from search engines to predict short-term demand for air journeys. Vosen and Schmidt (2011) constructed an index for private consumption based on Google search categories associated with consumer behaviour. The authors compared the forecasting performance of the indicator with the two most commonly used indicators based on survey data: the University of Michigan Consumer Sentiment Index and the Conference Board Consumer Confidence Index. The Google indicator outperformed the survey-based indicators. Similarly, Woo and Owen (2019) showed that Google Trends data deliver essential information about research trends prior to consumption shifts and changes in durable goods consumption. Eichenauer et al. (2022) constructed daily economic sentiment indices (DESI) using Google search volumes for Germany, Austria, and Switzerland. The authors found significant correlations between the DESI and traditional economic indicators (a consumer confidence index in Germany and Austria and the KOF Economic Barometer for Switzerland).

1.3. Contributions of this study

To summarise - among many factors that influence the choice of the mode of transport, the authors frequently name income and the cost of travel. During the COVID period, the fear of catching the virus was one of the crucial factors as well. Thus, it is justified to analyse the interest in alternative transport modes concerning the increasing fuel prices and the COVID-19 pandemic dynamics. The increase in fuel prices is especially harmful to the EU economies of lower GDP-per-capita and heavily dependent on oil imports from Russia. Therefore, we investigate the V4 economies and compare the results with a Western European economy, i.e. Germany and Sweden. To approximate the interest in the various transport modes, we use the tool already well-grounded in the literature: Google Trends data.

Thus, our study extends the literature on the change in consumers' travel preferences since the COVID outbreak and during the period of spiraling fuel prices. Moreover, we fill a gap in the existing literature by extending the analysis to the Central and Eastern European (CEE) economies, which are less frequently analysed and have severely suffered from the overall price increase, including fuel prices.

2. Research methods and data

We analyze weekly data on consumer prices of petroleum products (PB95) inclusive of duties and taxes (see Figure 1). The source of fuel data is the weekly oil bulletin prepared by the European Commission[2]. The price changes exhibit similar patterns with an exception of Hungary for most of 2022, when petrol price caps were applied. We collected Google search volume data from January 2020 to the end of February 2023 via the website https://trends.google.com/. We use search terms for public transport, alternative transport and electric cars in Czechia, Germany, Hungary, Poland, Slovakia and Sweden. We considered the total Google search volume related to a given means of transport for various phrases in national languages. Table 1 provides detailed information on the keywords used.

Table 1. Google search phrases

Country	Means of transport	Search phrases
Czechia	Public transport	jízdní řády+mhd+bus+autobus+ autobusy+vlaky+vlak+České dráhy
	Alternative transport	jízdní kola+jízdní kolo+elektrokoloběžky+ elektrokoloběžka+elektrické kolo+elektrokola
	Electric cars	elektromobily+elektromobil+ elektroauta+elektroauto
Hungary	Public transport	menetrend+menetrendek+busz+autóbusz+ autóbuszok+vonat+vonatok
	Alternative transport	kerékpárok+kerékpár+elektromos kerékpárok+ elektromos kerékpár+elektromos roller+ elektromos rollerek
	Electric cars	elektromos autók+elektromos autó
Poland	Public transport	rozkład jazdy+mpk+pkp+pociąg+ pociągi+bus+autobus+autobusy
	Alternative transport	rower+rowery+hulajnoga elektryczna+ hulajnogi elektryczne+rower elektryczny+rowery elektryczne
	Electric cars	samochód elektryczny+samochody elektryczne+ auto elektryczne+auta elektryczne
Slovakia	Public transport	cestovný poriadok+vlaky+vlak+ bus+autobusy+autobus+MHD
	Alternative transport	bicykle+bicykel+elektrobicykle+elektrobicykel+ elektrokolobežky+elektrokolobežka
	Electric cars	elektromobily+elektromobil+elektroauta+elektroauto
Germany	Public transport	Fahrplan+Bahn+Zug+Bus+DB
	Alternative transport	Fahrräder+Fahrrad+e-bike+e-bikes+Elektroroller
	Electric cars	Elektroautos+Elektroauto+E-auto+E-autos
Sweden	Public transport	Tidtabell+Tåg+tågen+SJ+Buss+bussar+SL
	Alternative transport	cykel+cyklar+elscooter+elsparkcykel+elcykel+elcyklar
	Electric cars	elbil+elbilar

Source: *own compilation*

In Fig.3-Fig.5, we present popularity indices of three alternative transportation modes for Czechia, Germany, Hungary, Poland, Slovakia and Sweden. The source of COVID-19 new

[2] https://energy.ec.europa.eu/data-and-analysis/weekly-oil-bulletin_en

cases (see: Figure 2) is World Health Organization[3]. We use the information on the number of confirmed cases per week. We emphasize that we are aware of the partial imperfection of this data - in many countries, COVID-19 testing facilities were overloaded, especially at the beginning of the pandemic, but also later. In addition, not all people experiencing disease symptoms decided to test. Therefore, some cases were not detected. However, in general, our goal was not to measure the exact intensity of the disease but to consider the information about the extent of the pandemic that consumers received at the time, as this information may have influenced their choice of mode of transport.

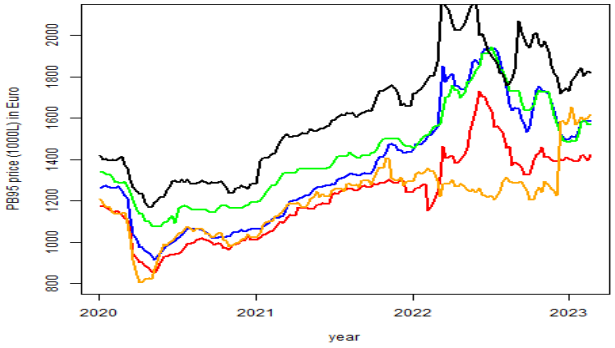

Figure 1. The price of PB95 (1000L, with taxes) in Euro
Source: *own compilation*
Note: This figure presents consumer price of PB95 in Czechia (blue), Germany (black), Hungary (orange), Poland (red), Slovakia (green) and Sweden (yellow).

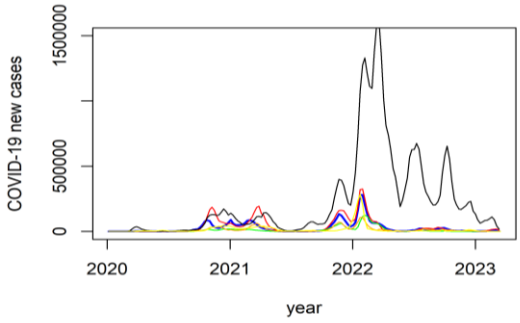

Figure 2. COVID-19 new cases
Source: own compilation
Note: This figure presents official weekly counts of COVID-19 cases in Czechia (blue), Germany (black), Hungary (orange), Poland (red), Slovakia (green) and Sweden (yellow).

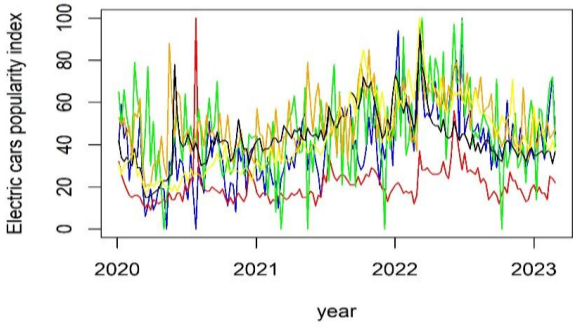

Figure 3. Electric cars popularity index
Source: *own compilation*

[3] https://covid19.who.int/data

Note: This figure presents Google Trends indices calculated for search terms related to electric cars in Czechia (blue), Germany (black), Hungary (orange), Poland (red), Slovakia (green) and Sweden (yellow). The following phrases in national languages were used to construct these indexes: "electric car", "electric cars" and their synonyms.

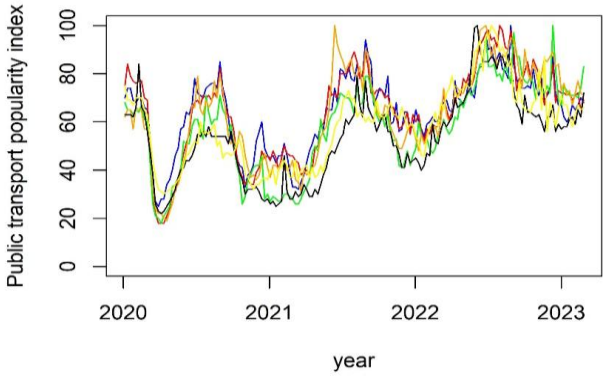

Figure 4. Public transport popularity index
Source: *own compilation*
Note: This figure presents Google Trends indices calculated for search terms related to public transport in Czechia (blue), Germany (black), Hungary (orange), Poland (red), Slovakia (green) and Sweden (yellow). The following phrases in national languages were used to construct these indexes: "timetable", "train", "trains", "bus", "buses" and their synonyms.

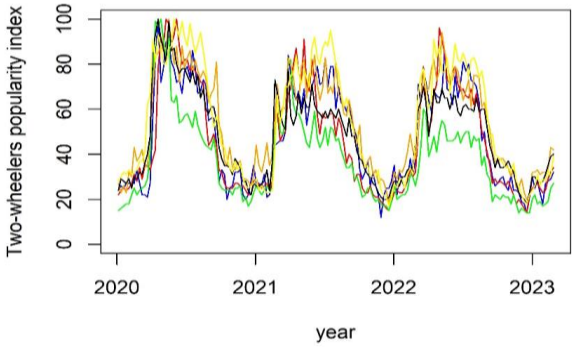

Figure 5. Alternative transport popularity index
Source: *own compilation*
Note: This figure presents Google Trends indices calculated for search terms related to alternative transport (bicycles, electric bicycles, electric scooters) in Czechia (blue), Germany (black), Hungary (orange), Poland (red), Slovakia (green) and Sweden (yellow). The following phrases in national languages were used to construct these indexes: "bicycle", "bicycles", "electric bicycle", "electric bicycles", "electric scooter", "electric scooters" and their synonyms.

2.1. Seasonality adjustment

Graphs for the consumers' interest in public transport and alternative modes such as bicycles and other two-wheelers show a strong seasonal pattern: interest increases in spring and summer and decreases in autumn and winter. On the one hand, this is because travelling by bike or scooter is much more convenient in summer than in winter. On the other hand, travelling by public transport for longer distances by train may be associated with going on vacation in the

summer. Since our paper aims to capture non-seasonal factors determining the interest in these means of transport, we decided to remove seasonality from the data.

For this purpose, we use analogous data from the entire period available on Google Trends (from January 2004 to the end of February 2023). With such a period length, only monthly data are available. Hence, we determined the average interest in the selected means of transport for each month of the year. Next, we divided the consumer interest values in the sample by the corresponding seasonal component. In Fig.6 and Fig.7, we present seasonally adjusted indices of interest in public transport and alternative transport.

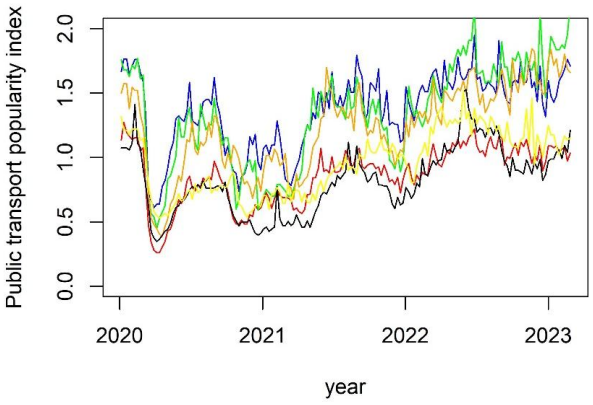

Figure 6. Public transport popularity index (seasonally adjusted)
Source: *own compilation*
Note: This figure presents deseasonalized Google Trends indices calculated for search terms related to public transport in Czechia (blue), Germany (black), Hungary (orange), Poland (red), Slovakia (green) and Sweden (yellow). The following phrases in national languages were used to construct these indexes: "timetable", "train", "trains", "bus", "buses" and their synonyms.

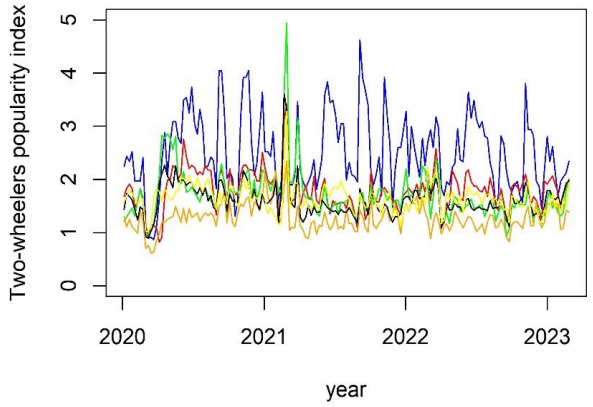

Figure 7. Alternative transport popularity index (seasonally adjusted)
Source: *own compilation*
Note: This figure presents deseasonalized Google Trends indices calculated for search terms related to alternative transport (bicycles, electric bicycles, electric scooters) in Czechia (blue), Germany (black), Hungary (orange), Poland (red), Slovakia (green) and Sweden (yellow). The following phrases in national languages were used to construct these indexes: "bicycle", "bicycles", "electric bicycle", "electric bicycles", "electric scooter", "electric scooters" and their synonyms.

2.2. Non-linear ARDL model

Since the reaction of preferences to the changes in petrol prices or COVID dynamics may not be immediate, we concentrate on the long-run asymmetrical relationships using the non-linear ARDL model. The model requires the decomposition of shocks into positive and negative ones. As an opening step, we define the variables as the random walk process:

$$Fuel_t = Fuel_{t-1} + v_{C,t} = Fuel_0 + \sum_{i=1}^{t} v_{F,i}, \quad (1)$$

where $Fuel_0$ is the first observed value of the process and the variable v_F denotes white noise residuals. Next, we construct two kinds of shocks, positive and negative ones:

$$v_{F,t}^{+} = max(v_{F,t}, 0), \; v_{F,t}^{-} = min(v_{F,t}, 0). \quad (2)$$

Later, we analogously define positive and negative cumulative shocks of fuel prices and interest:

$$y_{F,t}^{+} = \sum_{i=1}^{t} v_{F,i}^{-}, \quad (3)$$
$$y_{F,t}^{-} = \sum_{i=1}^{t} v_{F,i}^{-}.$$

The NARDL model has the following form (Shin et al., 2014):

$$Interest_t = \sum_{j=1}^{p} \phi_j Interest_{t-j} + \sum_{j=0}^{q} \left(\theta_j^{+} y_{F,t-j}^{+} + \theta_j^{-} y_{F,t-j}^{-}\right) + \varepsilon_t, \quad (4)$$

where $y_{F,t}^{+}$ and $y_{F,t}^{-}$ are defined by equation (3). The equation can be re-written into the error-correction form as (Shin et al., 2014):

$$\Delta Interest_t = \rho Interest_{t-1} + \theta^{+} y_{F,t-1}^{+} + \theta^{-} y_{F,t-1}^{-} + \sum_{j=1}^{p-1} \gamma_j \Delta Interest_{t-j} + \sum_{j=0}^{q-1} \left(\phi_j^{+} \Delta y_{F,t-j}^{+} + \phi_j^{-} \Delta y_{F,t-j}^{-}\right) + \varepsilon_t$$
$$= \rho \xi_{t-1} + \sum_{j=1}^{p-1} \gamma_j \Delta Interest_{t-j} + \sum_{j=0}^{q-1} \left(\phi_j^{+} \Delta y_{F,t-j}^{+} + \phi_j^{-} \Delta y_{F,t-j}^{-}\right) + \varepsilon_t, \quad (5)$$

where $\xi_t = Interest_t - \beta^{+} y_{F,t}^{+} - \beta^{-} y_{F,t}^{-}$ is the non-linear error correction term, and $\beta^{+} = -\frac{\phi^{+}}{\rho}$ and $\beta^{-} = -\frac{\phi^{-}}{\rho}$ are the asymmetric long-run relationship parameters.

If $\rho = 0$, we obtain the regression with the first differences of the data only. Thus, no long-run relationship between the levels of $Interest_t, y_{F,t}^{+}$ and $y_{F,t}^{-}$ exists. Hence, the cointegration test requires testing the hypothesis $\rho = 0$ against $\rho < 0$ (Banerjee et al., 1998). The test statistics t_{BDM} has t Student distribution. To test for asymmetry of the relationships, we use the test of Pesaran et al. (2001), i.e. the *F*-test of the null hypothesis $\rho = \theta^{+} = \theta^{-} = 0$ - further denoted as F_{PSS}. The model was estimated using the R package "ardl.nardl" (Otoakhia, 2023).

3. Results

Table 2 presents the descriptive statistics calculated for log changes of variables. The pandemic and war-related periods are characterized by the extreme changes in fuel prices. Their mean value is positive - which resulted in an upward trend visible in the Fig. 1. Interestingly, when we compare properties of interest in all transport modes between different countries, we observe that the highest volatility of interest occurs in Czechia and Slovakia.

Table 2. Descriptive statistics of log changes of variables

	Czechia	Hungary	Poland	Slovakia	Germany	Sweden
Public transport						
Min	-0.5878	-0.4261	-0.5108	-0.5261	-0.3947	-0.4406
Mean	0.0002	0.0006	-0.0006	0.0013	0.0007	-0.0008
Max	0.3066	0.2792	0.2077	0.3285	0.5185	0.2915
Std.dev.	0.1116	0.1067	0.1002	0.1263	0.1062	0.0979
Skewness	-0.8265	-0.1684	-1.1012	-0.7069	0.1983	-0.4103
Excess kurtosis	3.8654	1.0602	3.7294	2.9036	4.1466	2.0644
Alternative transport						
Min	-0.7715	-0.8024	-0.8201	-0.9192	-0.6813	-0.7914
Mean	0.0002	0.0004	0.0011	0.0029	0.0019	0.0013
Max	0.8858	0.5147	0.6381	0.6931	0.7069	0.5831
Std.dev.	0.2644	0.1937	0.1932	0.1950	0.1699	0.1612
Skewness	0.5338	-0.5864	-0.0052	-0.7637	-0.0721	-0.4040
Excess kurtosis	1.6600	1.5955	2.8279	3.8540	3.9655	4.2756
Electric cars						
Min	-2.9444	-0.6614	-1.2730	-4.2047	-0.3830	-0.4560
Mean	0.0006	-0.0006	-0.0023	-0.0031	-0.0008	0.0011
Max	3.4657	1.2585	1.4697	4.0604	1.0986	0.3969
Std.dev.	0.6526	0.2875	0.2583	1.0041	0.1528	0.1346
Skewness	0.7631	0.7100	0.8658	-0.0525	2.4108	-0.0410
Excess kurtosis	11.8743	1.9254	8.8856	6.9063	15.9589	0.6445
PB 95						
Min	-0.0834	-0.1094	-0.1077	-0.0399	-0.0926	-0.1298
Mean	0.0014	0.0017	0.0012	0.0009	0.0015	0.0009
Max	0.0914	0.2572	0.1073	0.0665	0.1190	0.1454
Std.dev.	0.0204	0.0305	0.0230	0.0152	0.0227	0.0287
Skewness	0.1398	2.9722	-0.6164	0.2207	1.2104	-0.2225
Excess kurtosis	5.6544	29.1964	7.1574	2.2411	8.4319	7.0111
COVID: new cases						
Min	-0.6677	-1.5283	-1.2116	-2.1226	-0.9163	-1.3419
Mean	0.0530	0.0419	0.0594	0.0396	0.0696	0.0400
Max	2.9957	1.6582	2.5337	3.4340	2.4485	2.6027
Std.dev.	0.4385	0.4347	0.4208	0.4698	0.4371	0.4391
Skewness	2.5961	0.5928	1.7327	1.7077	2.6526	1.9500
Excess kurtosis	13.2444	2.3509	8.2519	17.6065	11.0528	11.6404

Source: *own calculations*

For each country, we estimated a non-linear ARDL model, where we allowed for the asymmetric response to the changes in petrol prices. We included the control variable for the COVID dynamics. Table 3 presents the estimation results. In each case, the best model was chosen automatically, using the general-to-specific approach, conducting the multi-path backward elimination, diagnostics tests and goodness-of-fit measures, according to Sucarrat (2021).

Table 3. Asymmetric long-run relationships between the interest in various transport modes and the dynamics of fuel prices and pandemics

	PB(-)	PB(+)	COV	asym.*p*-val
PT: Czechia	0.891(***)	0.794(***)	-0.065(***)	0.513
PT: Hungary	0.819(-)	0.052(-)	-0.075(***)	0.281
PT: Poland	0.702(*)	0.831(***)	-0.043(***)	0.359
PT: Slovakia	1.283(**)	1.468(***)	-0.084(***)	0.577
PT: Germany	1.693(**)	1.7(***)	-0.037(***)	0.984
PT: Sweden	1.213(***)	1.321(***)	-0.03(***)	0.204
AT: Czechia	0.746(**)	0.19(-)	-0.04(**)	0.007
AT: Hungary	-0.307(-)	-0.339(-)	0.028(***)	0.78
AT: Poland	-0.689(**)	-0.552(***)	0.003(-)	0.21
AT: Slovakia	-1.428(**)	-1.033(***)	0.06(***)	0.151
AT: Germany	-0.884(**)	-0.72(***)	0.025(-)	0.17
AT: Sweden	0.131(-)	-0.016(-)	-0.025(.)	0.081
EC: Czechia	2.174(***)	1.611(***)	-0.033(-)	0.043
EC: Hungary	0.483(-)	0.471(-)	-0.005(-)	0.959
EC: Poland	2.277(***)	1.569(***)	-0.054(**)	0.004
EC: Slovakia	1.939(***)	1.319(***)	-0.008(-)	0.082
EC: Germany	0.781(-)	-2.88(***)	-0.03(-)	0
EC: Sweden	2.951(**)	2.399(***)	0.068(-)	0.159

Source: *own calculations*

Note: (***) denote significant result at 0.01 level, (**) - at 0.05 level, (*) - at 0.1 level, while (-) -insignificant. PT denotes "public transport", AT - "alternative transport modes", EC- "electric cars". The *p*-value in the last column is the result of the test of the hypothesis for asymmetric long-run relationship. The null hypothesis is that the coefficients are equal. Small *p*-value denotes the rejection of the null hypothesis (the long-run relationship is asymmetrical).

We observe that the reaction of the preferences for public transport was negatively correlated with the COVID dynamics. In all countries, the increase in the dynamics of the pandemic contributed to the decline in interest in public transport (and the pandemic slowdown - to the increase in the respective interest). The relationship was also present in Sweden, although the anti-COVID policy in the country and stringency measures taken by the Swedish government differed from the policy implemented in the rest of Europe.

The changes in fuel prices did not affect the interest in public transport in Hungary. In all other countries, the increases in petrol prices increased the interest in public transport, while the decreases - decreased it. The response of the interest was symmetric to the increases and decreases of the fuels' prices (see the *p*-values in the last column of Table 3).

The results obtained for the popularity of the alternative transport modes are not as straightforward as for public transport. In all the countries, apart from Hungary and Sweden, the relationships between fuel prices and the interest in alternative transport were significant. In Poland, Slovakia and Germany, the decreases in petrol prices increased the interest in alternative transport, while the increases - decreased it. We note that the increases in fuel prices and energy prices co-occurred. The set of keywords for alternative transport included electric scooters and electric bikes. Thus, the increase in energy prices may also denote the increase in the cost of using these transport modes. However, the result can also denote that the alternative transport modes are not perceived as substitutes to car transport (such as public transport) and that also other factors - not only the price - affect the popularity of the alternative transport modes.

In the Czech Republic, the decrease in petrol prices contributed to declining interest in alternative transport. We note, however, that in Czechia (similarly to Sweden), the relationship

between the interest in alternative transport was negatively related to the dynamics of the COVID pandemic. The increase in COVID cases contributed to the decline in interest in alternative transport (which can be the consequence of the decline in overall mobility), while the decrease - to the increase in that interest. The latter can indicate a long-run trend of increased interest in alternative transport modes, regardless of the direction of petrol price changes.

In Hungary and Slovakia, the interest in alternative transport was positively related to COVID dynamics - the increase in COVID cases resulted in the growth of interest in alternative transport modes and the decline - in weakened interest. The latter result could be explained by the decline in the availability of public transport when the pandemic intensified.

Eventually, the interest in electric cars was unrelated to petrol prices only in Hungary. In the rest of the V4 group and Sweden, the increase in petrol prices contributed to the growth in interest in electric cars and the decline - to the decrease in interest. Interestingly, in Germany, only the growth in petrol prices affected the interest. Nevertheless, it contributed to the decline in interest in electric cars.

Moreover, only in Poland, the dynamic of the pandemic affected the interest in electric cars - the increase in COVID cases contributed to the drop in the interest and the decline - to the increase. The result could indicate that electric cars are perceived as a luxury good in Poland and that the pandemics - in the long run - contributed to the pauperising of society.

4. Discussion, conclusions and policy implications

This article analyses the changes in interest in public transport, alternative transport and electric cars, measured by the number of weekly Google searches, concerning the dynamics of the pandemic and changes in fuel prices. We concentrate on long-run dependencies starting from the pandemic.

We note a strong reaction of the interest in public transport to the changes in COVID dynamics. Secondly, the interest in public transport depends on fuel prices on the condition that the price changes are high. The exception was Hungary, where the interest in public transport did not depend on the dynamics of petrol prices. We note, however, that Hungarian consumers were protected from high gasoline prices during the key period of rising fuel prices in other countries. Moreover, the rate of public transport usage in Hungary is the highest among V4, and the satisfaction rate is the lowest. Thus, we can guess that the high rate of this kind of transport usage does not result from choice but from no other choice and that this passenger group may not possess cars.

Also, the interest in electric cars depended on the dynamics of fuel prices when the changes were substantial. Again, Hungary was an exception here. The rest of V4 countries exhibited similar patterns to Sweden, where in 2022, more than half of newly-registered cars were electric cars (BEV, PHEV and hybrids) (Rodríguez, 2023), which was the second result, just after Norway. Germany took the third place in the ranking. However, the interest in electric cars in Germany exhibited different patterns than in V4 and Sweden. The growth in petrol prices contributed to the decline in interest in electric cars there, while in the rest of the countries (apart from Hungary), the interest in that type of car grew as a response to the growth in petrol prices. In the case of Poland, the Czech Republic, Slovakia, and Sweden the increase in electricity prices accompanying increases in fuel prices did not reduce consumer interest in electric cars. This may therefore mean, that this interest was largely shown by users who have access to electricity from photovoltaics and are only slightly affected by increases in electricity prices. Most importantly, consumers are looking for information about electric cars in the face of rising fuel prices, when public transport is unavailable or perceived as an unattractive alternative.

The difference in reaction of the end-users interest in Germany and Hungary from the other countries can be explained by the cost of travel with an electric car relative to a "traditional" one. LeasePlan (2023) calculates the so-called energy price index, i.e. the relation of the cost of travelling 100km with an electric car to the analogous cost of driving a "traditional" car. For Germany, the index reached 131% in 2023, compared to 78% in 2021, which gives the 53 percentage points increase. On the contrary, for Hungary, the relative magnitudes amounted to 53% (2023) and 44% (2021) - i.e. the 9 percentage points increase[4]. Thus, in Germany, the cost of travel ceased to be an advantage when choosing the electric vehicle over the traditional car. In Hungary, the change was so small that it may not be enough to change the customers' preferences, especially since the fuel prices in Hungary were regulated by the government.

The interest in alternative transport was the least related to the changes in petrol prices. The results varied across countries and did not exhibit intuitive patterns. Most often, the increase in fuel prices resulted in a decrease in interest in alternative transport and a decrease - in its increase. These results could be explained twofold: the increase in fuel prices and energy prices co-occurred. The increase in the cost of using these transport modes draw away large part of consumers (i.e. inhabitants of urban areas who rarely have access to electricity generated from photovoltaics). However, the result can also denote that two-wheelers are not perceived by all consumers as substitutes to car transport and the purchase of such a vehicle was treated as an unnecessary expense in a period of rising living costs. Moreover, as other researchers show (see, e.g. Félix et al. (2020)), the crucial factor for promoting cycling is the proper infrastructure rather than the cost factors.

The conclusions from the research can be summarised as follows. First, we support the results obtained by other authors that the interest in travel modes changed after the outburst of the COVID-19 pandemic. We show that the dynamics of the pandemic affected the interest in travelling using public transport. That result supports our hypothesis H2, that the safety factor was crucial for the passengers.

Second, the cost of travelling is an essential factor driving the changes in travel preferences when the consumers have the choice. Although only a few research papers document the significant influence of petrol prices on the choice of public transport or electric cars, we show that it can influence the preferences provided that the changes in its price are substantial. Similarly to Lin et al. (2017), who showed that the usage of electric bikes in China increased, inter alia, because of the low cost of travel associated with this transport mode, and Du et al. (2024) who demonstrated that the gasoline prices are the main determinant influencing the decisions of Chinese consumers to buy electric vehicles, we show that in V4 countries (except for Hungary), the rising cost of petrol contributes to the increase in interest in electric cars. However, we did not obtain such explicit results for the popularity of electric bikes and scooters. That may suggest that alternative transport is not treated as a replacement for car transport in V4 countries (probably because of the underdeveloped infrastructure), while electric cars may have such potential. That result supports our hypothesis H1, that the increasing petrol prices should boost the consumers' interest in electric vehicles.

Based on the research results, we can formulate the following policy implications. The price of conventional fuels affects the popularity of public transport and electric cars. However, our results show that petrol price increases may not directly affect the popularity of alternative transport modes. Hence, also other factors, besides the cost, influence that interest. Thus, policymakers should intensify the beyond-cost factors to stimulate the change in transport preferences. Such factors can be campaigns promoting sustainable transport or creating new

[4] For comparison: in the Czech Republic, the index grew from 58% in 2021 to 98% in 2023, in Poland: from 56% to 76% and in Slovakia from 52 to 80%, while in Sweden from 46 to 86%.

trends (the fashion factor). Moreover, in the case of electric cars the cost factor seems to be important. Therefore, it may be necessary to provide some fiscal stimulus to boost the adoption of energy-efficient road vehicles, such as the Rabla Plus programme in Romania or generous tax incentives in Norway, recognised as the main drivers of success in promoting electric vehicles in this country.

The research has some limitations. First, as in each study that utilises search engines, we could extend the set of keywords. Secondly, we could also analyse the changes when our regressor (petrol price) crosses some pre-defined level. Eventually, we analyse only the preferences of the Internet users who used the Google search engine. Thus, the sample does not include those who do not use the Internet or prefer other search engines. However, Google search engine accounts for nearly 90% of market share in Europe (Statcounter GlobalStats, 2024) and the share of the population connecting to the internet in European Union is around 91% (Eurostat, 2024), hence we believe, that the results' bias towards web users is limited and acceptable.

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