UDC 339.9; 504 https://doi.org/10.33271/ebdut/82.049

ECONOMIC GROWTH, TRADE, AND GREENHOUSE GAS EMISSIONS IN THE EUROPEAN UNION - INVESTIGATING POLLUTION LEAKAGE

M. A. Hnatyshyn, Ph. D (Econ.), Associate Professor, Ivan Franko National University of Lviv, maria.hnatyshyn@lnu.edu.ua, https://orcid.org/0000-0002-0854-0568

Methods. This research employs econometric modeling and panel data analysis to investigate the intricate relationship between economic growth, environmental policies, and greenhouse gas (GHG) emissions within the European Union (EU). Panel data from 27 EU countries during the period from 2008 to 2021 is used to assess the impact of various factors on GHG emissions, including per capita GDP, primary energy consumption, renewable energy share, technological development, and extra-EU trade.

Results. The study reveals that there is a positive correlation between GDP per capita and emissions, suggesting that the EU has not yet reached full decoupling of GDP growth and growth in GHG emissions. Increased primary energy consumption is associated with higher emissions, while a greater proportion of renewable energy sources is linked to reduced emissions. Technological advancements are found to mitigate GHG emissions. Importantly, the research uncovers a positive relationship between extra-EU trade and emissions, indicating the pollution leakage through trade.

Novelty. This study contributes to the literature by offering a comprehensive examination of the dynamics between economic growth, changes in energy consumption, technological advancement, trade patterns, and GHG emissions within the EU. A more specific international trade variable is introduced into the model – the trade balance of EU countries with the outside EU countries. It explores the concept of pollution leakage, shedding light on how changes in foreign trade may impact emissions levels.

Practical Value. The findings have significant policy implications, highlighting the need for a holistic approach to environmental policymaking within the EU. The study emphasizes that while progress has been made in adopting cleaner technologies and supporting renewable energy, challenges remain, including the potential for pollution leakage through international trade. This insight underscores the importance of globally impactful environmental policies and international cooperation to address GHG emissions effectively.

Keywords: economic growth, European Union, greenhouse gas emissions, international trade, pollution leakage, renewable energy.

Statement of Problem. With economic growth, global environmental issues become more severe. But at the same time, humanity gets more resources and experience in tackling those problems. In most of the «developed» world, we can see a growing concern about the state of the environment. A good example is the Paris Agreement, a universal, legally binding global climate deal. The problem of the climate change it addresses is one of the most critical global problems. The countries adopting the deal agreed to provide to developing countries with international support for adaptation (Paris Agreement, 2015). It is generally known that developed countries are well ahead of the developing ones in clean technologies; it is also known that developed countries have emitted large amounts of pollution during industrialization and that it would be disastrous for the global environment if developing countries followed the same path. So far, developing countries will have to implement clean technologies at the earlier stages of economic development and adopt environmental legislation sooner. However, even if they implement environmental measures, they usually do not have such high environmental standards as developed countries. So, the problem is whether the developed countries' efforts will not be fruitless for the global environment if the developing countries lag behind. We look for the answer to a more specific question: How do the economic growth and changes in foreign trade in the EU influence GHG emissions in EU countries? We suppose that changes in environmental regulations will cause the relocation of polluting industries to countries outside of the Union and will be reflected in its foreign trade. The analysis will allow us to determine the importance of the pollution leakage effect in determining the emissions level in the EU. It is an important question for EU policymakers, as stated in the briefing on «Economic Assessment of Carbon Leakage and Carbon Border Adjustment» (2020) requested by the Committee on International Trade of the European Parliament. The briefing concludes that carbon leakage is an empirically relevant concern that can be lowered through adequate policy.

There are few hypotheses explaining the consequences of GDP growth and more stringent environmental policy on emissions. The environmental Kuznets Curve hypothesis (EKC) is the most popular one among the many hypotheses, explaining the impact of economic growth on the natural environment. According to this hypothesis, a relationship exists between economic growth and the state of the natural environment in the shape of an inverted «U» curve. When an economy grows at a low level of income, pollution initially grows because of increased production-generated pollution. At a higher income level, further economic growth causes pollution to decline. Most likely, it is due to priorities shifting to environmental quality protection. Nevertheless, it is unclear what the mechanism of those changes in pollution is. Perhaps the consumption pattern changes, new clean technologies are being adopted, or polluting industries migrate abroad, undermining the positive effect on the global environment.

The mechanism of pollution leakage through trade is as follows: Due to a greater concern for the environment and a more stringent environmental policy polluting industries in developed countries tend to change to cleaner technologies, close their activities, relocate abroad, or outsource the polluting processes abroad. If the demand for products from polluting industries remains the same inside the country, this relocation process will be reflected in the country’s imports. The process of pollution leakage becomes possible due to the means of transportation development and world trade liberalization, as those processes lower trade costs. The demand for polluting goods in one country can be satisfied by importing from another. Countries’ production patterns can differ from their consumption patterns as the production and consumption of a product can be separated in space. It is a part of the composition effect of per capita GDP growth (Bouvier, 2004). Moreover, the whole lifecycle of a product can be dispersed through different countries. Furthermore, pollution may occur at various stages of production.

Analyses of recent papers. A number of scientists have found that the EKC relationship occurs at least partly due to the trade effect. For example, Cole and Neumayer (2005) suppose that developed countries have achieved reductions in local air pollution partially due to importing polluting products from less developed countries. Cole (2004) examines the PHH in relation to EKC and states that the first is a possible explanation for the latter. However, having studied the trade flows between developed and developing countries for pollution-intensive products, he found only small pollution haven effects, showing that other determinants of EKC may be more important. Antweiler, Copeland, and Taylor (2001) also find evidence of PHH, but the overall effect of trade liberalization is positive for the environment. Grether, Mathys, and de Melo (2006) express the effect of "pollution havens" through the pollution content of imports and find evidence of this effect. Broner, Bustos, and Carvalhoy (2013) perform a standard cross-country cross-industry test of comparative advantage and find out that the influence of environmental regulation is a statistically and economically significant determinant of comparative advantage in polluting industries comparable to other determinants. Kiuila, Wójtowicz, Żylicz and Kasek (2014) address the problem of carbon leakage slightly differently. There are so many possible ways in which the decrease in emissions in one country can influence the level of emissions in another that they propose to narrow the definition of carbon leakage to the one in which «the only source of the leakage is a shift from the current carbon reduction target to a more ambitious target.» They consider a few policy scenarios for the EU and developing countries using the global CGE model. The analysis showed that more stringent environmental regulations in the EU without any anti-leakage measures lead to higher carbon leakage rates and undermine both environmental effectiveness and economic efficiency.

On the other hand, Ederington, Levinson, and Minier (2004) did not find any connection between lower levels of pollution in the US due to changes in production structure due to trade liberalization during 1978–1994. The same changes towards cleaner production were observed in imports. No disproportionate impact of changes in tariffs for polluting production was observed. Eskeland and Harrison (2002) also found no definite evidence of «pollution havens». They studied the issue of polluting production relocation to developing countries by international companies based on US investments. Apart from the low pollution costs, the location of production is also influenced by other factors so that the result can be positive, zero, or negative. Kearsley (2010) tests the Pollution Haven Hypothesis using several model specifications. What interests us most is that he tests the influence of dirty imports and exports on emissions. He finds more positive and significant coefficients for dirty import sectors in the regressions than negative. These results led him to reject the PHH. He generally finds that the correlation between trade in polluting categories of commodities and emissions is very weak statistically. Naegele and Zaklan (2017) analyzed the EU ETS carbon leakage effect in the European manufacturing sector and found no evidence of it.

It is obvious from the literature overview that the problem of PHH and pollution leakage remains, being supported by some scientists and rejected by others. In most models, the trade effect on emissions is captured through the variable of trade openness – the ratio of exports plus imports to GDP (Antweiler et al., 2001; Frankel & Rose, 2005; Hnatyshyn, 2016), which does not allow for making any conclusions based on the structure of trade.

The aim of the paper is to determine the existence of pollution leakage through trade by assessing the influence of extra-EU trade on GHG emissions in EU countries. Other important variables influencing GHG emissions are also analyzed.

Materials and methods. In our previous study, we verified the environmental Kuznets curve hypothesis and the pollution haven hypothesis for 28 countries of the European Union (Hnatyshyn, 2016). The study's results confirmed an inverted U relationship between economic growth and emissions for the examined pollutants (CO_2 and SO_x). The pollution haven hypothesis was tested through international trade intensity impact on emissions. Intensification of external trade reduces CO_2 and SO_x emissions. The negative influence of trade intensity on emissions suggests the existence of a pollution leakage effect, i.e., relocation of polluting industries emitting these gases abroad to countries beyond the EU. However, we do not have enough evidence to finally support or reject this possibility because we considered only the general share of exports and imports in GDP.

This time, we include more specific determinants of pollution leakage – the trade balance of EU countries with the countries from outside the EU. The dependent variable in this study is greenhouse gases (GHG) emissions per capita (CO_2, N_2O in CO_2 equivalent, CH_4 in CO_2 equivalent, HFC in CO_2 equivalent, PFC in CO_2 equivalent, SF_6 in CO_2 equivalent, NF_3 in CO_2 equivalent). An increase in imports and a decrease in exports' negative influence on GHG emissions in EU countries would mean that the country may have substituted its polluting production with imports from outside the EU countries. We assume that pollution leakage can be measured through changes in trade flows. One more dependent variable in our study is real GDP per capita. It should reflect the existence of the EKC. Other dependent variables in our study include statistical data for EU countries on primary energy consumption and the share of energy from renewable sources. They represent the changes in the energy sector, which is usually the most polluting one. We suspect that increased primary energy consumption is connected with higher emissions. We suspect that the increase in the share of clean (renewable) energy sources decreases emissions. Last but not least, we include the variable to account for technology development. We measure it by patent applications to the EPO by country of applicants. That is the approach used by Allard, Takman, Uddin, and Ahmed (2017). We build an econometric model using the above-mentioned variables and conduct econometric analysis using the Stata statistics package. We use data from the Eurostat database for 27 EU countries for the years 2008–2021.

Finding. Let us make a short overview of the data we use in econometric analysis. First of all, it is the GHG emissions. We can see the general decrease in GHG emissions in EU countries over the analyzed years (Fig. 1). Decoupling GDP growth from GHG emissions is crucial to addressing climate change and achieving sustainable development. The aim is to ensure that economic growth can occur without a corresponding increase in greenhouse gas emissions, which are the primary drivers of global warming and climate change. This happens when the rate of GHG emissions growth is slower than the rate of economic growth. In other words, emissions still increase, but at a slower pace compared to GDP growth. This can be achieved through improvements in energy efficiency, technological advancements, and shifts to cleaner energy sources. So let us look at the per capita GDP of EU countries (Fig.1). As we can see on the graph, there is a general contraction of per capita GDP in EU countries after 2008. The 2008 crisis led to a global recession, marked by a contraction in economic activity in many countries. Overall, the 2008 financial crisis had a negative impact on GDP per capita in many countries due to the recession, unemployment, reduced consumer spending, and disruptions to the financial system. Over time, as economies stabilized and policies were implemented to address the crisis's root causes, GDP per capita in many countries began to recover. We can see that GDP per capita slightly increases over the next years, with one more decline in 2020 due to Covid19 crisis and recovers again.

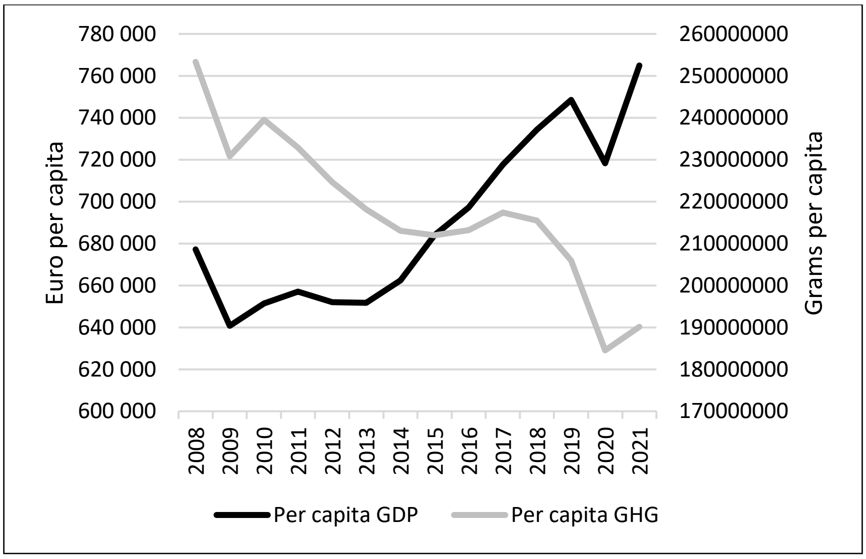

Figure 1. GDP per capita and GHG emissions per capita in EU countries

Source: Developed by authors based on Eurostat

We used a scatter plot to visually assess the strength, direction, and nature of the relationship between the two variables (Fig.2). Although on the previous graphs, we saw an increase in per capita GDP and a decrease in per capita GHG emissions, here we see a positive relationship. Therefore, we will need some further analysis.

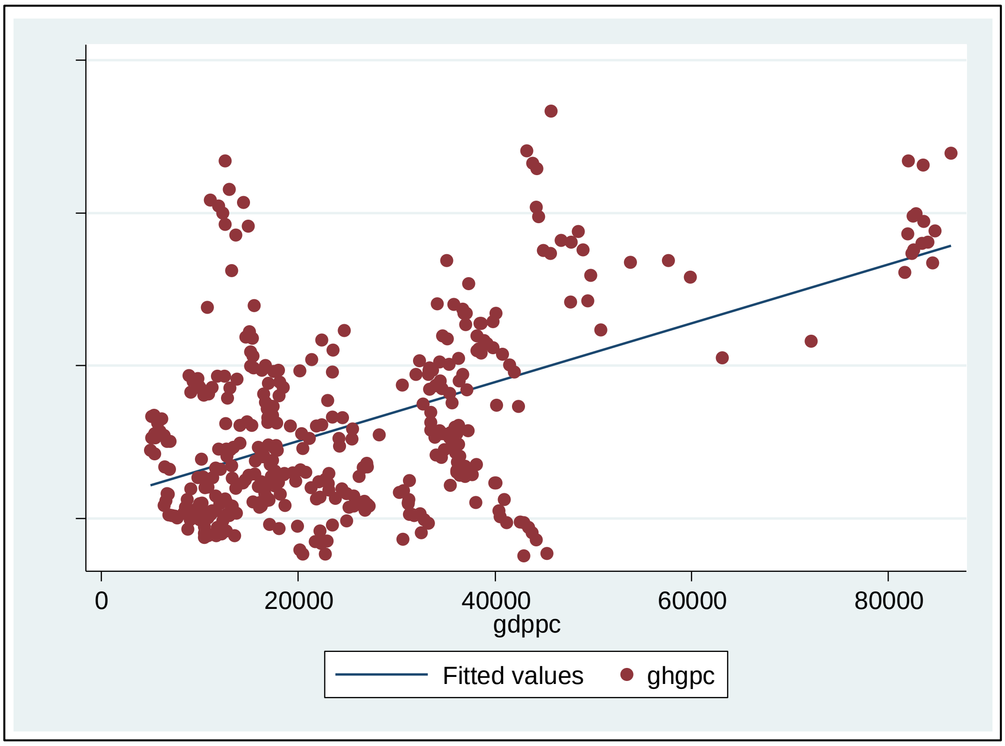

Figure 2. The per capita GHG emissions against per capita GDP
Source: Eurostat data visualized using Stata

Decoupling can also be achieved through improvements in energy efficiency, shifts to cleaner energy sources, and technological advancements. Those dimensions we include in our model through primary energy consumption, the share of energy from renewable sources (Fig. 3), and patent applications to the EPO by country of applicants (Fig. 4). We can see the general decline in primary energy consumption and increase in the share of energy from renewable sources.

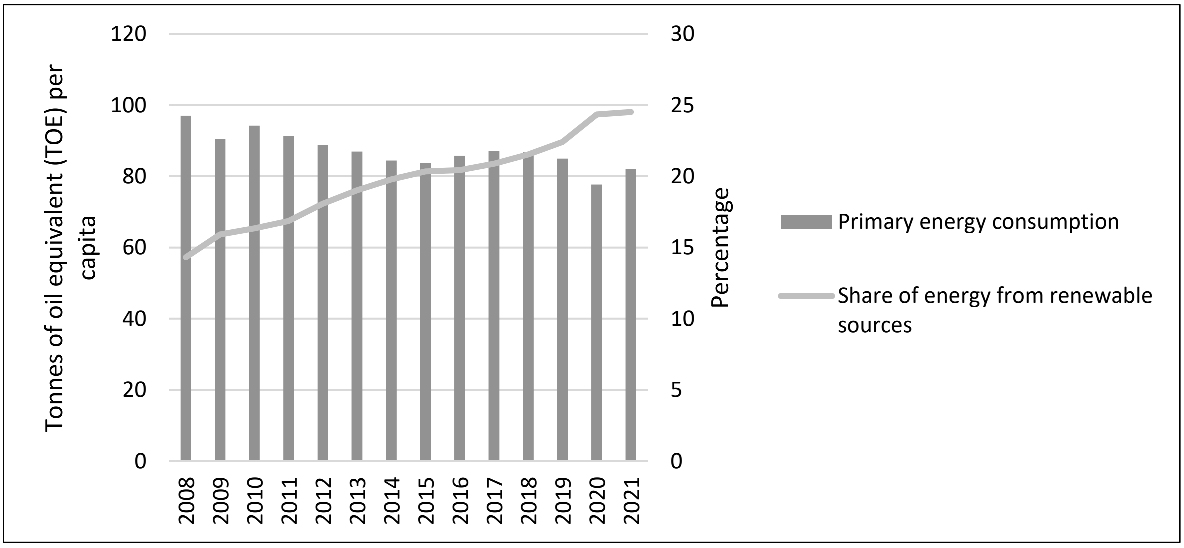

Figure 3. Primary energy consumption by EU countries and the share (EU average) of energy from renewable sources.
Source: Developed by authors based on Eurostat

In Fig. 4, we present data for EU countries for the year 2021, as data differs more by country than by year. To minimize the influence of country size on the number of patents, we use patents per million inhabitants data.

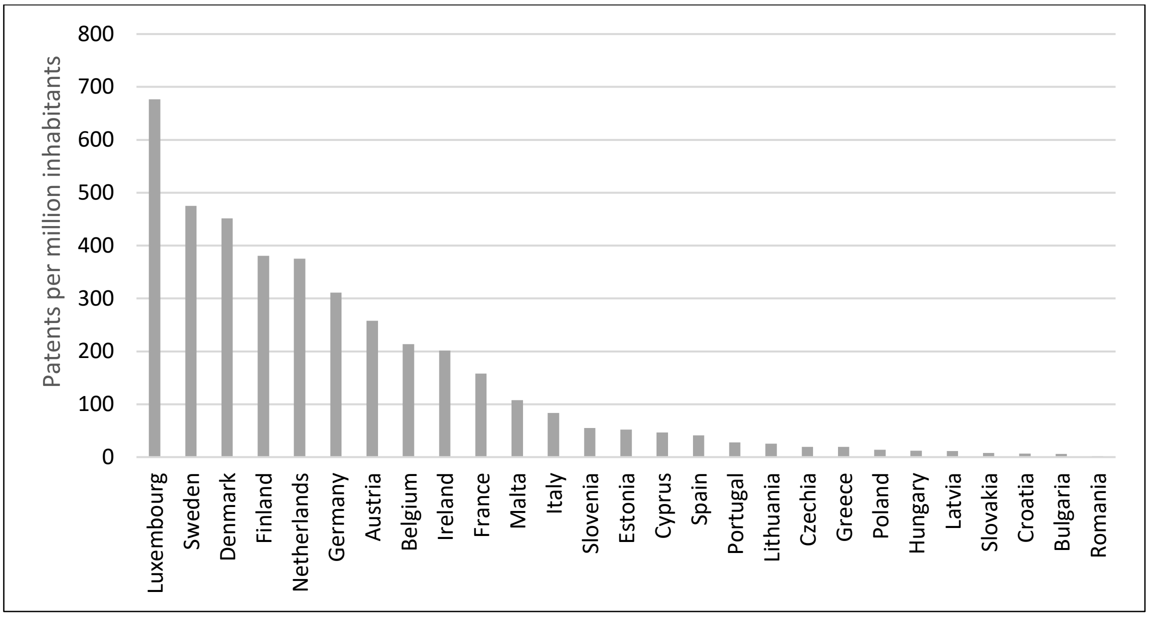

Figure 4. Patent applications to the EPO by country of applicants in 2021.
Source: Developed by authors based on Eurostat

Besides the described above data, we introduce one more variable into our analysis to measure pollution leakage. It is an extra-EU trade. We analyze the trade balance of member states with extra-EU countries as it suits our purpose of pollution leakage detection best (Fig. 5).

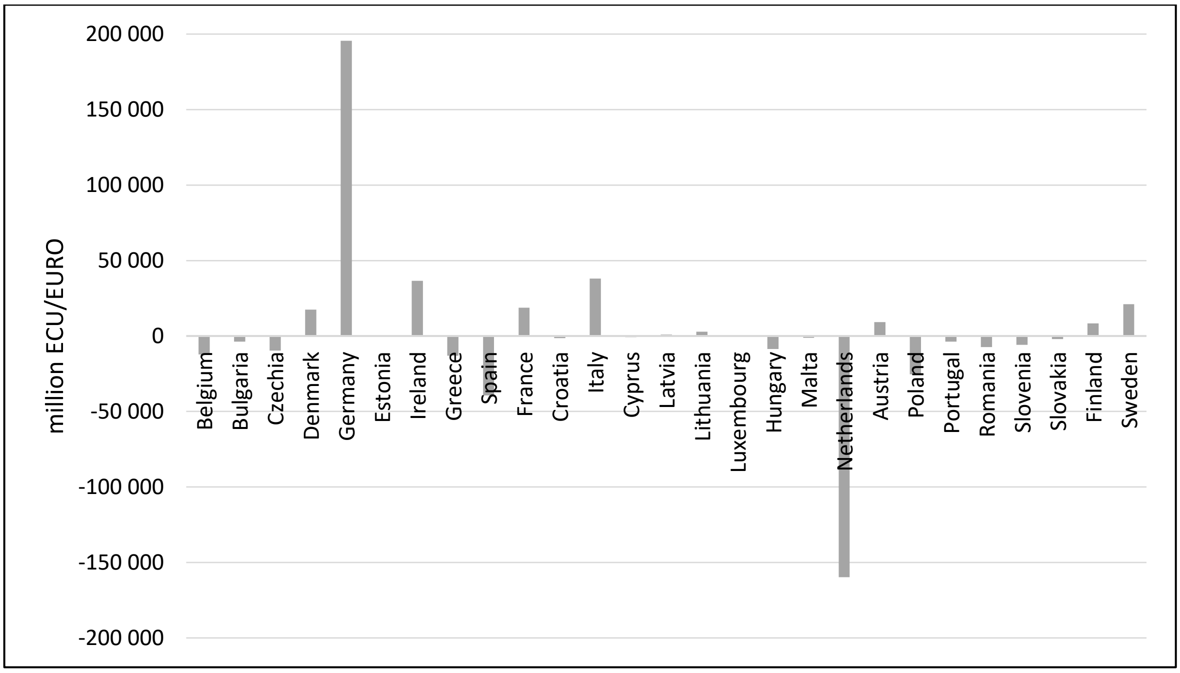

Figure 5. Extra-EU trade balance by EU Member State in 2021.
Source: Developed by authors based on Eurostat

For econometric modeling, we use ex-post analysis. The econometric analysis was conducted using the Stata statistics package. All the data we use is retrieved from the Eurostat database. We use panel data for 27 EU countries for the years 2008–2021.

In accordance with previous literature, we estimated an empirical model consisting of a relationship between GHG emissions and the following explanatory variables: income (per capita GDP), primary energy consumption, share of renewable energy, technological development, and extra-EU trade. The model is given by:

(1) $ghgpc_{k,t} = \alpha_0 + \alpha_1\ gdppc_{k,t} + \alpha_2\ pecpc_{k,t} + \alpha_3\ resp_{k,t} + \alpha_4\ patpc_{k,t} + \alpha_4\ tbeeup_{k,t} + \varepsilon_{k,t}$

where: ghgpc – GHG emissions per capita; gdppc – GDP per capita; pecpc – primary energy consumption per capita; recp – share of energy from renewable sources; patpc – patent applications per million inhabitants; tbeeup – trade balance extra-EU27 per GDP; α_0 – specific parameters for countries and years.

We carried out the model estimation using the Stata program. We employed the generalized least squares method. To decide between fixed and random effects models, we performed the Hausman test, which tests whether the individual characteristics are correlated with the regressors. The null hypothesis is that they are not (random effects). In Table 1, the output of the test for the equation is presented. If Prob > chibar2 < 0.05, we fail to accept the null hypothesis and conclude that random effects are needed. According to our test results, we accept the hypothesis that random effects are better than fixed ones.

Table 1

The Hausman Test of the model

	Coefficients (b) fixed	Coefficients (B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
gdppc	54.77918	48.15084	6.62834	4.529029
pecpc	1757289	1724854	32435.26	45947.6
resp	-130980.6	-126572.1	-4408.41	4199.882
patpc	-3118.429	-3582.794	464.3658	386.5672
tbeeup	6266113	6172527	93586.01	203568.8

```
                b = consistent under Ho and Ha; obtained from xtreg
 B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

             chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                     =        5.04
           Prob>chi2 =      0.2832
```

Although the test showed that random effects are preferable in our model, heteroscedasticity is common when using panel data for countries. Therefore, we control for it using the "robust" command in Stata. The results of model estimation are presented in Table 2.

Based on the model estimation, we conclude that our model explains 42 % of changes in per capita GHG emissions in EU countries. All variables are significant. There is a positive relationship between GDP per capita and emissions, which demonstrates that, in general, the EU has not passed the EKC turning point over the analyzed years. There turned out to be a positive relationship between primary energy consumption and emissions, as we predicted. In turn, the increase in the share of renewable energy decreases emissions. That means that the existing EU policy of supporting renewable energy and minimizing primary energy consumption is feasible in terms of combating climate change. Technological advancement, according to estimation results, also mitigates GHG emissions. This supports the results obtained by Pimonenko (2019) (based on basic empirical calculations for EU countries) that a 1% increase in the volume of green investments leads to an increase in GDP by 6.4% and a decrease in greenhouse gas emissions by 3.08%, and an increase in the share of renewable energy sources in the total energy consumption by 5.6%. The extra-EU trade variable showed a positive relationship with emissions. That means that the increase in exports and/or the decrease in imports increases GHG emissions and vice versa. We can make a conclusion that an increase in imports may decrease emissions, and that is a sign of the pollution leakage effect when pollution decreases due to polluting production substitution by imports.

Table 2

Results of the model estimation

Random-effects GLS regression		Number of obs =	378
Group variable: country		Number of groups =	27
R-sq:		Obs per group:	
within	= 0.6695	min =	14
between	= 0.4007	avg =	14.0
overall	= 0.4213	max =	14
		Wald chi2(5) =	172.52
corr(u_i, X)	= 0 (assumed)	Prob > chi2 =	0.0000

(Std. Err. adjusted for 27 clusters in country)

ghgpc	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
gdppc	48.15084	18.40832	2.62	0.009	12.07121	84.23048
pecpc	1724854	566563.1	3.04	0.002	614410.7	2835297
resp	-126572.1	21789.56	-5.81	0.000	-169278.9	-83865.4
patpc	-3582.794	1079.351	-3.32	0.001	-5698.284	-1467.305
tbeeup	6172527	2017806	3.06	0.002	2217700	1.01e+07
_cons	4298904	1833231	2.34	0.019	705837.8	7891970
sigma_u	2505527.7					
sigma_e	596742.23					
rho	.94631992	(fraction of variance due to u_i)				

In general, the model estimation results are in line with the theory. Some important policy implications can be made based on the results. We can see that the decoupling has not yet been reached, and we need to find new ways to make GDP cleaner. We have strong convictions that pollution leakage is present. Therefore, a one-sided environmental policy of developed countries may not be sufficient. However, due to some methodological drawbacks and the relatively short time period included in the study, further investigations are needed to determine the extent of pollution leakage effect on emissions. It could include the measurement of pollution intensity of export and import of EU countries.

Conclusions. This article delves into the complex relationship between economic growth, environmental policies, and GHG emissions in the European Union countries. The study's primary focus was to investigate the concept of pollution leakage through international trade and its impact on GHG emissions. The developed world, including EU countries, has shown an increasing concern for environmental issues, exemplified by international agreements like the Paris Agreement. This reflects a growing awareness of the importance of addressing climate change and pollution. The article introduces the concept of pollution leakage through trade, where polluting industries in developed countries might relocate or outsource their production to less regulated countries. This shift in production can affect GHG emissions. The literature review highlights a mixed body of research regarding pollution leakage. Some studies support the idea that trade can influence emissions, while others find limited evidence of this effect.

The study employs econometric modeling using panel data from EU countries between 2008 and 2021. It incorporates per capita GDP, primary energy consumption, renewable energy share, technological development, and extra-EU trade variables. The research indicates a positive relationship between GDP per capita and emissions, suggesting that the EU has yet to reach the EKC turning point. Increased primary energy consumption is associated with higher emissions, while a more significant share of renewable energy decreases emissions. Technological advancement is also found to mitigate GHG emissions. Importantly, extra-EU trade exhibits a positive relationship with emissions, indicating the pollution leakage.

The findings have significant policy implications. The study suggests that the EU still needs to achieve the decoupling of economic growth from emissions. It also provides evidence supporting the idea that pollution leakage through trade may be occurring. Therefore, more than a one-sided environmental policy in developed countries may be required to combat global emissions effectively.

This research sheds light on the intricate relationship between economic growth, environmental policies, and GHG emissions in the EU. It suggests that while progress has been made in adopting cleaner technologies and supporting renewable energy, challenges remain, including the potential for pollution leakage through international trade. Further research is necessary to refine our understanding of these dynamics and to form more effective environmental policies on a global scale.

References

1. Paris Agreement. (2015) United Nations. Retrieved from https://unfccc.int/sites/default/files/english_paris_agreement.pdf
2. Felbermayr, G. & Peterson, S. (2020). Economic assessment of carbon leakage and carbon border adjustment. Policy Department for External Relations Directorate General for External Policies of the Union, PE 603.501. Retrieved from https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/603501/EXPO_BRI(2020)603501_EN.pdf
3. Bouvier, R. A. (2004), Air Pollution and Per Capita Income: a Disaggregation of the Effects of Scale, Sectoral Composition, and Technological Change, Political Economy Research Institute, working paper series number 84, 24 p.
4. Cole, M. A., Neumayer, E. (2005), Environmental policy and the environmental Kuznets curve: can developing countries escape the detrimental consequences of economic growth? «International Handbook of Environmental Politics», Cheltenham and Northampton: Edward Elgar, p. 298-318.
5. Cole, M. A. (2004), Trade, the pollution haven hypothesis and the environmental Kuznets curve: examining the linkages. «Ecological Economics», 48, p. 71-81. https://doi.org/10.1016/j.ecolecon.2003.09.007
6. Antweiler, W., Copeland, B. R., & Taylor, M. S. (2001), Is free trade good for the environment?, "American Economic Review", 91(4), p. 877-908. https://doi.org/10.1257/aer.91.4.877
7. Grether, J. M., Mathys, N. A., de Melo, J. (2006), Unraveling the World-Wide Pollution Haven Effect, Nota di lavoro 122, Milano : Fondazione Eni Enrico Mattei, 29 p. https://doi.org/10.2139/ssrn.1962482
8. Broner, F, Bustos, P., Carvalhoy, V. M. (2012), Sources of Comparative Advantage in Polluting Industries, NBER Working Paper No. 18337, 51 p.
9. Kiuila, O., Wójtowicz, K., Żylicz, T., Kasek, L. (2014), Economic and environmental effects of unilateral climate actions, "Mitigation and Adaptation Strategies for Global Change", vol. 21, p. 263-278. https://doi.org/10.1007/s11027-014-9597-9
10. Ederington, J., Levinson, A., Minier, J. (2004), Trade Liberalization and Pollution Havens, NBER Working Paper No. 10585, 31 p.
11. Esceland, G. S., Harrison, A.E.(2002), Moving to greener pastures? Multinationals and the pollution haven hypothesis, NBER Working Paper No. 8888, 39 p.
12. Kearsley, A., Riddle, M. (2010), A further inquiry into the Pollution Haven Hypothesis and the Environmental Kuznets Curve, «Ecological Economics», vol. 69, p. 905–919. https://doi.org/10.1016/j.ecolecon.2009.11.014
13. Naegele, H. and Zaklan, A. (2017) Does the EU ETS cause carbon leakage in European manufacturing? DIW Berlin Discussion Paper No. 1689 http://dx.doi.org/10.2139/ssrn.3050323
14. Frankel, J. A., Rose A. K. (2002), Is trade good or bad for the environment? Sorting out the causality, NBER Working Paper No. 9201, 55 p. DOI:10.1162/0034653053327577
15. Hnatyshyn, M. (2016), Decomposition of carbon dioxide and sulphur oxides emissions intensity change in the European Union, "Ekonomia. Rynek, gospodarka, społeczeństwo", vol. 44, s. 31−50 https://doi.org/10.14254/2071-8330.2018/11-1/15
16. Allard, A., Takman, J., Uddin, G.S. et al. The N-shaped environmental Kuznets curve: an empirical evaluation using a panel quantile regression approach. Environ Sci Pollut Res 25, 5848–5861 (2018). https://doi.org/10.1007/s11356-017-0907-0
17. Pimonenko, T. V. (2019). Determinants of improving the efficiency of green investment management. Economic Bulletin of the National Mining University scientific journal, 65(65), 158-165. https://doi.org/10.33271/ev/65.158

ЕКОНОМІЧНЕ ЗРОСТАННЯ, ТОРГІВЛЯ ТА ВИКИДИ ПАРНИКОВИХ ГАЗІВ У ЄВРОПЕЙСЬКОМУ СОЮЗІ – ДОСЛІДЖЕННЯ ВИТОКУ ЗАБРУДНЕННЯ

Гнатишин М. А., к. е. н., доцент, Львівський національний університет імені Івана Франка

Методологія дослідження. Щоб дослідити складний зв'язок між економічним зростанням, екологічною політикою та викидами парникових газів (ПГ) у Європейському Союзі (ЄС) у дослідженні використовується економетричне моделювання та панельний аналіз даних. Для оцінки впливу на викиди парникових газів таких факторів, як ВВП на особу, споживання первинної енергії, частка відновлюваної енергії, технологічний розвиток і торгівля з країнами з-поза меж ЄС використані панельні дані 27 країн ЄС за період з 2008 до 2021 року.

Результати. Результати дослідження показали, що існує пряма залежність між ВВП на особу та викидами, що свідчить про те, що ЄС ще не досяг повного відокремлення зростання ВВП від зростання викидів ПГ. Збільшення споживання первинної енергії пов'язане з більшими викидами, тоді як більша частка відновлюваних джерел енергії пов'язана зі зменшенням викидів. Встановлено, що технологічний прогрес зменшує викиди парникових газів. Важливо, що дослідження виявило значущий зв'язок між торгівлею з країнами з-поза меж ЄС та викидами, що вказує на витік забруднення через торгівлю.

Новизна. Це дослідження пропонує всебічний аналіз динаміки зв'язку між економічним зростанням, змінами у споживанні енергії, технологічним прогресом, торговельними потоками та викидами парникових газів у межах ЄС. У модель введено нову змінну для вивчення впливу на викиди міжнародної торгівлі – торговий баланс країн ЄС із країнами з-поза ЄС. Такі дані дозволяють краще проаналізувати концепцію витоку забруднення, проливаючи світло на те, як зміни у зовнішній торгівлі можуть вплинути на рівень викидів.

Практична значущість. Результати мають вагоме значення в контексті реалізації екологічної політики, наголошують на необхідності цілісного підходу до її розробки. Незважаючи на прогрес ЄС у впровадженні більш екологічних технологій і розвитку відновлюваних джерел енергії, розмір ВВП країн ЄС все ж позитивно корелює з викидами, а також простежуються ознаки витоку забруднення через міжнародну торгівлю. Це означає, що одностороннє підвищення екологічних вимог у межах одного регіону без застосування торговельних заходів може не мати бажаного глобального ефекту. Для уникнення витоку забруднення особливу вагу має міжнародне співробітництво та формування глобальної екологічної політики.

Ключові слова: економічне зростання, Європейський Союз, викиди парникових газів, міжнародна торгівля, витік забруднення, відновлювана енергія.

Надійшла до редакції 08.06.23 р.