Impact of Covid19 pandemic on domestic used passenger car sales in Poland

Aleksandra A. Olejarz [1]*

[1]*University of Warmia and Mazury in Olsztyn, Faculty of Economics, Department of Market and Consumption, Olsztyn, Poland*

Abstract

The global pandemic of the coronavirus (Covid-19) has prompted a number of restrictions, including travel, in order to limit the spread of the virus. These restrictions have led to alterations in the patterns of travel. Long-distance travel was curtailed in favour of shorter journeys. In lieu of public transportation, individuals have opted for private motorised and non-motorised mobility. This has led to an increased demand for private vehicles. This study aims to assess the impact of the Covid-19 pandemic and the restrictions introduced on the demand for second-hand passenger cars in Poland. The ARIMA-X-13 and TRAMO-SEATS seasonal adjustment methods were used to identify market shocks based on monthly data on the number of registrations of used passenger cars purchased in the country from the Central Vehicles and Drivers Register. The results demonstrated that the Covid-19 pandemic led to a decline in sales, which can be considered a market shock.

Keywords: used passenger cars, pandemic, Covid-19, outliers, shock market

1. Introduction

The outbreak of the novel coronavirus (Covid-19) in early 2020 prompted a series of socio-economic countermeasures with the objective of limiting the spread of the virus. In nearly all countries, restrictions have been imposed on the operations of educational institutions and childcare facilities (e.g., the implementation of remote education), catering establishments, hospitality venues, and retail outlets (Olejarz, 2021). These restrictions have entailed the total or partial closure of these facilities. Furthermore, cinemas, theaters, and other cultural institutions were compelled to cease operations. The extent to which these establishments were subject to restrictions varied across different countries. Nevertheless, the vast majority of governments implemented regulations mandating the use of personal protective equipment (masks and gloves) and imposed restrictions on individual mobility. Furthermore, it was recommended that individuals remain indoors and avoid physical contact with others (Hale et al., 2020). In an effort to curtail the propagation of the novel coronavirus, various governments across the globe have enacted restrictions on individual mobility and the capacity of public and private

---

* Corresponding author: Aleksandra A. Olejarz (aleksandra.olejarz@uwm.edu.pl)

transportation. This led to the suspension of numerous car, air, and sea services due to their unprofitability. This event had a profound impact on numerous sectors of the economy and society. Consequently, the suspension of transportation services resulted in employees encountering challenges in accessing their respective workplaces. Where feasible, remote work was implemented (Shibayama et al., 2021), however, this was not applicable to manufacturing companies. The data demonstrate a clear correlation between the restrictions implemented in response to the pandemic and the subsequent economic consequences, including a decline in employment and consumer spending, accompanied by an uptick in the social poverty rate. These findings, as reported by Coibion et al. (Coibion et al., 2021), underscore the need for targeted policy interventions to mitigate the adverse economic impacts of crises like the pandemic. According to Mulla et al., the restrictions on movement implemented by the government had a positive effect, reducing the transmission of the virus. (Mulla et al., 2023; Olejarz, 2021). The restrictions imposed also led to a decrease in the use of public transportation in favor of private motorized and non-motorized vehicles. This shift could have led to an increase in the sales of passenger cars, among other consequences. It is plausible that the most sought-after vehicles were used passenger cars, given their affordability and accessibility, as well as the constrained availability of both domestic and imported vehicles (used and new) due to restricted international trade, labor shortages, and disrupted supply chains (Hyży, 2023).

The aim of this article is to present changes in the movement of the European population during the pandemic and changes in passenger car sales during this period. Furthermore, the results of a study on the impact of restrictions on market shocks in used car sales in Poland are presented. The hypothesis posited was that "the restrictions on movement caused market shocks in the sale of used passenger cars." The specific objective of the study was to identify shocks (changes) in the market for used passenger cars purchased in Poland and to determine the nature of these shocks and their causes.

2. Literature Review

2.1. Mobility in Selected European Countries

The ongoing global pandemic has had a significant impact on the way people travel. The introduction of passenger quotas on public transport and the order to maintain social distance led to a shift in travel habits. Italy, the European country most affected by the social impact of the pandemic, has experienced notable changes in the number and extent of journeys. The number of journeys outside the provinces decreased, while the number of journeys within the provinces increased. The population shifted from utilising public transport to relying on private mobility, including both motorised and non-motorised options (De Cet et al., 2024). A similar decline in long-distance travel was observed in the Czech Republic (Purkrábková & Hrubeš, 2023). Furthermore, a reduction in confidence in using public transport has been documented (Fridisek & Janos, 2022). In the Netherlands, the number of journeys undertaken for work purposes decreased in correlation with the advent of remote working. A reduction in the number of journeys made for shopping and leisure purposes was also observed. Concurrently, there was an increase in the sale of personal vehicles (Taale et al., 2022; Olde Kalter et al., 2022). In contrast, a study by Soler et al. (Soler et al., 2023) in 20 European cities (Dublin, Stockholm, Lisbon, Paris, Malmoe, Porto, Berlin, Milano, Malaga, Madrid, Charleroi, Poznan, Cluj Nappoca, Krakow, Catania, Brno, Lille, Dresden, Bacău) demonstrated a decline in private vehicle travel among individuals who worked remotely and an increase

in private vehicle use among those who did not work remotely. Those who avoided travelling by public transport did so for health reasons, namely to avoid virus infection. Similarly, German residents, particularly women, were also more likely to avoid public transport, citing concerns about virus transmission. At the same time, those with higher incomes were more likely to use private cars for travel (Schaefer et al., 2021). The lockdown resulted in a significant reduction in mobility in Spain, with the public opting for public transport and walking over private vehicles (Mars et al., 2022). Similarly, in Poland, there was a notable decline in the use of public transport, which was not directly related to the introduction of restrictions but rather to the number of infections. The higher the number of infections, the less frequently public transport was used (Wielechowski et al., 2020). A decline in the popularity of public transport in Poland, during and after the Covid-19 pandemic, was also indicated by Gorzelańczyk and Pawłowski (Gorzelańczyk & Pawłowski, 2023).

2.2 Car ownership in European Union

The Covid-19 pandemic led to a significant increase in the use of private transport, which in turn led to changes in car ownership patterns. A study by Vega-Gonzalo et al. (Vega-Gonzalo et al., 2023a) based on data from the European-wide Urban Mobility Survey, using 10,152 individuals from a total of 21 European urban areas (Dublin, Calais, Lille, Paris, Charleroi, Malmö, Berlin, Dresden, Poznan, Krakow, Praha, Brno, C;uj-Napoca, Bacau, Milano, Catania, Madrid, Málaga, Lisboa, Porto) of different sizes, geographical locations and urban forms, demonstrated that changes in car ownership were strongly associated with socio-economic characteristics. Prior to the pandemic, individuals with higher levels of education and those with greater financial resources were more likely to own a vehicle. Additionally, as the number of children in the household increased, the frequency of car ownership also increased. During the pandemic, demographic and economic characteristics also played a pivotal role in the purchase and sale of cars. The frequency of vehicle purchase increased with the number of minors in the household and inversely with the age of the children. This was demonstrated by the fact that the younger the children, the more likely they were to purchase a vehicle. A noteworthy finding of the study was that those who were working remotely were more likely to purchase a vehicle than those who were working in a fixed location. This was attributed by the authors to the willingness of the former group to accept greater distances to work, which was associated with a relocation of residence (Vega-Gonzalo et al., 2023a; de Abreu e Silva & Melo, 2018). The majority of car sales were made by younger individuals and middle-aged adults. Individuals in the middle and upper-middle income brackets sold a car less frequently. Furthermore, an investigation by Vega-Gonzalo et al. (Vega-Gonzalo et al., 2023b) revealed a positive correlation between an increase in the frequency of car ownership and the utilisation of shared mobility services. In contrast, a study by Bucsky and Juhász (Bucsky & Juhász, 2022) covering 2021 found that the prevalence of shared mobility services increased in line with an increase in car ownership. Although this study did not include the effects of the Covid-19 pandemic, it indicates an increased prevalence of car ownership. Increased private car ownership during the pandemic did not correspond with increased new vehicle sales in Europe (László, 2021). New vehicle sales in Europe during the pandemic decreased by approximately 36%.

2.3 Car sales in the European Union

The automotive industry is considered to be one of the pillars of economic development, being a driver of technological progress. The production and sale of cars, especially new ones, is also one of the key factors in the development of the European Union's economy (László, 2020). The SARS-CoV-2 pandemic has affected the automotive industry worldwide. Supply chains were disrupted and consumer demand and preferences changed (Yadav & Bansal, 2025). The car manufacturers have encountered problems related to liquidity, declining revenues, rising costs, and labor shortages (Hyży, 2023). This also affected European countries, which are heavily dependent on the automotive sector, and the outbreak of the pandemic caused panic in the new car market. This panic was reflected in a decline in new car sales that was almost three times greater than the decline in GDP in individual EU countries (László, 2020). The impact of the SARS-CoV-2 pandemic on the automotive market varied across EU countries. The destructive impact of the pandemic was determined by Shevczenko et al. (Shevczenko et al., 2021). In their study, they classified countries according to the extent to which the COVID-19 pandemic affected production and sales of new cars. A decrease of less than 5% was considered a minor disruptive effect (group 1); a decrease of 5-15% was considered quite significant (group 2); a decrease of 15-25% was considered significant (group 3); and a decrease of more than 25% (group 4) was considered a very significant disruptive effect. No EU country was included in the first group, either in terms of production or sales of new passenger cars. The second group included Slovakia and Romania in terms of production and Denmark in terms of sales. A significant destructive effect (group 3) on passenger car production was observed in Spain, Italy, Czechia, Germany, Hungary and Finland, and on sales in Austria, Belgium, Czechia, Finland, Germany, Hungary, Poland, Switzerland, Romania, the Netherlands, Slovakia and Sweden. In the automotive industry, the most affected countries were Poland, Portugal, the United Kingdom, Austria and Slovenia (passenger car production) and Bulgaria, Croatia, France, Greece, Italy, Portugal, Spain and the United Kingdom (new passenger car sales).

As noted by Velten et al. (Velten et al., 2019), unlike the used car market, the new car market is well recognized and described in the literature due to constant monitoring and access to current reports. In this case, there is a lack of available global and regional data on vehicle movements, including imports, exports, and domestic sales.

According to research by Zacharof et al. (Zacharof et al., 2025), sales of used passenger cars in the European Union varied from country to country. The authors highlighted France and Germany in particular as countries where the volume of transfers of ownership of passenger cars (sales) increased until around 2016, after which the trend reversed and the number of used car sales began to decline year on year. This trend started before the pandemic, continued during the pandemic and continued after the pandemic. In Italy and Spain, there was an upward trend in used car sales before the pandemic. The pandemic caused a decline in these sales, but by the end of the pandemic period, sales began to increase again. At the same time, France and Germany were found to be the countries from which used cars were most frequently sold to other European countries. The average age of used cars sold also increased from around 8 years to 10.3 years in Germany and 14.2 years in Spain. It was also noted that the sales structure has changed in recent years. Electric and hybrid vehicles have appeared on the used car market and their sales are growing and depend on the sales of new vehicles of this type. It should be noted that these

vehicles change ownership faster (on average after 4 years) than internal combustion engine vehicles (Olejarz & Kędzior-Laskowska 2024).

Available analyses of new car sales, especially of passenger cars, are mainly based on annual data. Such data, including country of sale and engine type, are available from EUROSTAT, among others. Monthly data are published by organizations representing car manufacturers and dealers, such as ACEA (European Automobile Manufacturers Association), and changes are usually interpreted as percentages. Data on vehicle fleets, including their purpose, type of drive and age, are also available (e.g. EUROSTAT). However, there are gaps in access to data sets on transfers of ownership, i.e. sales of used cars in individual countries. The available data are usually based on information provided by used car dealers, which is also mostly limited to general data sets with preferences for car brands and models. However, it should be remembered that cars are also sold without dealers, which means that the published data may not reflect reality. Therefore, there is a lack of publications based on more detailed (monthly) data on used car sales (especially in European countries) and the impact of the SARS-CoV-2 pandemic on these sales. In order to fill this gap, a study on changes in sales trends of used passenger cars in Poland was conducted, identifying potential market shocks, indicating their date of occurrence and nature.

3. Methodology

2.1 Data collection

The study of the occurrence of shocks on the used passenger car market in Poland was based on data from the Central Vehicles and Drivers Register (pl. Centaralna Ewidencja Pojazdów i Kierowców - CEPIK). The requisite data was downloaded via the application programming interface (API) from the CEPIK registers. Thereafter, the data was selected (data on sales of used passenger cars selected, data on other vehicles rejected) and aggregated (the number of transactions in each month has been added up), resulting in a time series of monthly data from 2012 to 2023, which covered the number of registrations of used passenger cars purchased in the country (hereafter, used car sales). The data set was further refined by excluding cars purchased from the services (vehicles used by local government units, the police, the army, etc., sold at end-of-life), purchased after forfeiture to the State Treasury (cars auctioned for debt to the State Treasury), recovered (re-registered after theft) and vehicles entrusted by foreign entities. The number of excluded vehicles was relatively small and did not occur in every month. Passenger cars were considered second-hand cars purchased in the country when, in the CEPIK register, the date of first registration in the country differed from the date of last registration.

2.2 Methods

A market shock (also called an outlier) being an unexpected change in the studied phenomenon (Balke, 1993) is an observation whose value differs so much from the other observations in the sample that it may cause doubts as to whether it comes from the same population as the other observations in the sample (Hawkins, 1980). Identification of these anomalies causes many problems in the modeling process (Chang et al., 1988) and often depends on the quality of the data. There are many methods that allow identifying outliers, e.g. discriminant methods, taxonomic methods, density function estimation or

data visualization and signal processing (Trzęsiok, 2016). In the case of demand series, including car demand, where demand is understood as the number of car registrations, autoregressive models with conditional heteroskedasticity (ARCH) are the optimal choice for analysis due to their suitability for high volatility (Toppur & Thomas, 2023). Nevertheless, series pertaining to the period of the Covid-19 pandemic should be modelled in a distinct manner from series that did not experience a pandemic. Toppur and Thomas identified ARIMA class models as the most useful for this purpose. In light of the aforementioned considerations, the TRAMO-SEATS and ARIMA-X-12 procedures, which are based on ARIMA class models, were used to identify shocks to the market for imported and domestically purchased used passenger cars in Poland. The TRAMO-SEATS procedure is recommended for time series analysis within the European Statistical System (ESS) by both EUROSTAT and the Central Statistical Office (Poland Statistics). This is to ensure comparability of national data and to improve the overall quality of European statistics. ARIMA-X-12 was developed and is recommended by the United States Census Bureau (USCB). Both procedures are used for seasonal cleaning of processes and might be utilised in the analysis of daily, weekly, monthly, or quarterly data. Both procedures can identify four types of abnormal observations in time series, as outlined by Muirhead (Muirhead, 1986), Fox (Fox, 1972), Chen and Liu (Chen & Liu, 1993), and the Handbook on Seasonal Adjustment (Handbook..., 2018):

- additive outliers (AO) – a one-time sudden change (increase or decrease) of the value of the studied phenomenon, which does not affect the sequence of values of the time series,
- level shift (LS) – a long-term change in the level of the value of the studied phenomenon,
- temporary change (TC) – a short-term change in the level of the value of the studied phenomenon, after which a return to the previous level takes place,
- innovation outliers (IO) – instances of innovative impulses, which may be triggered by the implementation of a novel production technology. This can result in a transformation of the entire data-generating process, including the emergence of a novel trend.

The use of disparate information criteria for the selection of ARIMA models and a distinct order of the individual stages of the procedures may result in disparate outcomes, which influenced the decision to utilise both to identify shocks to the Polish passenger car market. The calculations were performed using the JDemetra+ analysis tool, which is dedicated to the methods of seasonal adjustment, in particular ARIMA-X-12 and TRAMO-SEATS. This software was developed as part of a collaboration for seasonal adjustment and time series analysis, developed within the "Centre of Excellence on Statistical Methods and Tools" Eurostat and the National Bank of Belgium, the Bundesbank and Insee. In addition, since 2015, this software has been officially recommended by Eurostat for use within the European Statistical System. In JDemetra+, the seasonal adjustment and outlier identification procedures are performed automatically.

2.3 Time frame

The study looks at the time before the SARS-CoV-2 pandemic, the pandemic period with its waves of infection, and the period after the pandemic. The first case of SARS-CoV-2 infection in Poland was confirmed on March 4, 2020. On March 12, schools were

closed and a number of restrictions were introduced. Shopping malls and restaurants were restricted, gatherings of more than 50 people were banned, and sports, recreational, and cultural facilities were closed (March 13). A week later (March 20), the state officially declared a state of epidemic and imposed restrictions on movement outside the home, except for essential activities such as shopping, healthcare, and work, and the number of passengers on public transportation was limited. On March 24, gatherings were completely banned, the number of customers in shops was limited, and hotels and beauty salons were closed. On March 31, they also banned visits to beaches and green spaces. On April 9, a new rule was introduced that people had to cover their mouth and nose. Starting April 11, restrictions were slowly being lifted. This included allowing more people in shops and allowing people to travel for fun and go to green areas (April 16). In May, shopping centers reopened, hotels, libraries, and museums resumed operations on May 9, and nurseries and kindergartens reopened on May 6. On May 13, hairdressers and beauty salons resumed operations, restaurants opened, limits on public transportation increased, the requirement to cover the mouth and nose in open spaces was lifted, and limits on the number of people in shops were lifted on May 27. The lifting of restrictions meant that there were fewer reported cases of infection, and the first wave of the pandemic had ended. On October 17, 2020, the second wave of the pandemic was announced. The country was divided into yellow and red zones, depending on the number of cases of the virus. However, on October 23, the whole country was put in the red zone, with restrictions similar to those during the first wave. It wasn't until January 2021 that they started to ease these restrictions, including bringing back in-person education for the youngest kids. The third wave of infections began on March 25, 2021. It brought back restrictions on the operation of large shopping centers. It also continued remote education and restrictions on movement. The country was divided into zones, depending on the number of people vaccinated against the virus, not the number of cases. In the fall of 2021, the fourth wave of infections hit. On May 16, 2022, the state declared a state of epidemic threat and announced more easing of restrictions. The end of this state was announced on July 1, 2023, and there were no outliers identified for this period. By the time the state of epidemic threat in Poland was over, there were hardly any restrictions on movement. Only schools and universities were closed, and students learned from home. Shops, shopping malls, sports, recreational, and cultural facilities were closed only when there was an increase in cases. According to the dates of the restrictions introduced, the following were distinguished:

- Period 1 - before the pandemic, lasting until the end of February 2020
- Period 2 - first wave of the pandemic - from March 4, 2020,
- Period 3 - second wave of the pandemic - from October 17, 2020,
- Period 4 - third wave of the pandemic - from March 25, 2021,
- Period 5 - fourth wave of the pandemic – from the end of August 2021,
- Period 6 - state of epidemic threat – from May 16, 2022,
- Period 7 - post-pandemic – from July 1, 2023.

4. Results

The sale of second-hand passenger cars in Poland, purchased domestically, exhibited a progressive increase between 2012 and 2023. These sales increased almost sixfold from approximately 30,000 units per month in 2012 to approximately 180,000 units per month in 2023 (Figure 1). Prior to the pandemic, there were slight fluctuations in the sales

figures. However, there was a notable decrease in sales during the pandemic period of 2020-2022. This may indicate that the restrictions put in place to limit the spread of the SARS-CoV-2 virus had an impact on sales.
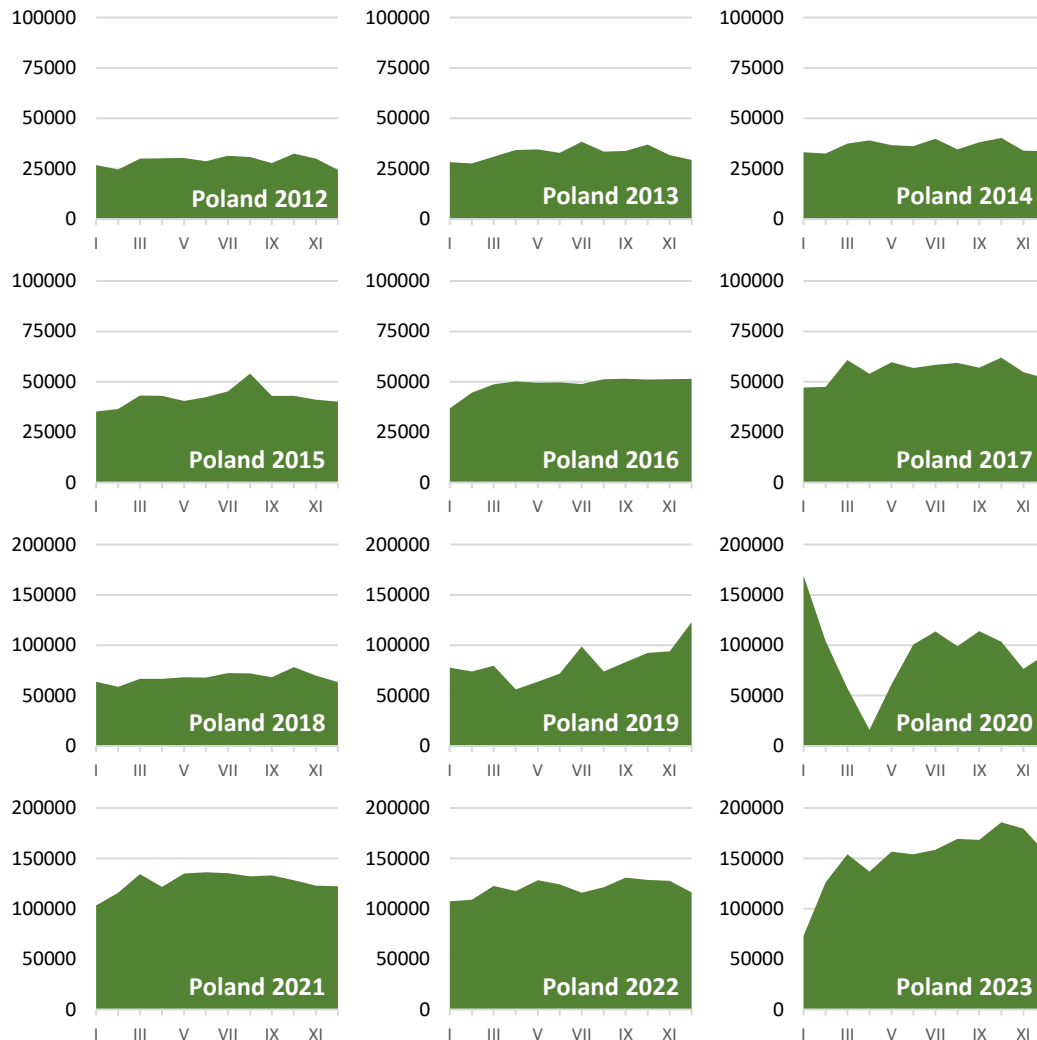

Figure 1. Number of registrations of domestic used passenger cars
Source: own study

The ARIMA-X-12 and TRAMO-SEATS procedures were used to estimate models for the number of registrations of used passenger cars purchased in the country. Different models were obtained in both cases, with no seasonality identified in either. The remaining estimated models did not possess all the desired properties, namely the absence of autocorrelation, linearity and randomness. Notwithstanding this limitation, the models exhibited a satisfactory alignment with the development of used car sales in Poland. In both cases, the differences between theoretical and empirical values were in the range of 5-7%, which is a very good result. In addition, the models were not estimated to predict future sales values; rather, they were employed to deseasonalize and identify outliers representing market shocks (Table 1).

Table 1: Results of the model estimation of the number of domestic used passenger car registrations in Poland between 2012 and 2023

Specification	TRAMO-SEATS	ARIMA-X-12
Model	(0,1,1)x(0,1,1)	(0,0,0)x(0,1,0)
Transformation	Logarithmic	NOT
Trading Day Effect	YES	NOT
Moving Holiday Effect	NOT	YES
Composite seasonality test	Seasonality not present	Seasonality not present
Outliers	YES	YES
Normality of the residuals	0.5483	0.0002
Independence of the residuals	0.7171^{LB}	0.7417^{LB}
	0.8138^{BP}	0.8490^{BP}
Randomness of the residuals	1.0000	1.0000
Linearity of the residuals	0.0237^{LB}	0.5081^{LB}
	0.0465^{BP}	0.6688^{BP}
MAE	3836.34	3104.94
MAPE	5.6147 %	5.1308 %
RMSE	5313.06	3958.77
V_RMSE	7.2281 %	5.3857 %

Note: LB – Ljung-Box Test, BP – Box-Pierce Test, MAE – Mean Absolute Error, MAPE Mean Absolute Percentage Error , RMSE – Root Mean Square Error, V-RMSE – Relative Prediction Error.

A comparison of the actual values of the number of registrations of used passenger cars purchased in the country with the empirical values obtained from the estimated models demonstrates a high degree of correlation and the ability to reflect outliers (Figure 2), which was further confirmed by model fit measures (Table 1).
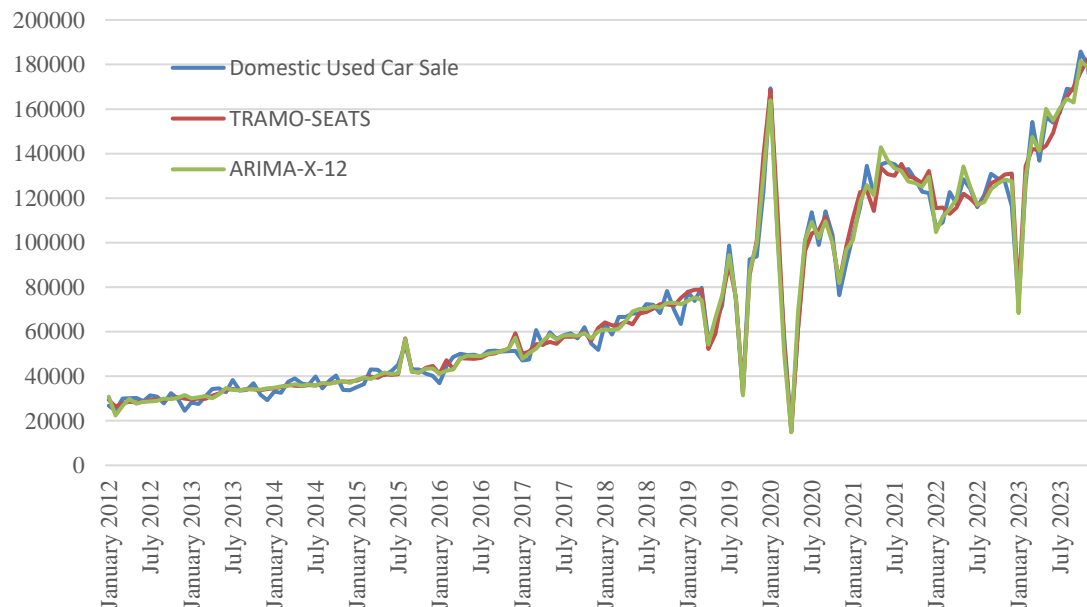

Figure 2. Number of registrations of domestic used passenger cars - empirical and theoretical values
Source: own study

The application of seasonal adjustment methods led to the identification of 28 outliers using the ARIMA-X-12 (hereinafter AX12) procedure and 21 using the TRAMO-SEATS (hereinafter TS) procedure. These figures refer to the entire analyzed period of 2012-2023. In order to provide a comprehensive analysis, the period of the SARS-CoV-2 epidemic in Poland was divided into seven segments, with the dates of the introduction of the epidemic serving as the division points. The initial period precedes the pandemic and extends until March 2020. During this time, 11 outliers were identified in AX12 and 13 in TS, respectively. For the period of the epidemic (Periods 2-5 — 4 waves of infection), i.e., from March 2020 to May 2022, when the epidemic was declared over and a state of epidemic threat was introduced, 10 (AX12) and 7 (TS) outliers were identified, respectively. During the epidemic threat period, 6 (AX12) and 1 (TS) outliers were identified. The period included six months (period 7) after the lifting of the epidemic threat, for which one outlier was identified using the ARIMA-X-12 procedure.

Table 2: Number of outlier observations identified

Period	ARIMA-X-13	TRAMO-SEATS
Period 1 - Before the pandemic (98 months)	11	13
Period 2 - Epidemic - The first wave of infections (7 months)	4	3
Period 3 - Epidemic - The second wave of infections (7 months)	4	2
Period 4 - Epidemic - The third wave of infections (7 months)	1	1
Period 5 - Epidemic - The fourth wave of infections (7 months)	1	1
Period 6 - State of epidemic emergency (14 months)	6	1
Period 7 - After the pandemic (6 months)	1	0

Source: own study

Shocks in the number of registrations of used cars purchased in the country occurred more frequently during the epidemic and the state of epidemic threat in Poland than before this period, with the TRAMO-SEATS method identifying fewer outliers than the ARIMA-X-13 method. Taking into account the waves of COVID-19 infections, it is noticeable that the results of the TRAMO-SEATS procedure seem to be better. Until the end of 2020, no changes in legislation were recorded that could cause a sudden increase or decrease in the sale of used cars in Poland. The reasons for such increases should be sought in promotional campaigns for new passenger cars, which occurred especially in 2019, when many manufacturers offered attractive conditions for the sale of "end-of-year models". People who bought new cars were able to put their existing vehicles up for sale, which, for example, contributed to an increase in the overall level of used car sales. This situation occurred, for example, in October 2019, when sales of used cars increased by 187.39% compared to the previous month.

The market shocks identified for the epidemic period clearly reflect the movement restrictions that were introduced. The first wave of the epidemic began in March 2020, and in that month a temporary change (TC 03/2020) was identified, corresponding to a 44.98% drop in sales. The following month, stricter restrictions were introduced, resulting in a further decrease in used car sales of 72.04% compared to the previous month, which was identified as a one-time change (AO 4/2020). The end of the first wave of the epidemic and the easing of restrictions resulted in an increase in sales, which was identified as a trend level increase in June 2020 (LS 06/2020) - a 64.52% increase in sales. The second wave of the epidemic, which began in the fall of 2020, was characterized, like the first wave, by a decrease in sales at the beginning of the period (a decrease of 9.25%

in October and a decrease of 26.18% in November 2020) and an increase at the end of the period (an increase of 19.05% in December 2020 and 13.57% in January 2021). It should be noted that these one-off changes (AO) were identified using the ARIMA-X-12 procedure. The TRAMO-SEATS procedure identified only the first two declines, which in this case were considered temporary changes (TC). In the third wave of the epidemic, there was a 9.49% decrease in used car sales in April 2021, which was identified by the TRAMO-SEATS procedure as a one-time change (AO), and a 10.91% increase in sales in May, which was identified by the TRAMO-SEATS procedure as a temporary change (TC). In the case of the fourth wave of the epidemic, only a 1,234% decrease in sales was identified in January 2022, which was identified as a temporary change using the ARIMA-X-12 procedure and as a trend level change (decrease) using the TRAMO-SEATS procedure. For the sixth period, or state of epidemic threat, six outliers were identified using the ARIMA-X-12 procedure and only one using the TRAMO-SEATS procedure. This may reflect the trend in sales of new passenger cars, i.e. the sale of previous model years at the beginning of the current year, which made consumers more willing to buy new vehicles at attractive prices. It should be noted that the outliers identified using the ARIMA-X-12 procedure were alternating increases and decreases and did not reflect changes in movement restrictions or changes in legislation that could stimulate or suppress demand for used or new passenger cars. The most recent period shows one outlier identified by the ARIMA-Z-12 procedure as a temporary change (a 10.28% increase in sales). The absence of further shocks during this period may indicate a stabilization of the used car market.

Table 2: Zidentyfikowane wartości odstające liczby rejestracji używanych samochodów osobowych

Date	ARIMA-X-13			TRAMO-SEATS		
	Outlier type	Coefficients	Change %	Outlier type	Coefficients	Change %
2/2012[1]				TC ***	-0.11	-8.31 %
8/2015[1]	AO ***	15526.65	19.36 %	AO ***	0.32	19.36 %
1/2016[1]				AO ***	-0.11	-8.34 %
3/2016[1]				AO ***	-0.10	9.30 %
4/2016[1]	LS ***	4667.13	2.99 %			
12/2016[1]				AO ***	0.15	0,33 %
4/2017[1]	LS ***	4108.65	-11.02 %			
11/2017[1]				AO ***	-0.08	-11.76 %
5/2018[1]	LS ***	8790.44	2.28 %			
4/2019[1]	AO ***	-21651.06	-29.57 %	TC ***	-0.42	-29.57 %
6/2019[1]				AO ***	0.13	12.36 %
7/2019[1]	AO ***	18696.83	37.64 %	AO ***	0.24	37.64 %
9/2019[1]	AO ***	-44613.53	-56.45 %	AO ***	-0.90	-56.45 %
10/2019[1]	LS ***	10900.36	187.39 %			
11/2019[1]	LS ***	12684.87	1.51 %	TC ***	0.13	1.51 %
12/2019[1]	AO ***	29832.27	30.94 %	TC ***	0.33	30.94 %
1/2020[1]	AO ***	63248.12	37.67 %	AO ***	0.31	37.67 %
3/2020[2]	TC ***	-54296.22	-44.98 %	TC ***	-0.72	- 44.98 %
4/2020[2]	AO ***	-49264.10	-72.04 %	AO ***	-1.53	-74.04 %
5/2020[2]				AO ***	0.31	281.43 %
6/2020[2]	LS ***	17513.10	64.52 %			
8/2020[2]	TC ***	-8527.77	-12.91 %			

10/2020[3]	AO ***	-11759.34	-9.25 %	TC ***	-0.16	-9.25 %
11/2020[3]	AO ***	-32468.10	-26.18 %	TC ***	-0.28	-26.18 %
12/2020[3]	AO ***	-21490.71	19.05 %			
1/2021[3]	AO ***	-17558.40	13.57 %			
4/2021[4]				AO ***	-0.12	-9.49 %
5/2021[4]	TC ***	20751.49	10.91 %			
1/2022[5]	TC ***	-22185.27	-12.34 %	LS ***	-0.15	-12.34 %
5/2022[6]	AO ***	11799.52	9.32 %			
7/2022[6]	TC ***	-9553.85	-6.69 %			
1/2023[6]	AO ***	-59965.03	-37.27 %	AO ***	-0.56	-37.27 %
3/2023[6]	AO ***	17832.70	22.30 %			
4/2023[6]	LS ***	10655.19	-11.27 %			
5/2023[6]	LS ***	17885.88	14.37 %			
10/2023[7]	TC ***	19169.53	10.28 %			

Note: 1 - Before the pandemic, 2 – Epidemic – First wave of the pandemic, 3 - Epidemic – Second wave of the pandemic, 4 - Epidemic – Third waveof the pandemic, 5 - Epidemic – Fourth wave of the pandemic, 6 – State of pandemic threat, 7 - After the pandemic, LS – Level Shift, TC – Temporary Change, AO – Additive Outliers, Statistical Significance at level ***- 0.001, **- 0.05, * - 0.1

5. Conclusion

It was assumed that as a result of the restrictions aimed at limiting the spread of SARS-CoV-2 in Poland, in particular the introduction of restrictions on public transport and social distancing measures, there would be a decline in interest in using public transport. This was proved by Wielechowski et al. (Wielechowski et al., 2020) and Gorzelańczyk and Pawłowski (Gorzelańczyk & Pawłowski, 2023). People unable to commute by public transport may have increased their willingness to use private transport, which may have increased the demand for passenger cars, especially used passenger cars registered in the country, as these are potentially immediately available and cheaper than new ones. The analysis of the number of registrations of used passenger cars purchased in Poland identified market shocks. These shocks were related to the introduction of restrictions in individual waves of virus infections. At the beginning of each of the four waves of the SARS-CoV-2 epidemic, there were significant declines in sales, which were identified as shocks (one-time or temporary changes). As movement restrictions were lifted, sales increased and were also identified as market shocks. These market shocks, both decreases and increases, were stronger in the first waves of the epidemic and weakened in subsequent waves. However, these results provide a basis for concluding that the hypothesis that "restrictions on movement caused market shocks in used car sales" has been positively tested. However, given the nature of the shocks and their values, it should not be assumed that during the epidemic the population was particularly looking for cheaper used cars to meet their mobility needs. Purchases were definitely postponed during the restrictions and resumed when the restrictions were eased. There was also no significant increase in the overall level of used car sales in Poland. This suggests that the epidemic disrupted the sale of used cars, but as the epidemic subsided, the market returned to its pre-pandemic state and maintained an upward trend. This paves the way for forecasting future sales of used passenger cars, taking into account possible extreme situations such as pandemics, natural disasters, etc.

The analysis presented is based on data for the whole country. However, access to public transport mainly concerns large urban centers where the population could use non-motorized means of transport. In smaller towns, where people had to travel longer

distances to work in larger centers, the need for private cars may have been greater. Therefore, an increased demand for used cars may have occurred in areas with reduced access to transportation, which opens the way for further research, particularly to examine:

- Did fluctuations in used car sales in Poland during the SARS-CoV-2 pandemic affect large and small urban centers and rural areas to the same extent?
- Do sales of used cars in Poland depend on access to public transport?
- Was the age structure of used cars sold in Poland the same before, during, and after the pandemic?
- Did the pandemic bring older cars onto the market that would not have found buyers before the pandemic?

Similar research can be conducted for sales of new and imported vehicles, not only in Poland, but also in other countries.

In addition, outliers in monthly sales of domestically purchased used passenger cars were identified using seasonal adjustment methods: the ARIMA-X-12 and TRAMO-SEATS procedures. The results of the TRAMO-SEATS procedure seem to better and more accurately reflect the changes due to the restrictions introduced. The results of the ARIMA-X-12 procedure indicate the occurrence of a greater number of shocks occurring in successive months, reflecting each change, including a return to the level prior to the identified shock. Thus, the TRAMO-SEATS procedure better identified changes for the period of the Covid-19 pandemic in Poland. Similar conclusions were drawn from a study of market shocks in new car sales in Poland in the period before the 2008-2018 pandemic (Lewicki & Olejarz, 2020).

References

Balke, N.S. (1993) "Detecting Level Shifts in Time Series", *Journal of Business & Economic Statistics*, Vol. 11(1), pp. 81-92. https://doi.org/10.2307/1391308

Bucsky, P., Juhász, M. (2022) "Is car ownership reduction impact of car sharing lower than expected? A Europe wide empirical evidence" , Case Studies on Transport Policy, Volume 10, Issue 4, pp. 2208-2217. https://doi.org/10.1016/j.cstp.2022.09.014.

Chang, C., Tiao, G.C., Chen, C. (1988) "Estimation of Time Series Parameters in the Presence of Outliers", *Technometrics*, Vol. 30(2), pp. 193-204. https://doi.org/10.2307/1270165

Chen, C., Liu, L.M. (1993) "Joint Estimation of Model Parameters and Outlier Effects in Time Series", *Journal of the American Statistical Association*, Vol. 88(421), p. 284-297. https://doi.org/10.2307/2290724

Coibion, O., Gorodnichenko, Y., Weber, M. (2020) "The cost of the Covid-19 crisis: lockdowns, macroeconomic expectations, and consumer spending". *NBER Working Paper*, No. 27141, National Bureau of Economic Research, Cambridge, pp. 1-51, http://www.nber.org/papers/w27141

de Abreu e Silva, J., Melo, P.C. (2018) "Home telework, travel behavior, and land-use patterns: A path analysis of British single-worker households", Journal of Transport and Land Use, 11(1), pp. 419–441. https://www.jstor.org/stable/26622411.

De Cet, G., Vianello, Ch., Ceccato, R., Campisi, T. (2024) "What means of transport did Italians Choose during pandemic? A literature review"*, European Transport/Transporti Europei*, Issue 96, Paper no 5. https://doi.org/10.48295/ET.2024.96.5.

Fox, A.J. (1972) "Outliers in Time Series", *Journal of the Royal Statistical Society*, Series B (Methodological), Vol. 34., No. 3., pp. 350-363. https://www.jstor.org/stable/2985071

Fridrisek, P., Janos, V. (2022) "COVID-19 and suburban public transport in the conditions of the Czech Republic", Transportation Research Interdisciplinary Perspectives, Volume 13, 100523. https://doi.org/10.1016/j.trip.2021.100523.

Gorzelańczyk, P., Pawłowski, A. (2023) "Analysis and forecast of passenger flows in public transport - the case of Poland". Technical Sciences, 26(26), 161–184. https://doi.org/10.31648/ts.9304.

Hale, T., Angrist, N., Goldszmidt, R., Ira. B., Petherick, A., Philips, T., Webster., S., Cameron-Blake, E., Hallas, L., Majumdar, S., Tatlow, H. (2021) "A global panel database of pandemic policies (Oxford COVID-19 Government Responde Tracker)", Nature Human Behaviour, 5, pp. 529–538. https://doi.org/10.1038/s41562-021-01079-8

Handbook on Seasonal Adjustment. Publications Office of the European Union (2018) Luxembourg. http://doi.org/10.2785/279605

Hawkins, D. (1980) *Identification of Outliers. Monography on statistics and Applied Probability*. Springer Dordrecht. https://doi.org/10.1007/978-94-015-3994-4

Hyży, M. (2023). Impact of the COVID-19 pandemic on the financial results of selected companies in the development and automotive industries. ZTR, 47(1), 39-54. https://doi.org/10.5604/01.3001.0016.2906.

Hyży, M. (2023). Impact of the COVID-19 pandemic on the financial results of selected companies in the development and automotive industries. ZTR, 47(1), 39-54. https://doi.org/10.5604/01.3001.0016.2906.

László, T. (2020). The Link Between Car Sales and the Economic Crisis in the European Union at the Time of the Covid-19 Epidemic, International Journal of Economics and Business Administration Volume VIII Issue 4, 1033-1042. https://doi.org/10.35808/ijeba/648

László, T. (2021) "The Link Between Car Sales and the Economic Crisis in the European Union at the Time of the Covid-19 Pandemic", International Journal of Finance, Insurance and Risk Management, Volume XI, Issue 1, pp. 68-77. https://journalfirm.com/journal/250/download/The+Link+Between+Car+Sales+and+the+Economic+Crisis+in+the+European+Union+at+the+Time+of+the+Covid-19+Pandemic.pdf.

Lewicki, W., Olejarz-Wahba, A.A., (2020) "Modeling of Trend in Salesof New Passenger Vehiclesin Poland Using the Arima-X-12and Tramo-Seats Methods", Statistika, Vol. 100(3), pp. 333-344. https://www.czso.cz/documents/10180/125507865/32019720q3_lewicki_analyses.pdf

Mars, L., Arroyo, R., Ruiz, T. (2022) "Mobility and wellbeing during the covid-19 lockdown. Evidence from Spain", Transportation Research Part A: Policy and Practice, Volume 161, pp. 107-129. https://doi.org/10.1016/j.tra.2022.05.004.

Muirhead, C.D. (1986) "Distinguishing Outlier Types in Time Series", Journal of Royal Statistical Society, Series B (Methodologial), Vol. 48., No. 1., pp. 39-47.

Mulla, D.P., Bochicchio, M.A., Longo, A. (2023) "Is Human Mobility an Appropriate Indicator for COVID-19 Dynamics? An Italian Experience". In: Papadopoulos, G.A., Achilleos, A., Pissaloux, E., Velázquez, R. (eds) *ICT for Health, Accessibility and*

Wellbeing. IHAW 2022. Communications in Computer and Information Science, vol 1799. Springer, Cham. https://doi.org/10.1007/978-3-031-29548-5_14.

Olde Kalter, M-J., Karst T. Geurs, T.K., Wismans, L. (2021) "Post COVID-19 teleworking and car use intentions. Evidence from large scale GPS-tracking and survey data in the Netherlands", Transportation Research Interdisciplinary Perspectives, Volume 12, 100498. https://doi.org/10.1016/j.trip.2021.100498.

Olejarz, A. A. (2021). Impact of the Covid-19 Pandemic on the Pharmacy Market in Poland. Olsztyn Economic Journal, Vol. 16, No. 2, 159–167. https://doi.org/10.31648/oej.7883

Olejarz, A. A., & Kędzior-Laskowska, M. (2024). How Much Progress Have We Made towards Decarbonization? Policy Implications Based on the Demand for Electric Cars in Poland. Energies, 17(16), 4138. https://doi.org/10.3390/en17164138.

Purkrábková1, Z., Hrubeš, P. (2023) "Basic Characteristics of floating car data from the perspective of traffic loss during the COVID-19 pandemic", *European Transport/Transporti Europei*, Issue 93, Paper no 5. https://doi.org/10.48295/ET.2023.93.5

Schaefer, K.J., Tuitjer, L., Levin-Keitel, M. (2021) "Transport disrupted – Substituting public transport by bike or car under Covid 19", Transportation Research Part A: Policy and Practice, Volume 153, pp. 202-217. https://doi.org/10.1016/j.tra.2021.09.002.

Shevchenko, I. Y., Dmytriiev, I. A., Dmytriieva, O. I. (2021). Impact of the COVID-19 pandemic on the production and sales of cars in the world. Avtomobilʹnyj Transport (Harʹkov), Vol. 49, pp. 63-70. https://doi.org/10.30977/AT.2019-8342.2021.49.0.06 .

Shibayama, T., Sandholzer, F., Laa, B., & Brezina, T. (2021) "Impact of COVID-19 lockdown on commuting: a multi-country perspective", *European Journal of Transport and Infrastructure Research*, 21(1), pp. 70-93. https://doi.org/10.18757/ejtir.2021.21.1.5135

Soler, J.R.L., Christidis, P., Vassallo, J.M. (2023) "Evolution of teleworking and urban mobility changes driven by the COVID-19 pandemic across European Cities" , Transportation Research Procedia, Volume 69, pp. 488-495. https://doi.org/10.1016/j.trpro.2023.02.199.

Taale, H., Olde Kalter, M-J., Haaijer, R., Damen, C. (2022) "The impact of COVID-19 and policy measures on commuting in the Netherlands", *Case Studies on Transport Policy*, Volume 10, Issue 4, pp. 2369-2376, ISSN 2213-624X, https://doi.org/10.1016/j.cstp.2022.10.018

Toppur B.; Thomas T.C. (2023) "Forecasting Commercial Vehicle Production Using Quantitive Techniques", *Contemporaty Economics,* Vol. 17, Issue 1, pp. 10-23. https:/doi.org/10.5709/ce.1897-9254.496.

Trzęsiok, M. (2016) „Identyfikacja obserwacji oddalonych w szeregach czasowych", Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach, Nr 265, pp. 95-105.

Vega-Gonzalo, M., Christidis, P., Gomez, J. (2023a) "Car Ownership and Post-COVID Urban Mobility across European Cities", Transportation Research Procedia, Vol. 69, pp. 305-312. https://doi.org/10.1016/j.trpro.2023.02.176

Vega-Gonzalo, M., Gomez, J., Christidis, P. (2023b) "How has COVID-19 changed private car use in European Urban areas? An analysis of the effect of socio-economic characteristics and mobility habits", Transportation Research Part A: Policy and Practice, Vol 172, No. 103679. https://doi.org/10.1016/j.tra.2023.103679

Velten, E. K., Brauer, C., Thie. J-E. (2019). Used Vehicle Trade and Fleet Composition in Europe. European Environment Agency (EEA) within the framework service contract EEA/ACC/18/001/LOT1. Ecologic Institute and Fraunhofer IS. https://www.ecologic.eu/sites/default/files/publication/2021/2632-01-Ecologic-ISI-UsedVehiclesStockTrade-March2020-final.pdf.

Wielechowski, M., Czech, K., Grzęda, Ł. (2020) "Decline in Mobility: Public Transport in Poland in the time of the COVID-19 Pandemic", Economies, No. 8(4):78. https://doi.org/10.3390/economies8040078.

Wielechowski, M., Czech, K., Grzęda, Ł. (2020) "Decline in Mobility: Public Transport in Poland in the time of the COVID-19 Pandemic", Economies, No. 8(4):78. https://doi.org/10.3390/economies8040078.

Yadav, V., Bansal, T. (2025). Financial performance analysis of automobile industry after Covid-19 Pandemic. Journal of Advances and Scholarly Researches in Allied Education, 22(01), 234-245. https://doi.org/10.29070/htqqmx91

Zacharof, N., Nur, J., Kourtesis, D., Krause, J., Fontaras, G. (2024). A review of the used car market in the European Union, Publications Office of the European Union. https://data.europa.eu/doi/10.2760/3237256.