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DOI: 10.15290/oes.2024.03.117.01

DECARBONIZATION OF THE LOGISTICS SECTOR IN POLAND IN THE CONTEXT OF MACROECONOMIC AND FINANCIAL CONDITIONS[1]

Summary

Purpose – The paper is primarily aimed to assess the impact of selected macroeconomic conditions and the financial situation of decarbonization of the logistics sector in Poland from 2008 to 2020.

Research method – To verify the main research hypothesis, the author creates a synthetic indicator of decarbonization, of macroeconomic conditions and of the sector's financial situation, using one of the normalization methods. To estimate the impact of explanatory variables on the dependent variable, the author used the Ordinary Least Square Method (OLS).

Results – The research results show a positive trend in the decarbonization indicator of the logistics sector, which is particularly visible at the end of the period under study, i.e. in 2019–2020. EU regulations undoubtedly influence this state of affairs regarding the reduction of greenhouse gas emissions, including carbon dioxide. The estimation results indicate that macroeconomic conditions and the sector's financial situation from the previous period (t-1) statistically significantly impact ($p < 0.05$) the decarbonization of logistics. It should be noted that the directions of their influence are different. Macroeconomic conditions from the period (t-1) positively impact decarbonization, and the financial situation has a negative impact.

Originality/value/implications/recommendations – The paper's novelty is expressed in presenting a model estimating the impact of macroeconomic and financial conditions on the decarbonization of logistics. The decarbonization process was also presented, and the literature in the examined area was reviewed. The study results indicate that economic and financial factors are important for decarbonization. Hence, their improvement should positively impact the ecological investments of enterprises in the logistics sector.

Keywords: decarbonization, logistics sector, macroeconomic conditions, financial situation

JEL classification: B22, C50, D22, O13, Q01

[1] The article received on 23.03.2024, accepted on 9.07.2024.

1. Introduction

Decarbonizing and developing renewable energy sources are a priority among the climate challenges. The European climate law includes a mandatory EU climate goal of reducing emissions in the EU by at least 55% by 2030. From the point of view of the EU environmental protection policy, reducing carbon dioxide emissions is a key challenge and a task faced by the community countries. Reducing CO_2 emissions in industries and economic sectors characterized by high carbon intensity is important to obtain stringent climate goals. The key sectors from the point of view of transformation are energy and transport.

Decarbonizing transport in the logistics sector means striving to reduce carbon dioxide emissions by transport companies. It is a process that aims to reduce or eliminate CO_2 production through various activities, such as using alternative energy sources, developing electric vehicles or increasing energy efficiency of vehicles.

Several factors, exogenous and endogenous, determine the decarbonization of logistics. The primary goal and contribution to the literature on the subject is to assess the impact of macroeconomic and financial conditions on the decarbonization of the logistics sector in Poland from 2008 to 2020. The study was conducted on the basis of the data from Eurostat, covering the period from the financial crisis to the Covid-19 pandemic. The author used the Ordinary Least Square Method to estimate the model.

The research complements the literature on the subject with a statistical assessment of the impact of economic and financial conditions, which is important from the point of view of both theory and economic practice. The analysis indicates which group of factors has a statistically more significant impact on the decarbonization of the logistics sector in Poland ($p < 0.05$).

In the first part of the paper the author referred to the current considerations and threads that dominate the topic of decarbonization in scientific publications. The second part of the article is a discourse on the research methodology and a presentation of the analysis results.

The article has research limitations related to data availability, the research period and the estimation method. Nevertheless, it may constitute an important complement to the existing scientific research devoted to the determinants of logistics decarbonization.

2. Theoretical background

Decarbonization (DeCarbon), in the light of environmental protection policy, means reducing and ultimately ending CO_2 emissions to the atmosphere [Jankow-

ska, 2016, p. 265]. Decarbonization should start with a change of pace, with regard to the production and transfer of heat and with changing the perception of energy acquisition processes as exothermic (energy emitting) rather than endothermic (energy absorbing) processes [Dziennik, 2021, p. 59].

Decarbonization of economies is a process that requires large financial outlays, a shift from fossil fuels towards renewable energy sources, investments and the development of new environmentally friendly energy storage technologies [Bataille et al., 2016; Plazas-Niño et al., 2022; Brinken et al., 2022; Kalantzakos et al., 2023].

According to the International Energy Agency (IEA) the cost of decarbonizing the economy by 2050 will be 100 trillion USD (3.57% of world GDP). Therefore, it is necessary to rebuild the world's finances and be credible and honest in monitoring the situation. It is important to introduce fair mechanisms for distributing financial burdens and for countries to invest in environmentally friendly natural energy sources. Additionally, it will be important to introduce a financial support mechanism and a system in which countries with low GDP per capita will have to receive appropriate financial support [Kozłowski, 2022, p. 11].

Decarbonizing the logistics sector means aiming to reduce carbon dioxide emissions [Neagoe et al., 2024]. Decarbonizing transport involves reducing carbon dioxide emissions associated with the logistics sector [Ghisolfi et al., 2022]. It is a process that aims to reduce or eliminate CO_2 production through various activities, such as using alternative energy sources, developing electric vehicles or increasing energy efficiency of vehicles [Dolge et al., 2023; Tsemekidi Tzeiranaki et al., 2023].

Transport is Poland's main source of air pollution and the second largest source of CO_2 emissions [Zowada, 2023]. According to the European Environment Agency, transport accounted for 25.9% of the total greenhouse gas emissions in the European Union in 2019. It should be emphasized that although the total greenhouse gas emissions decreased by 24%, emissions from transport increased by 33%. Since the economic transformation, the importance of individual motorization has increased significantly, increasing the emission intensity of transport [Chrzanowski, Krawiec, 2023; Borucka, Kozłowski, 2023].

Moreover, since the beginning of the 1990s, the Polish logistics sector has been developing dynamically, which is important for the stable economic growth and for the development of other sectors of the economy [Comporek et al., 2022].

Being currently implemented, The Strategy for Sustainable and Smart Mobility sets out the following intermediate goals by 2030: carbon neutral, regular transport; collective in the EU over a distance of up to 500 km; at least 30 million zero-emission vehicles on European roads; doubling of high-speed rail traffic; at least 100 climate-neutral cities; automated mobility implemented on a large scale; and by

2050: almost all passenger cars and delivery vehicles – emission-free; buses and new heavy vehicles – tripling high-speed rail traffic; a multimodal trans-European transport network (TEN-T) adapted to the needs of sustainable and intelligent transport, ensuring fast connections within a comprehensive network [Kunytska et al., 2023].

The basic instruments and directions for the decarbonization of transport include: replacing combustion drives with zero-emission electric drives (hydrogen vehicles, electric drives), developing more efficient public and bicycle transport and reducing transport intensity by introducing remote and hybrid work and learning, as well as changes in the spatial planning, leading to limit the volume of movements [Tomanek, 2022; Frankowski et al., 2023].

Actions to reduce the emission intensity of the logistics sector undertaken by enterprises take place in precisely defined socio-economic and geopolitical conditions. They require compliance with legal regulations and standards in environmental protection [Karaduman et al., 2020; Kozłowski, 2022].

Implementing low-emission transport and ecological solutions in warehouses requires adequate financial resources. Therefore, a good financial and property situation should support ecological investments and solutions. Therefore, if enterprises maintain the ability to repay liabilities on an ongoing basis, high profitability, and an appropriate structure of assets and liabilities, this should increase investments in ecological technologies [Stojanović et al., 2021].

In turn, the positive macroeconomic situation increases the prospects for developing individual sectors of the economy, including logistics [Metcalf, Stock, 2023]. On the other hand, however, high economic growth in economies with high energy intensity may increase greenhouse gas emissions and thus contribute to further degradation of the natural environment [Ortega et al., 2021].

In the literature on the subject there is no consensus on which factors, macroeconomic ones or the internal financial situation of the sector, have a statistically higher impact on the sustainable development and decarbonization of logistics [Drożdż et al., 2021].

Moreover, the logistics sector's decarbonization in 2020 was influenced by the COVID-19 pandemic, which, due to business restrictions, decreased the emission intensity of most economic sectors, including logistics [Chiaramonti, Maniatis, 2020; Figura, Gądek-Hawlena, 2022; Stavroulakis et al., 2023].

Some researchers emphasize that maintaining macroeconomic stabilization (economic balance) has a positive impact on the sustainable development of enterprises [Comporek et al., 2022], while others point out that, to a significant extent, eco-innovations of enterprises are conditioned by internal factors, including the financial and property situation, the adopted strategy and management model, and the environmental management in the enterprise [Lefèvre et al., 2021].

3. Research methodology

The research is primarily aimed at assessing the impact of macroeconomic and financial conditions on the decarbonization of the logistics sector in Poland from 2008 to 2020. The research period covers the financial crisis till the pandemic outbreak. The study is aimed to indicate the influence of specific explanatory factors on the explained variable during the analyzed period before the introduction of the Green Deal and the Fit for 55 strategy.

In the context of the research goal, the following main hypothesis was put forward: "Macroeconomic conditions have a higher statistically significant impact on the decarbonization of the logistics sector compared to the financial situation of the sector in 2008–2020", and this is because the logistics sector depends on the situation in other sectors of the economy and, therefore, external conditions have a key impact on the situation of enterprises. Additionally, the following research questions were formulated:

- Is the dynamics of decarbonization of the sector positive?
- Do macroeconomic conditions have higher growth dynamics than the logistics sector's financial situation?
- Does decarbonization have higher growth dynamics than macroeconomic conditions and the financial situation of the logistics sector?

Data for the study come from Eurostat. The study includes the following stages:

- I create the indicator of decarbonization. I use the following formula:

$$\mathrm{DeCarbon}_i = \frac{min\mathrm{CO}_2}{\mathrm{CO}_{2i}},$$

where CO_2 emission of carbon dioxide in in the i-year, $\mathrm{DeCarbon}_i$ – the indicator of decarbonization in the i-year, min CO_2 – minimum value of carbon emissions in 2008–2018;

- I create the indicators of explanatory indicators:
  - macroeconomic conditions (Macro) based on analytical indicators: stimulants (GDP, export, wages) and destimulants (import, unemployment rate, HICP). I use the following formula:

$$\mathrm{Macro} = \left(\sum_{i=1}^{n} \frac{\mathrm{GDP\ ij}}{\mathrm{maxGDP\ ij}} + \sum_{i=1}^{n} \frac{\mathrm{Exp\ ij}}{\mathrm{maxExp\ ij}} + \sum_{i=1}^{n} \frac{\mathrm{minImp\ ij}}{\mathrm{Imp\ ij}} + \right.$$

$$\left. + \sum_{i=1}^{n} \frac{\mathrm{W\&S\ ij}}{\mathrm{maxW\&S\ ij}} + \sum_{i=1}^{n} \frac{\mathrm{minU\ ij}}{\mathrm{U\ ij}} + \sum_{i=1}^{n} \frac{\mathrm{minHICP\ ij}}{\mathrm{HICP\ ij}}\right) / n;$$

$$E_{Sec} \in [0;1] \mathrm{Macro} \in [0;1]$$

where:
GDPij, Expij, Impij, W&Sij, Uij, HICPij stand for the normalized value of the j-th variable in the i-th year
GDP – gross domestic product
Exp – export of goods and services
Im – import of goods and services
W&S – wages and salaries
U – unemployment rate
HICP – Harmonised Indices of Consumer Prices.

- financial conditions of the logistics sector (FC), based on the following stimulants: current ratio, quick ratio, return on sales, return on assets, return on equity; and destimulants: debt ratio. I use the following formula:

$$FC = \left(\sum_{i=1}^{n} \frac{CR\ ij}{maxCR\ ij} + \sum_{i=1}^{n} \frac{QR\ ij}{maxQR\ ij} + \sum_{i=1}^{n} \frac{ROS\ ij}{maxROS\ ij} + \right.$$
$$\left. + \sum_{i=1}^{n} \frac{ROA\ ij}{maxROA\ ij} + \sum_{i=1}^{n} \frac{ROE\ ij}{maxROE\ ij} + \sum_{i=1}^{n} \frac{minDR\ ij}{DR\ ij}\right) / n;$$
$$FC \in [0;1]$$

where:
CR – current ratio
QR – quick ratio
ROS – return on sales
ROA – return on assets
ROE – return on equity
DR – debt ratio.

– I use the OLS method to estimate the model, which is given by the equation:

$$DeCarbon_i = \beta_0 + \beta_1 \cdot \mathrm{Macro}_i + \beta_2 \cdot \mathrm{FC}_i + \varepsilon_i$$

where β_0 is the intercept, β_1; β_2; β_3; is the slope; εi denotes the i-th residual; i is an observation index.

The regression was written with the formula:

$$s(\hat{\beta}_0, \ldots, \hat{\beta}_2) = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} (I_i - I_i)^2 \rightarrow \min$$

$$s(\hat{\beta}_0, \ldots, \hat{\beta}_2) = \sum_{i=1}^{n} (DeCarbon_i - \hat{\beta}_0 - \hat{\beta}_1 \cdot \mathrm{Macro}_i - \hat{\beta}_2 \cdot FC_i - \varepsilon_i)^2 \rightarrow \min$$

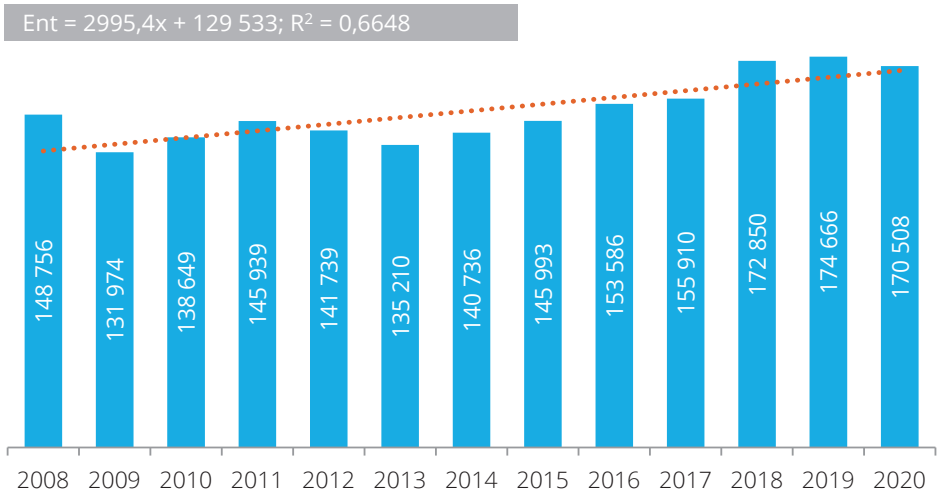
I checked the assumption of the method, including unit root tests (KPSS test), homoskedaskity (White test), autocorrelation (Durbin–Watson, Breusch–Godfrey tests), normality (Doornik–Hansen test), collinearity (Variance Inflation Factor).

4. Research results

The number of logistics companies in Poland from 2008 to 2020 increased from 148.8 thousand to 170.5 thousand (Chart 1). The clear positive trend should be assessed positively, but the problem, which is also visible, is the fact that the survival rate of enterprises could be higher.

CHART 1

Enterprise number in the logistics sector in Poland from 2008 to 2020



Source: the author's own elaboration on the basis of: [www 1].

Table 1 shows the greenhouse gas emissions in Poland's logistics sector from 2008 to 2020. Statistical data show that emissions of individual greenhouse gases are decreasing, which indicates positive changes in the sector and the implementation of new environmentally friendly solutions.

TABLE 1

Greenhouse gases emission (tonne) in the logistics sector in Poland from 2008 to 2020

Year	Carbon dioxide	Methane	Nitrous oxide	Sulphur oxides	Ammonia	Greenhouse gases
2008	14 625 702	4 456,31	485,04	2 980,70	745,98	15 161 853
2009	14 668 443	3 825,04	484,98	02 628,3	642,19	15 203 867
2010	15 676 914	4 699,00	522,86	2 890,35	556,99	16 254 543
2011	15 968 687	4 450,50	553,35	2 724,24	498,44	16 568 275
2012	15 901 233	4 088,95	551,70	2 816,03	433,46	16 474 677
2013	14 919 743	4 265,85	526,29	2 591,76	358,59	15 485 821
2014	15 565 245	4 249,54	551,87	2 519,24	307,11	16 151 565
2015	16 191 288	4 755,44	581,77	2 551,06	292,54	16 783 261
2016	18 781 047	5 192,30	681,32	2 724,39	305,01	19 411 978
2017	20 853 419	4 959,48	787,32	3 031,04	353,50	21 533 719
2018	21 283 172	4 910,72	872,50	3 153,48	440,76	21 970 078
2019	9 232 879	4 445,59	409,23	2 941,36	346,37	9 791 648
2020	8 485 732	3 927,83	400,99	2 016,29	341,57	9 043 798

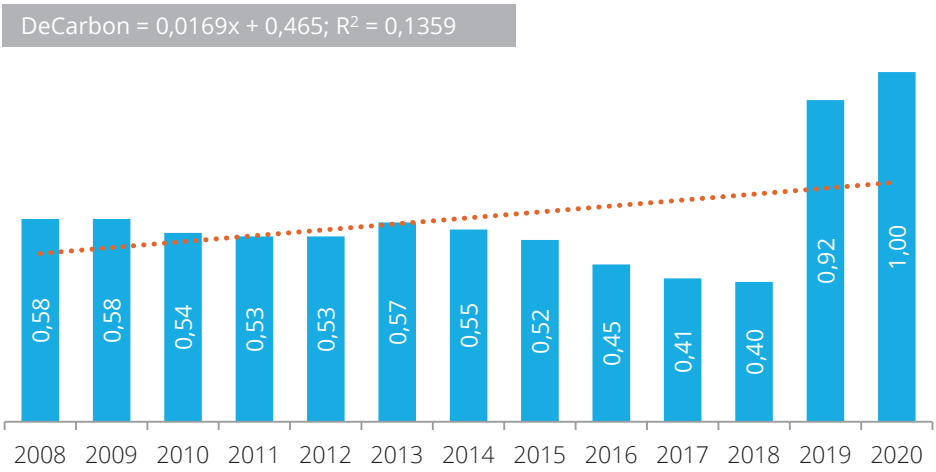
Source: the author's own elaboration on the basis of [www 2].

Chart 2 shows the logistics decarbonization rate. The trend of the indicator is positive, which means a reduction in carbon dioxide emissions into the atmosphere, but it should be noted that from 2015 to 2018 we had an increase in CO_2 emissions, largely due to good economic conditions and an increasing number of enterprises. The increase in the decarbonization indicator in 2019 and 2020 results from the increasingly restrictive environmental protection laws. In 2020, the decarbonization of logistics was additionally positively influenced by the COVID-19 pandemic due to temporary restrictions and reductions in the scope of conducting business activities [Borucka, Kozłowski, 2023].

Table 2 presents selected indicators of the logistics sector's financial and asset situation analysis from 2008 to 2020. Liquidity in the sector is relatively good (the current financial liquidity for the sector should be in the range of 1.2 to 2). The sector's problem is the low profitability of assets, sales and equity. In the period under review, the sector's debt is also growing, which is a negative phenomenon, especially with relatively low liquidity and profitability.

CHART 2

Decarbonization indicator of the logistics sector from 2008 to 2020



Source: the author's own elaboration on the basis of: [www 2].

TABLE 2

Financial indicators in the logistics sector in Poland from 2008 to 2020

Year	CR	QR	ROS	ROA	ROE	DR
2008	1,31	1,17	0,01	0,01	0,01	0,55
2009	1,24	1,11	0,02	0,01	0,03	0,55
2010	1,30	1,17	0,03	0,02	0,05	0,55
2011	1,33	1,21	0,03	0,02	0,06	0,57
2012	1,31	1,20	0,03	0,02	0,05	0,59
2013	1,39	1,29	0,03	0,02	0,06	0,60
2014	1,42	1,31	0,03	0,02	0,06	0,63
2015	1,52	1,41	0,04	0,03	0,07	0,64
2016	1,62	1,49	0,04	0,03	0,09	0,66
2017	1,52	1,39	0,04	0,03	0,08	0,66
2018	1,51	1,38	0,04	0,03	0,08	0,66
2019	1,48	1,35	0,04	0,03	0,09	0,67
2020	1,58	1,45	0,02	0,01	0,04	0,68

Source: the author's own elaboration on the basis of: [www 2].

The macroeconomic situation in Poland improved from 2008 to 2020 (Table 3). GDP and wages increased, the unemployment rate decreased, and the inflation rate was relatively low.

TABLE 3

Selected macroeconomic indicators (million euro) in Poland from 2008 to 2020

GDP	Export	Import	Wages	Unemployment rate	HICP	DR
2008	366 040,5	138 417,8	157 730,1	120 307,8	8,5	4,2
2009	317 040,6	117 756,0	120 873,5	100 916,7	8,5	4,0
2010	359 067,8	143 955,2	152 466,8	117 046,6	10,0	2,6
2011	377 042,4	160 521,5	168 575,7	120 530,7	10,0	3,9
2012	385 389,4	170 643,8	173 384,2	122 194,7	10,4	3,7
2013	388 356,4	178 569,9	173 977,6	124 148,9	10,6	0,8
2014	406 412,5	188 936,3	187 274,3	130 214,9	9,2	0,1
2015	429 834,6	203 957,8	195 009,4	135 456,4	7,7	-0,7
2016	424 735,3	213 507,3	200 779,2	138 214,6	6,3	-0,2
2017	465 772,6	242 461,1	229 279,1	152 882,5	5,0	1,6
2018	499 004,1	263 214,8	253 007,4	166 064,5	3,9	1,2
2019	532 504,7	283 267,6	263 554,5	179 507,4	3,3	2,1
2020	526 147,2	278 810,3	249 042,8	181 810,0	3,2	3,7

Source: the author's own elaboration on the basis of: [www 2]; [www 4]; [www 5].

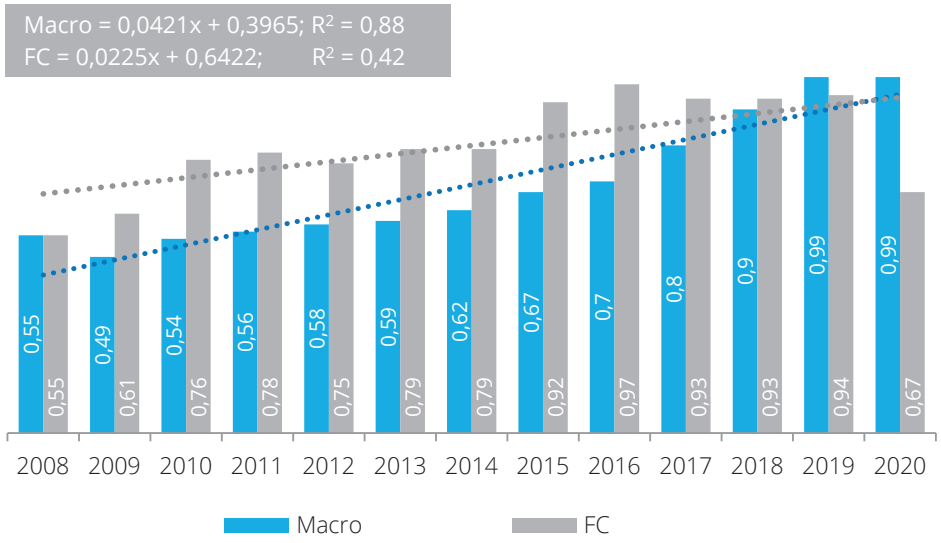
Chart 3 presents the designated synthetic indicators of the macroeconomic condition of the Polish economy and the financial situation of the logistics sector in Poland. A much higher level was recorded in the case of the Macro indicator, which indicates that the macroeconomic environment in Poland is stable. The financial situation indicator is also increasing, but its average values are relatively low.

Table 4 presents the estimation results obtained with the use of the Classical Least Squares Method. The estimation results show a statistically significant ($p < 0.05$) impact of two variables from the previous period: macroeconomic con-

ditions and the financial situation of the logistics sector. However, the impact of macroeconomic conditions from the t-1 period is positive, and the financial situation is negative.

CHART 3

Indicators of macroeconomic conditions (Macro) and financial conditions of the logistics sector (FC) from 2008 to 2020



Source: the author's own elaboration on the basis of: [www 6]; [www 3].

TABLE 4

The OLS estimation results: dependent variable: decarbonization (2009–2020)

	Coefficient	Std. Dev.	p- value	R^2	DW
Const	0,469549	0,215166	0,0570	0.68	1.72
Macro(-1)	1,482820	0,348561	0,0021		
FC(-1)	−1,079120	0,403483	0,0254		
Test White'a: LM = 6,34906; p = P(Chi-kwadrat(5) > 6,34906) = 0,27372					
Chi-square(2) = 4,62589; p = 0,0989694					
LMF = 0,0290634; p = P(F(1, 8) > 0,0290634) = 0,868865					

Source: the author's own elaboration on the basis of: [www 2]; [www 3].

The results indicate that the sector's financial situation, which was diversified in 2009 and 2020, negatively affects the sector's decarbonization and may result from insufficient financial resources for carrying out ecologically responsible tasks. In turn, enhancing the macroeconomic situation leads to an increase in the sector's decarbonization; in other words, improving the economic situation causes the expectations of consumers and enterprises to improve, which may lead to an increase in investments.

5. Discussions

The decarbonization of the Polish logistics sector from 2008 to 2020 has a positive trend, although the indicator levels are varied and fluctuate around the trend line. The research results confirm the previous analysis indicating that endogenous and exogenous factors impact the logistics' emission intensity [Ghisolfi et al., 2022; Comporek et al., 2022; Zowada, 2023; Neagoe et al., 2024].

Fluctuations in the decarbonization indicator around the trend line and the relatively low level of its dynamics confirm that the decarbonization process is complicated and dependent on several factors, often macro-social [Kozłowski, 2022; Frankowski et al., 2023].

Moreover, the decarbonization of the logistics sector accelerated at the beginning of the COVID-19 pandemic. The reduced scale of business and restrictions related to the pandemic restrictions contributed to a decline in carbon emissions [Figura and Gądek-Hawlena, 2022; Stavroulakis et al., 2023; Borucka, Kozłowski, 2023].

The estimation results indicate that macroeconomic conditions and the financial situation of enterprises have a statistically significant impact on the decarbonization of logistics. Therefore, like other authors, I noted that exogenous and endogenous factors influence the logistics sector's environmental development and emission reduction [Karaduman et al., 2020; Comporek et al., 2022; Chrzanowski, Krawiec, 2023].

The analysis reported the impact of explanatory variables from the previous period on the explained variable, which indicates that the decarbonization of the sector is somehow a consequence of what happened in the past in the economy and in the financial situation of enterprises. Therefore, the main research hypothesis is true.

The research results confirm the results that indicate the impact of macroeconomic conditions on the environmental development and, more broadly, on the

sustainable development [Comporek et al., 2022; Zowada, 2023; Metcalf, Stock, 2023]. Additionally, there is an autoregression, which is important for managing the decarbonization process of enterprises.

Maintaining an appropriate level of liquidity, profitability, and financial structure is important not only for the economic development of enterprises but also for reducing the emission intensity of the sector.

The analyses indicate that the answer to the first research question is affirmative, so decarbonization has a positive trend, although it can be seen that just before the pandemic the decarbonization rate slightly worsened. However, European Union initiatives, especially the one from 2019 included in the Green Deal, will cause the sector's emission intensity to decrease.

The macroeconomic condition indicator is also improving, proving that the Polish economy has gradually recovered from the trouble after the economic crisis in 2008. The macroeconomic indicator is higher than the indicator of the financial situation of the logistics sector. The answer to the second question is affirmative.

The financial situation indicator is also increasing, although it should be noted that the problem of the logistics sector regards the low profitability and the increasing level of debt. In turn, the decarbonization indicator is lower than the macroeconomic and financial indicators; this means that it is necessary to take further actions to reduce the sector's emission intensity.

The limitation of the study regards the fact that it was conducted on an annual basis; the results are undoubtedly also influenced by issues related to the construction of indicators and the selection of estimation methods.

6. Conclusions

Decarbonization of the logistics sector means reducing CO_2 emissions into the atmosphere. It takes place in strictly defined socio-economic conditions. From 2008 to 2020, there were positive dynamics of decarbonization of the logistics sector, which resulted from more restrictive transport regulations and restrictions related to the COVID-19 pandemic.

The econometric model indicated that macroeconomic conditions and the financial situation influence the decarbonization of the logistics sector in a statistically significant and diversified way. I noted that the impact of macroeconomic conditions is positive and the financial situation is negative, which proves that it is necessary to take actions aimed at financial stabilization of the sector.

The research results allowed for the formulation of several important implications. The results important from the point of view of theory include: verification of current knowledge about the decarbonization of the logistics sector and the factors influencing it, creation of a set of information and data on decarbonization and the economic and financial conditions of the sector, indication and drawing attention to the significant relationships between decarbonization and macroeconomic and financial situation, illustrating the directions and dynamics of changes in a given period. Practical solutions, important from the point of view of business activities, include increasing public opinion's pressure on the need to take socially and ecologically responsible activities by enterprises, the need for systematic research of the market environment of enterprises, including macroeconomic situation and financial and property situation.

Further research will be devoted to assessing the decarbonization process in European Union countries, analyzing greenhouse gas emissions, and assessing the impact of endogenous and exogenous determinants on their levels.

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