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Pollution, income inequality and green finance in the new EU member states

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Income inequality and pollution represent major challenges for the New EU Member States. In this context, the main objective of this paper is to check if income inequality enhances pollution in the EU-13 countries in the period 2002–2021. The results depend on the type of method that was employed (Fully Modified Least Square (FMOLS) estimators and method of moments quantile regression). In most of the cases, Gini index and gender pay gap have a negative impact on GHG emissions. An inverse U pattern is supported for the pollution—economic growth nexus. Foreign direct investment contributes to pollution, while renewable energy consumption proved to be the most efficient tool in the fight with pollution. For robustness check, in the period 2006–2021, the environmental protection investments of general government reduced the GHG emissions only in the long run. The results are the basis for the formulations of various proposals to reduce pollution in the New EU Member States.

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Introduction

Income inequality and pollution are current challenges for the entire world that generate social tensions. Besides their obvious negative consequences if they are separately analysed, income inequality could also enhance pollution. Income inequality is an important issue also for the EU. According to latest available data for 2021, the highest inequality as disposable income was recorded in few New EU Member States: Bulgaria (almost 40%), Latvia (~36%), Lithuania (around 35%) and Romania (34.3%). On the other hand, pollution is still a problem for most of the EU countries, including new member states. Therefore, new European Commission directives suppose more efforts to ensure a cleaner air by 2030. In this context, the research question is: does income inequality enhance pollution in the New EU Member States? If the hypothesis is validated, more arguments are brought to improve the social and economic policies to reduce income inequality.

The connection between the two indicators is based on theoretical principles. The economic theory described the scale effect according to which the growth of production and consumption in conditions of initial income growth determines more pollution because of more resources and energy use (Koengkan and Fuinhas, 2021). The empirical evidence from literature is mixed and the issue worth being investigated for the New EU Member States to implement the most suitable policies to overcome these challenges.

Income inequality refers to unfair distribution of income across people, social categories and regions. It was felt as an acute issue since 1980 in the US and many developing countries because of social and economic problems that are generated (less demand, more poverty, higher unemployment, slowdown of economic growth, violence, crime) (Piketty and Saez, 2014). These issues generated by income inequality are specific also to New EU Member States where pollution is another challenge. There are many studies investigating the pollution in these states using Environmental Kuznets Curve (EKC) (Simionescu et al., 2021; Lazar et al., 2019), but none of them consider income inequality among explanatory variables. To cover this gap, this paper starts from EKC equation based on a polynomial function of order two that includes a measure of income inequality. Moreover, previous studies that employed income inequality resumed mostly to Gini index, but this paper introduces also gender pay gap in the equation as a measure of this type of economic inequality.

If income inequality is an old well-known issue, green finance remains a new concept that has been recently correlated with pollution. According to Muganyi et al. (2021), green finance is related to a strategy designed to ensure quality of the environment. Usually, the government expenditure is not enough to improve the quality of environment and many companies has financed environmental projects. However, this paper checks also if environmental investment of government plays a role in the fight against pollution.

Green finance is related to financial products, services, and investments supporting environmentally sustainable projects and initiatives. The main benefits of green finance are the promotion of the transition to a low-carbon and achievement of a climate-resilient economy. A detailed list of benefits of green finance could include:

- environmental protection: Green finance channels are directed to projects with beneficial impact on the environment, like sustainable agriculture, renewable energy, energy efficiency, and clean transportation, which contribute to mitigating climate change, reducing pollution, and preserving natural resources (Wang and Zhi, 2016).
- economic development: Green finance enhances investments in green technologies, which support innovation and sustainable business models that generate new jobs and economic growth (Yin and Xu, 2022).
- risk management: more investment in environmentally sustainable projects might reduce financial risks associated with climate change (Tian and Pan, 2022).
- stakeholder engagement: the adoption of green finance proves a commitment to sustainability and responsible business practices, which may attract socially conscious investors, and engage stakeholders who prioritize environmental considerations (Liu and Abu Hatab, 2022).
- regulatory compliance: by aligning financial activities with sustainability goals as governments require, companies can avoid penalties and reputational damage associated with non-compliance (Falcone, 2020).
- access to capital: green finance ensures the access to capital for projects that may have difficulty securing traditional financing. It provides green bonds or loans for investors that support environmental initiatives (Zhu et al., 2023).
- environmentally friendly infrastructure. Green finance supports the construction of infrastructure that improves long-run resource management (Mngumi et al., 2022).
- comparative advantage: By supporting low-carbon green development, green finance offers a comprative advantage under the pressure of environmental regulations (Soundarrajan and Vivek, 2016).

Green finance encompasses various financial instruments that support environmentally sustainable projects. These instruments include green bonds, which raise capital through bonds on public markets, with the proceeds dedicated to funding climate and environmentally friendly initiatives (Ozili, 2022). Sustainability-linked loans are another instrument, where the interest rate of the loan is tied to the environmental, social, and governance (ESG) performance of the borrower (Bhatnagar and Sharma, 2022). Green loans involve direct capital transfer between the lender and borrower without involving a public market. In addition, green insurance provides coverage for economic compensation liabilities arising from environmental pollution accidents (Ozili, 2022). The implementation of mandatory insurance can enhance returns and reduce risks associated with green finance.

There are many fields in which projects based on green finance instruments could be implemented: energy efficiency, solar and wind energy, waste-water treatment, soil remediation, waste, sustainable transport, re-forestation (Sachs et al., 2019).

Green growth requires long-term investment, but given the financial constraints on public finances, substantial private investment is necessary to facilitate the transition towards a green economy. Governments play a crucial role in strengthening domestic policy frameworks to encourage and mobilize private finance and investment to support green growth. Suitable policies should be designed to overcome obstacles to green investment and create an environment that attracts both domestic and international investment (Taghizadeh-Hesary and Yoshino, 2019).

Green finance can contribute to pollution mitigation in more ways. First, green finance supports the development of renewable energy sources, which might reduce the fossil fuels consumption that is associated with pollution in their extraction and combustion. Renewable energy projects could significantly reduce pollution since renewable energy sources do not produce pollution or the quantity of greenhouse gas emissions is very low compared to fossil fuels. Second, green finance might ensure the investment in energy-efficient technologies that supposes lower energy use and, consequently, lower pollution. Third, green finance can support sustainable agriculture and forestry, which imply less pollution from chemical fertilizers and pesticides and decrease of CO_2 due to reforestation. Fourth, green finance might support clean transportation through electric vehicles that are environmentally friendly. Fifth, green finance might support the development of green infrastructure projects (bike lanes, public transportation systems etc.), which reduce the dependence on personal vehicles leading to less pollution. Sixth, green finance might support circular economy initiatives based on efficient use of resource and waste minimization (waste management, recycling, sustainable production practices) that reduce resource extraction and waste. Investing in green infrastructure offers many benefits, including environmental sustainability by promoting the use of renewable energy sources and less pollution, more energy efficiency by implementing new technologies, better air and water quality, conservation of natural resource, economic growth and job creation, resilience to climate change, improvement in health and well-being, and more social equity (Vandermeulen et al., 2011).

Green finance can contribute to pollution reduction by directing investment towards sustainable and environmentally friendly projects and by improving access to clean technologies and services, which may address income inequality by creating a more equitable distribution of environmental benefits. By promoting green finance, governments can stimulate job growth, including jobs in those sectors that contribute to pollution reduction (Lan et al., 2023). More jobs might improve the economic prospects for marginalized communities, which reduces income inequality.

Studying the income inequality-pollution nexus using green finance is important for policymakers and researchers to develop strategies for addressing both issues simultaneously. Green finance provides a framework for financing environmentally sustainable projects and initiatives. By studying the income inequality-pollution nexus within this context, we can identify opportunities to promote equitable access to green finance and ensure that the benefits of sustainable development are shared by all segments of society. This paper contributes to literature by analysing the impact of income inequality on pollution considering the new concept of green finance that supposes, among other elements, the promotion of renewable energy consumption to tackle pollution and climate changes. This type of research is necessary since income inequality and pollution are old issues for which effective solutions are required by considering modern approaches like green initiatives. The novelty of the study is given by more strong points: the empirical results for New EU member states that were less analysed in previous studies, the use of gender pay gap as a new measure of income inequality, the policy recommendations for the New EU countries. Income inequality proved to reduce the GHG emissions in this region, but FDI enhanced pollution. The long-run economic development allowed the implementation of green technology with beneficial effects on environment. The renewable energy projects remain the strongest tool in the battle against pollution. The policy recommendations should encourage more the renewable energy consumption, but social policies to reduce income inequality should be implemented in a manner that is environmentally friendly.

After this short introduction, the paper provides details about research directions in literature based on few hypotheses. The methods refer to FMOLS estimator and method of moments quantile regression to ensure robustness check. The impact of income inequality measured by Gini index and gender pay gap on GHG emissions is assessed in the period 2002–2021 based on the data availability. The results are deeply discussed and in the end some conclusions and policy recommendations are proposed.

Literature review

COP 27 (the 27th Conference of the Parties to the United Nations Framework Convention on Climate Change) addresses climate change and its impacts. COP 27 is not directly related to pollution, but it is closely related to climate change that is interconnected with pollution. By promoting sustainable practices through policies and strategies proposed by COP 27, climate change is tackled and greenhouse gas emissions are reduced. COP 27 focused on various aspects that are related to pollution mitigation: transition to clean energy, stronger CO_2 emission reduction targets, better international cooperation (Arruda Filho et al., 2022).

Income inequality and pollution represent two of the main actual challenges for which government attempt to find solutions. However, a first debate in the literature is related to the most suitable indicators that should be used to measure pollution and income inequality, respectively. Pollution is usually measured using greenhouse gases emissions (GHG emissions) or carbon dioxide (CO_2), the latter being a part of GHG emissions. Other proxies for pollution are nitrogen dioxide (NO_2) and sulfur dioxide (SO_2). Income inequality is usually measured by Gini index or Gini coefficient, but only few recent studies focused on gender pay gap for which the availability of the data is limited (Koengkan and Fuinhas, 2021).

There are more measures used to proxy income inequality, but in this study we used only Gini index and gender pay gap to have a traditional proxy and a new one. A presentation of the most common indicators used to measure income inequality is made below based on De Maio (2007):

- The Gini coefficient measures the extent to which the income distribution deviates from perfect equality;
- The Theil index considers both within-group and between-group inequality;
- The Palma ratio compares the income share of the top 10% of the population to the income share of the bottom 40%. It takes into account the relative income differences between the richest and poorest people;
- Income quintile ratios divide the population into five equal groups based on income and compares the income of the highest quintile to the income of the lowest quintile;
- The Atkinson index measures inequality by considering individuals' aversion to inequality;
- The relative poverty rate measures the proportion of individuals or households with income below a certain threshold.

The Gini index was 30.1% in 2021 in the EU, with significant disparities between countries: Bulgaria, Lithuania and Latvia registered a Gini coefficient higher than 35%, being followed by a group of eight states with Gini index higher than the average: Romania, Italy, Germany, Greece, Estonia, Malta, Portugal, Spain. For the rest of the EU countries, Gini index is <25%, the lowest values of the indicator being registered by Slovenia, Slovakia, Czech Republic and Belgium. The EU has experienced a permanent decline in income inequality in the last decade and it has less income inequality than US. However, there are higher disparities between EU countries in terms of gender pay gap. Females earned in average 12.7% less many than men in the EU in 2021. The lowest value was recorded by Luxembourg (−0.2%) and the maximum one by Estonia (20.5%).

Uzar and Eyuboglu (2019) revealed no consensus in literature regarding the connection between pollution and income inequality. According to empirical results in literature, three types of conclusions were drawn for groups of countries and for a single country: positive impact of income inequality on pollution, negative effect of income inequality on pollution and no connection between the two variables.

First, income inequality enhances pollution as in Torras and Boyce (1998) who evaluated the impact of Gini ratios on pollution measured using various variables (SO_2, heavy particles, smoke, fecal coliform in water, dissolved oxygen in water) when the observations were recorded from 58 countries. In the case of countries in the upper-income range, the authors stated that more income inequality is associated to environmental degradation. In 180 states, the components of Environmental Performance Index were positively correlated with Gini index in the period 1995–2014. For 26 developed countries in the period 2000–2010, Knight et al. (2017) showed that higher income inequality enhanced pollution and political inequalities. In BRICS countries, Zhu et al. (2018) revealed that Gini index is positively correlated with CO_2 emissions in states with high and medium emissions in the period 1994–2013. Ravallion et al. (2000) indicated direct connection between the two indicators in a larger group of countries included both developed and developing one in the period 1975–1992.

Other studies that validate this hypothesis refer to a single country. Few studies were conducted for the US with similar results. For example, for the US, Baek, Gweisah (2013) showed that there is a long-run and short-run connection between Gini index and CO_2 emissions in the period 1967–2008. A similar conclusion for the US was formulated by Muller et al. (2018) regarding the period 2011–2014. For household data, Sager (2019) showed that income inequality enhances the CO_2 emissions during 1960–2009. Other papers focused on China. Household data from China in 2005 indicated that redistributive policies have the capacity to reduce income inequality (income deciles) which will generate less CO_2 emissions in urban environment (Golley and Meng, 2012). At regional level in China, Zhang and Zhao (2014) showed that less income inequality reduced CO_2 emissions in the period 1995–2010. A similar study for 23 regions in China indicated the same type of relationship in the period 1995–2012. For 85 Japanese cities, Kasuga and Takaya (2017) showed that a higher Gini coefficient determined the growth of NOx and SO_2 in the period 1990–2012. For Turkey, Uzar and Eyuboglu (2019) validated the political economic approach and Gini index had a positive impact on CO_2 emissions in the period 1984–2014.

Because of reduce data availability, gender pay gap is rarely used as proxy for income inequality in models discussing the pollution. For example, in the case of all EU states, Koengkan and Fuinhas (2021) suggested that gender pay gap enhanced CO_2 emissions in the period 1991–2016.

Second, income inequality reduces pollution in certain cases. For 88 countries belonging to three continents (Africa, Asia, America), Coondoo and Dinda (2008) showed that less income inequality in America and Europe enhanced pollution in the period 1960–1990. For a sample of low and middle-income states, Grunewald et al. (2017) showed a negative relationship between CO_2 and Gini coefficient in the period 1980–2008. Water pollution reduced in a sample of 120 states during 1960–2001 when the income inequality increased (Gassebner et al., 2011). Heerink et al. (2001) found a negative relationship between Gini coefficient of inequality in income distribution and various measures of pollution (CO_2 emission per capita, SO_2 emissions, suspended particulate matter) in Sub-Saharan Africa and other countries.

Regarding the studies for a single country, SO_2, CO_2 and nitrogen emissions decreased in Sweden at household level when the income inequality diminished in the analysed years (1984, 1988, 1996) as Brannlund and Ghalwash (2008) indicated. Gas emissions and industrial wastewater reduced with the increase in the income inequality in Chinese provinces during 1996–2008 (Simionescu et al., 2021).

Third, there is no relationship between pollution and income inequality in other studies. For example, Gini coefficient had no impact on organic water pollution and SO_2 in 83 developing and transition states in the period 1988–2003 (Clement and Meunie, 2010). The same hypothesis was validated by Policardo (2016) for 47 transition states in the period 1990–2002 using CO_2 as proxy for pollution, and by Barra and Zotti (2018) for 120 states during 2000–2009. No significant relationship between the two variables was also obtained for India and China by Wolde-Rufael and Idowu (2017) and for the US by Jorgenson et al. (2017).

A special case is given by the existence of all these types of results for the same group of countries, but in different periods. For G7 states, Uddin et al. (2020) showed that all the hypotheses are checked: direct correlation (1870–2014), indirect connection (1950–2000) and no relationship between income inequality and CO_2 (1880–1949 and 2000–2014).

Green finance is a recent topic in environmental research. There are only few studies in the literature that assess the impact of green finance on pollution. The role of green finance in reducing environmental degradation is explained by the investment in technology made by the companies (Wang et al., 2021). In the top ten countries with the highest investment in green finance, Meo, Abd Karim (2022) showed that green finance reduces pollution. The same conclusion was drawn by Li et al. (2022) for MENT countries in the period 1990–2020.

Data and methods

The pollution and income inequality nexus is analysed in the context of panel data models for New EU Member States in the period 2002–2021. The New EU Member States are represented by: Bulgaria, Cyprus, Croatia, Czechia, Latvia, Estonia, Lithuania, Hungary, Slovak Republic, Poland, Malta, Romania, and Slovenia. The pollution is measured using as indicator the GHG emissions (in Kilo tonnes CO_2 equivalent) that is provided by the European Environment Agency. The basic model starts from the Environmental Kuznets Curve (EKC) in a simplified form based on a polynomial function of order 2. The other variables used in the models refer to GDP per capita (constant $ 2015), Gini index (World Bank estimate), gender pay gap (%) provided by Eurostat, KOF Globalisation Index. Urban population, renewable energy consumption (% of total final energy consumption), human capital index (HCI) and foreign direct investment (net inflows, % of GDP) are provided by the World Bank.

The European Directive on Renewable Energy, also known as the Renewable Energy Directive (RED), is a legislative framework established by the EU to promote the use of renewable energy sources and increase their share in the overall energy mix. Targets are established for EU member states regarding the percentage of their energy consumption from renewable sources in total energy consumption. The EU countries are required to implement support schemes and own renewable energy action plans to achieved these targets, but also to report the progress in achieving the targets. In this context, RED provides a framework for member states to develop and implement policies that support the growth of renewable energy sources, reduce greenhouse gas emissions, and contribute to mitigating climate change (Skjærseth and Rosendal, 2023).

Let us start from a basic model with all the data series in natural logarithm (ln):

$$GHG_{it} = a_i + b_1 \cdot GDP_{it} + b_2 \cdot GDP_{it}^2 + b_{3j} \cdot X_{ijt} + e_{it}$$

GHG- ln(GHG emissions)

GDP- ln(gross domestic product/cap)

X_j- vector of control variables (GI- ln(Gini index) or GPG- ln(gender pay gap), REC- ln(renewable energy consumption),

Table 1 Descriptive statistics for data series in natural logarithm.

Indicator	Data sources	Mean	Standard deviation	Minimum value	Maximum value
GHG	https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer	4.196	0.519	0.531	5.148
GDP	https://data.worldbank.org/indicator/NY.GDP.PCAP.KD?locations=BJCIST	10.489	1.648	8.808	15.251
GPG		2.543	0.572	−0.105	3.430
URB	https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=RO	14.813	1.138	12.815	16.977
GI	https://data.worldbank.org/indicator/SI.POV.GINI?locations=ZA%26most_recent_value_desc=true	3.443	0.137	3.165	3.720
REC	https://data.worldbank.org/indicator/EG.FEC.RNEW.ZS?locations=DE	2.498	1.062	−2.439	3.751
Globali-sation	https://kof.ethz.ch/en/forecasts-and-indicators/indicators/kof-globalisation-index.html	4.358	0.076	4.110	4.470
HCI	https://datacatalog.worldbank.org/search/dataset/0038030/Human-Capital-Index	1.170	0.084	0.950	1.347
FDI	https://databank.worldbank.org/metadataglossary/world-development-indicators/series/BX.KLT.DINV.WD.GD.ZS	1.721	1.362	−2.631	6.107

Source: author's calculations in Stata 15.

URB- ln(urban population), FDI- ln(Foreign direct investment as net inflows), Globalisation- ln(Globalisation Index), HCI- ln(human capital index))

a_i,b_1,b_2,b_3,b_4,b_{3j} – parameters, where j- index for explanatory variables

e_{it}-errors

i-index for state, t- index for year,

The descriptive statistics in Table 1 suggest higher ranges for indicators like REC, GDP per capita, and FDI compared to the rest of the variables. The highest increase in GHG emissions is registered by Cyprus in 2008, while the minimum value is observed in Latvia in 2002. Estonia reached the maximum value for gender pay gap and this was registered in 2008, while the minimum was observed in Slovenia in 2011. Gender pay gap in natural logarithm ranges from almost 3.165 reached by Slovenia in 2008 to almost 3.72 registered by Bulgaria in 2018.

Under cross-sectional dependence and slope heterogeneity, covariate- augmented Dickey Fuller (CADF) test is used to check for unit root. For non-stationary data series with the same order of integration, Westerlund, Edgerton (2007) test is applied to check for cointegration. If the cointegration hypothesis is checked, the Fully Modified Least Square (FMOLS) estimators are computed. This approach described by Phillips and Hansen (1990) deals with heterogeneous cointegration, while the heterogeneous FMOLS estimator of Pedroni (2001) manages autocorrelation and endogeneity.

Let's consider a cointegrated system in a panel based on N cross-sections (i = 1,2,..,N):

$$y_{it} = \alpha_i + \beta x_{it} + \mu_{it}$$

$$x_{it} = x_{it-1} + e_{it}$$

x_i - vector of (m x 1) dimension with independent values

y_{it} has one unit root and then, x_i and y_i cointegrate for each cross-section

β - cointegrating vector, α_i - country fixed effects

$$\varepsilon_{it} = \Delta x_{it} = x_{it} - x_{it-1}$$

$\varepsilon_{it} = (\mu_{it}, e_{it})$ is stationary, Ω_i- asymptotic covariance matrix associated to vector error ε_{it}

$$\Omega_i = \begin{bmatrix} \Omega_{11i} & \Omega'_{21i} \\ \Omega_{21i} & \Omega_{22i} \end{bmatrix}$$

Ω_{11i} - scalar long run dispersion for residual μ_{it}

Ω_{21i}- vector of (m x 1) size for the long-term covariance between e_{it} and μ_{it}

Ω_{22i}- matrix (m x m) for long run covariance between e_{it} values

Under cross-sectional independence and invariance principle, the Asymptotic Bias of the Panel OLS Estimator corresponding to β parameter is:

$$\hat{\beta}_{NT} = \left[\sum_{i=1}^{N}\sum_{t=1}^{T}\left(x_{it} - \bar{x}_i\right)^2\right]^{-1} \cdot \sum_{i=1}^{N}\sum_{t=1}^{T}\left(x_{it} - \bar{x}_i\right)\left(y_{it} - \bar{y}_i\right)$$

$\bar{x}_i, \bar{y}_i$- individual averages

The Asymptotic Distribution of the Pooled Panel FMOLS Estimator corresponding to β parameter is:

$$\hat{\beta}^*_{NT} - \beta = \left[\sum_{i=1}^{N}\hat{L}_{22i}^{-2}\sum_{t=1}^{T}\left(x_{it} - \bar{x}_i\right)^2\right]^{-1}\sum_{i=1}^{N}\hat{L}_{11i}^{-1}\hat{L}_{22i}^{-1}\left(\sum_{t=1}^{T}\left(x_{it} - \bar{x}_i\right)\mu^*_{it} - T\hat{\gamma}_i\right)$$

$$\mu^*_{it} = \mu_{it} - \frac{\widehat{L_{21i}}}{\widehat{L_{22i}}}\Delta x_{it}$$

$$\hat{\gamma}_i \equiv \widehat{\Gamma_{21i}} + \hat{\Omega}^0_{21i} - \frac{\widehat{L_{21i}}}{\widehat{L_{22i}}}\left(\widehat{\Gamma_{22i}} + \hat{\Omega}^0_{22i}\right)$$

$\hat{L}_i$- lower triangular decomposition of $\hat{\Omega}_i$

Under the same hypotheses, we consider:

$$T\sqrt{N}\left(\hat{\beta}^*_{NT} - \beta\right) \sim N(0, v)$$

v = 2, if $\bar{x}_i = \bar{y}_i = 0$ and v = 6 in rest of the cases, where $N \to \infty$, $T \to \infty$

If the data series are non-normally distributed, an alternative model is employed to check for robustness of the results: method of moments quantile (MMQ) regression models on panel data.

According to correlation matrix, there is a stronger correlation between HCI and Gini index (−0.5854), HCI and FDI (−0.5247), HCI and globalization (0.4165), globalization index and GDP per capita (−0.5727). For MMQ models two specifications are considered:

$$GHG_{it} = f\left(GDP_{it}, GDP_{it}^2, GI_{it}, REC_{it}, URB_{it}, FDI_{it}\right)$$

$$GHG_{it} = f\left(GDP_{it}, GDP_{it}^2, GPG_{it}, REC_{it}, URB_{it}, FDI_{it}\right)$$

The panel quantile regression models present few important advantages like: more accuracy and robustness of results, no requirement of normal distribution of data, capacity to capture distributional heterogeneity and unobserved individual heterogeneity (Chang et al., 2020).

If α_i and α_i' represent the unobserved country effects, the models could be rewritten as:

$$E\left[GHG_{it} \middle| \left(GDP_{it}, GDP_{it}^2, GI_{it}, REC_{it}, URB_{it}, FDI_{it}\right), \alpha_i\right] = \begin{pmatrix} GDP_{it}^T, GDP_{it}^{2T}, REC_{it}^T, \\ GI_{it}^T, URB_{it}^T, FDI_{it}^T \end{pmatrix} \beta + \alpha_i$$

$$Q_{GHG_{it}}\left[\tau \middle| \left(GDP_{it}, GDP_{it}^2, GI_{it}, REC_{it}, URB_{it}, FDI_{it}\right), \alpha_i\right] = \beta_{1\tau} GDP_{it} + \beta_{2\tau} GDP_{it}^2 + \beta_{3\tau} REC_{it} + \beta_{4\tau} GI_{it} + \beta_{5\tau} URB_{it} + \beta_{6\tau} FDI_{it} + \alpha_i$$

$$E\left[GHG_{it} \middle| \left(GDP_{it}, GDP_{it}^2, GPG_{it}, REC_{it}, URB_{it}, FDI_{it}\right), \alpha_i'\right] = \begin{pmatrix} GDP_{it}^T, GDP_{it}^{2T}, REC_{it}^T, \\ GPG_{it}^T, URB_{it}^T, FDI_{it}^T \end{pmatrix} \beta' + \alpha_i'$$

$$Q_{GHG_{it}}\left[\tau \middle| \left(GDP_{it}, GDP_{it}^2, GPG_{it}, REC_{it}, URB_{it}, FDI_{it}\right), \alpha_i'\right] = \beta_{1\tau}' GDP_{it} + \beta_{2\tau}' GDP_{it}^2 + \beta_{3\tau}' REC_{it} + \beta_{4\tau}' GI_{it} + \beta_{5\tau}' URB_{it} + \beta_{6\tau}' FDI_{it} + \alpha_i'$$

Koenker and Hallock (2001) states that $\hat{\beta}(\tau)$ is computed as the τ^{th} quantile level. In our particular case, τ is the parameter size that receives the values 0.1, 0.25, 0.5, 0.75 and 0.9.

$$\hat{\beta}(\tau) = argmin_{\beta \in R^k}\left[\sum_{i \in \{i: y_i \geq x_i\beta\}} \tau\left|y_i - x_i\beta\right| + \sum_{i \in \{i: y_i < x_i\beta\}} (1-\tau)\left|y_i - x_i\beta\right|\right]$$

The conditional quantile of the GHG for different explanatory variables x_i is:

$$Q_{GHG}\left(\tau | GDP_{it}, GDP_{it}^2, GPG_{it}, REC_{it}, URB_{it}, FDI_{it}\right) = \begin{pmatrix} GDP_{it}, GDP_{it}^2, GPG_{it}, REC_{it}, \\ URB_{it}, FDI_{it} \end{pmatrix} \beta_\tau$$

$$Q_{GHG}\left(\tau | GDP_{it}, GDP_{it}^2, GPG_{it}, REC_{it}, URB_{it}, FDI_{it}\right) = \begin{pmatrix} GDP_{it}, GDP_{it}^2, GPG_{it}, REC_{it}, \\ URB_{it}, FDI_{it} \end{pmatrix} \beta_\tau'$$

Results

The first part of this section presents the results of preliminary tests that are employed before the description of the estimations (tests for cross-sectional dependence, normality, heterogeneity, unit root and cointegration). The second part reports the results of estimations.

From practical point of view, the cross-sectional dependence is expected because of the common political history of the countries in Central and Eastern Europe that implemented the same type of regulations in the post-communism period. The statistical approach based on Pesaran CD and Breusch-Pagan LM tests confirms cross-sectional dependence for all data series at 5% significance level (details in Table 2).

Table 2 The results of cross-sectional dependence tests.

Indicator	Breusch-Pagan LM	Pesaran CD
GHG	16.34*** (<0.01)	7.46*** (<0.01)
GDP	8.89*** (<0.01)	32.74** (<0.01)
GPG	5.84*** (<0.01)	3.03*** (<0.01)
URB	5.94*** (<0.01)	−2.34** (0.019)
GI	3.37*** (<0.01)	3.40*** (<0.01)
REC	26.11*** (<0.01)	32.05*** (<0.01)
Globalisation	26.73*** (<0.01)	24.38*** (<0.01)
HCI	44.28*** (<0.01)	37.15*** (<0.01)
FDI	8.85*** (<0.01)	8.19*** (<0.01)

Source: authors' calculations in Stata 15; statistics of the tests are reported, *p*-values are displayed in brackets; *** shows significance at 1% level, ** indicates significance at 5% level.

The slope heterogeneity test of Pesaran and Yamagata (2008) indicates homogeneity for logarithm of gender pay gap, while the heterogeneity is confirmed for the other variables at 10% significance level (details in Table 3).

Table 3 The results of slope heterogeneity test.

Indicator	$\bar{\Delta}_{adj}$
GHG	1.858* (0.065)
GDP	−2.285** (0.033)
GPG	−0.993 (0.482)
URB	2.45** (0.028)
GI	1.778*** (0.09)
REC	2.018** (0.040)
Globalisation	−1.978* (0.058)
HCI	3.978*** (<0.01)
FDI	3.077*** (<0.01)

Source: author's calculations in Stata 15; *p*-values are displayed in brackets; ***, **, * indicate significance at 1%, 5%, 10% level, respectively.

Since the panel is unbalanced and cross-sectional dependence and slope heterogeneity hypotheses are checked, CADF test is used to detect any presence of unit root. The sensitiveness of this test to the number of lags determines the use of two versions with one lag and two lags. Table 4 indicates that all the data series in level are integrated of order one at 10% significance level, excepting HCI series that is stationary in level at 1% significance level.

Panel quantile regression models are considered for robustness check, but these models require non-normal distribution. In this case, two tests are employed to check for the existence of normal distribution (Shapiro-Wilk test and Shapiro-Francia test). Table 5 indicates that all the data series are non-normal distributed. According to Shapiro-Francia test, HCI data series is non-normal distributed at 5% significance level, while Shapiro-Wilk test suggests the same result, but at 1% significance level. For the rest of the variables, both tests reject the normal distribution hypothesis at 1% significance level.

Table 6 with the results of Westerlund test show that in three out of four versions of the test the cointegration relationship is supported between GHG, the indicator for income inequality and various control variables (GDP, URB, FDI, REC). Therefore, specific panel data models that allow for cointegration could be built.

According to Table 7, an inverted U pattern is observed in the pollution-growth nexus. In the first stage, the economic growth enhances pollution and then it reduces GHG emissions, which suggests investment in green technology while economic development is registered. Income inequality based on Gini index and urban population have no significant impact on GHG emissions. On the other hand, FDI enhances GHG emissions, but only in the M1 model, while renewable energy consumption ensures environmental protection. Foreign companies are less interested in environmental protection, being focused more on profit maximization. As expected, renewable energy consumption proved its capacity to reduce pollution.

Robustness check

Robustness test- additional control variables. For robustness based on other control variables, M3, M4 and M5 models were run, which are not based on GDP, but include HCI or globalization index. Table 8 indicates a negative and significant impact of Gini index on GHG emissions in the analysed sample, while gender pay gap and urban population have no significant influence. FDI enhances pollution as in M1 model, while renewable energy use reduces it.

Model M3 states that income inequality based on Gini index reduces pollution, which is a beneficial impact on environment.

Table 4 Pesaran's CADF test.

Indicator	Data in level		Data in the first difference	
	One lag	Two lags	One lag	Two lags
GHG	−3.748*** (<0.01)	2.942 (0.998)	−7.861*** (<0.01)	−6.996*** (<0.01)
GDP	1.983 (0.976)	4.063 (0.999)	−6.445*** (<0.01)	−7.045*** (<0.01)
GPG	2.732 (0.997)	8.621 (0.999)	−1.385* (0.083)	−2.434*** (0.008)
URB	3.167 (0.999)	6.310 (0.999)	−2.354*** (0.009)	−5.445*** (<0.01)
GI	0.029 (0.512)	6.462 (0.999)	−4.556*** (<0.01)	−5.044*** (<0.01)
REC	5.239 (0.999)	−1.765** (0.039)	−4.667*** (<0.01)	−4.045*** (<0.01)
Globalisation	−7.063*** (<0.01)	2.509 (0.994)	−9.042*** (<0.01)	−6.036*** (<0.01)
HCI	−14.085*** (<0.01)	−3.847*** (<0.01)	−15.973*** (<0.01)	−5.396*** (<0.01)
FDI	1.711 (0.956)	9.443 (0.999)	−8.396*** (<0.01)	−5.077*** (<0.01)

Source: author's calculations in Stata 15; *** indicates *p*-value < 0.01, while 88 is used for *p*-value < 0.05.

Table 5 Tests to check for normal distribution in data.

Indicator	Shapiro-Wilk stat.	*p*-value	Shapiro-Francia stat.	*p*-value
GHG	6.946***	<0.01	6.549***	0.00001
GDP	9.008***	<0.01	8.282***	0.00001
GPG	5.400***	<0.01	5.075***	0.00001
URB	4.641***	<0.01	4.144***	0.00002
GI	4.037***	0.00003	3.607***	0.00015
REC	8.608***	<0.01	7.940***	0.00001
Globalisation	6.487***	<0.01	5.987***	0.00001
HCI	2.545***	0.00546	2.207**	0.01366
FDI	6.324***	<0.01	5.919***	0.00001

Source: author's computations in Stata 15; *** indicates *p*-value < 0.01 and ** shows *p*-value < 0.05.

Table 6 The Westerlund test to check for cointegration.

Statistics	GHG, GDP, GI, URB, FDI, REC		GHG, GDP, GPG, URB, FDI, REC	
	Stat.	*p*-value	Stat.	*p*-value
Gt	−2.0438**	0.0205	−1.9209**	0.0274
Ga	−1.1046	0.1347	0.7827	0.2169
Pt	−1.3735*	0.0848	1.7132**	0.0433
Pa	−5.055***	<0.01	−6.778***	<0.01

Source: author's computations in Stata 15; *** indicates *p*-value < 0.01, ** shows *p*-value < 0.05 and * is employed for *p*-value < 0.1.

Table 7 Panel data models to explain GHG (FMOLS estimators).

Model	M1		M2	
Variable	Coefficient	p-value	Coefficient	p-value
GDP	3.223***	<0.01	4.835***	<0.01
GDP^2	−0.026***	<0.01	−0.219***	<0.01
GI	0.011	0.990	-	-
GPG	-	-	0.251***	<0.01
URB	0.041	0.955	−0.255	0.872
FDI	0.039***	<0.01	−0.035	0.135
REC	−0.403***	<0.01	−0.754***	<0.01

Source: own calculations in Stata; *** indicates *p*-value < 0.01.

On the other hand, income inequality determines social tensions that should be dealt in a friendly way for environment. An inverted U pattern models the relationship between human capital index and GHG emissions, which is consistent with the previous findings that show the role of long-run economic development in ensuring environmental protection. More educated human capital has the capacity to protect better the environment and to address pollution issue with harmful effects on health and well-being.

Robustness test- alternative model. For robustness in terms of alternative method, MMQ regression models on panel data were considered. The same inverted U pattern is confirmed in the MMQ regressions. According to Table 9, Gini index has a negative and significant impact on GHG emissions only for inferior quantiles (10th, 25th and 50th). Urban population reduces pollution for all quantiles excepting the 10th. REC remains the most important solution in the fight against pollution and climate changes.

Table 10 indicates that gender pay gap has a negative impact on pollution only for superior quantiles (50th, 75th, 90th). Urban population and renewable energy consumption have beneficial effects on environment, while FDI enhances the GHG emissions at all quantiles excepting the 10th.

All in all, the pollution-economic growth nexus is described using an inverted U pattern in the CEEs countries that were analysed in the period 2002–2021. Income inequality acts like a factor that reduces pollution in most of the cases, but renewable energy consumption remains the most important solution for dealing with climate changes.

Robustness test- sub period 2006–2021 and additional control variable. Another variable that is considered in this study is environmental protection investments of general government (mil. euro, comparable prices) provided by Eurostat for the period 2006–2021. Given the availability of the data, the analysis is conducted for the period 2006–2021.

In the period 2006–2021, there is strong correlation between urban and investments, HCI and Gini, globalization and Gini, FDI and REC, FDI and HCI, GDP per capita and globalization, expenditure and REC, HCI and globalization, expenditure and Globalization. The data series for environmental protection investments of general government in natural logarithm is stationary in the first difference. According to Table 11, the inverted-U pattern is confirmed for the period 2006–2021, while Gini index reduced GHG emissions and FDI enhanced it. Environmental protection investments of general government had a negative impact on GHG emissions for all quantiles

Table 8 Alternative panel data models to explain GHG (FMOLS estimators).

Model	M3		M4		M5	
Variable	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
HCI	-	-	−1.599	0.103	21.036***	0.004
HCI^2	-	-	-	-	−8.837***	0.004
Globalization	0.193	0.992	-	-	-	-
GI	−2.294***	<0.01	-	-	-	-
GPG	-	-	−0.080	0.213	−0.099	0.119
FDI	0.019**	0.024	-	-	-	-
URB	0.803	0.486	−0.006	0.991	−0.064	0.903
REC	−0.450***	<0.01	−0.834***	<0.01	−0.909***	<0.01

Source: own calculations in Stata; *** indicates *p*-value < 0.01, ** indicates *p*-value < 0.05.

Table 9 MMQ regression models to explain GHG based on Gini index.

Variable	Quantile levels (coefficients and *p*-values in brackets)				
	10th	25th	50th	75th	90th
GDP	1.449*** (<0.01)	1.494*** (<0.01)	1.633*** (<0.01)	1.764*** (<0.01)	1.803*** (<0.01)
GDP^2	−0.059*** (<0.01)	−0.061*** (<0.01)	−0.067*** (<0.01)	−0.072*** (<0.01)	−0.074*** (<0.01)
GI	−0.708*** (<0.01)	−0.646*** (<0.01)	−0.461** (0.037)	−0.284 (0.235)	−0.232 (0.360)
URB	−0.034 (0.282)	−0.050* (0.095)	−0.098*** (<0.01)	−0.144*** (<0.01)	−0.158*** (<0.01)
FDI	0.056* (0.074)	0.056* (0.053)	0.058** (0.026)	0.059** (0.039)	0.059* (0.050)
REC	−0.149*** (<0.01)	−0.148*** (<0.01)	−0.145*** (<0.01)	−0.143*** (<0.01)	−0.142*** (<0.01)
Constant	−1.414*** (0.471)	−1.562 (0.392)	−2.010 (0.215)	−2.437 (0.17)	−2.562 (0.173)

Source: own calculations in Stata; *** indicates *p*-value < 0.01, ** indicates *p*-value < 0.05, * indicates *p*-value < 0.1

Table 10 MMQ regression models to explain GHG based on gender pay gap.

Variable	Quantile levels (coefficients and *p*-values in brackets)				
	10th	25th	50th	75th	90th
GDP	1.714*** (<0.01)	1.705*** (<0.01)	1.691*** (<0.01)	1.681*** (<0.01)	1.674*** (<0.01)
GDP^2	−0.068*** (<0.01)	−0.068*** (<0.01)	−0.068*** (<0.01)	−0.068*** (<0.01)	−0.069*** (<0.01)
GPG	−0.045 (0.576)	−0.077 (0.257)	−0.130** (0.019)	−0.167*** (<0.01)	−0.194*** (<0.01)
URB	−0.073* (0.065)	−0.096*** (<0.01)	−0.133*** (<0.01)	−0.159*** (<0.01)	−0.177*** (<0.01)
FDI	0.056 (0.13)	0.061** (0.048)	0.071*** (<0.01)	0.077***(<0.01)	0.082*** (<0.01)
REC	−0.181*** (<0.01)	−0.162*** (<0.01)	−0.130*** (<0.01)	−0.108*** (<0.01)	−0.092** (0.022)
Constant	−4.929397 (0.014)	−4.282 (0.011)	−3.221** (0.018)	−2.467* (<0.01)	−1.941 (0.176)

Source: own calculations in Stata; *** indicates *p*-value < 0.01, ** indicates *p*-value < 0.05, * indicates *p*-value < 0.1.

excepting 10th quantile, which suggests that these investments has no immediate effect on pollution, but there is a long-run connection between the two indicators.

According to Table 12, gender pay gap and environmental protection investments of general government reduced pollution only for superior quantiles (from 50th quantile), which indicates that these indicators improve the quality of environment only in the long-run.

The conclusion based on these results shows that more environmental protection investments of general government are necessary to reduce GHG emissions. Despite the negative social effect, the income inequality plays an important role in reducing pollution.

Discussion

Income inequality-pollution nexus makes the subject of few papers for developed countries where income inequality has been identified as a factor that enhances pollution (Uddin et al., 2020). First, the main reason is related to growth of demand for goods and services that generates more GHG emissions. Second, economic inequality limits the access to social services. Third, income inequality may support the policies that allow the use of polluting technologies. Fourth, income inequality might generate conflict related to resources with direct impact on the quality on environment. The results are in line with previous studies made for developing countries, like more low and middle-income states (Grunewald et al., 2017). On the other hand, our results are contrary to those obtained for certain developed countries in recent studies since Gini index reduces pollution in some estimations in the New EU Member States. Using a microeconomic approach, Sager (2019) indicated that income inequality supports the CO_2 emissions in the US in the period 1960–2009. However, the results might be sensitive to the period that is analysed. For example, Uddin et al. (2020) showed different patterns in the income inequality-CO_2 nexus for G7 countries in the period 1870–2014. In the period 1870–1880, income inequality enhanced pollution in these countries, the period 1950–2000 revealed a negative influence of income inequality on pollution, while the periods 1880–1949 and 2000–2014 are characterized by no significant impact of Gini coefficient on CO_2.

Table 11 MMQ regression models to explain GHG based on Gini index and environmental protection investments of general government.

Variable	Quantile levels (coefficients and *p*-values in brackets)				
	10th	25th	50th	75th	90th
GDP	2.058*** (<0.01)	2.011*** (<0.01)	1.896*** (<0.01)	1.772*** (<0.01)	1.741*** (<0.01)
GDP^2	−0.088*** (<0.01)	−0.086*** (<0.01)	−0.080*** (<0.01)	−0.075*** (<0.01)	−0.073*** (<0.01)
investments	−0.0571 (0.125)	−0.063* (0.064)	−0.076** (0.011)	−0.092***(<0.01)	−0.095*** (0.008)
GI	−1.228*** (<0.01)	−1.206***(<0.01)	−1.154*** (<0.01)	−1.097***(<0.01)	−1.083***(<0.01)
FDI	0.150*** (<0.01)	0.142*** (<0.01)	0.122** (0.026)	0.100***(<0.01)	0.095*** (0.001)
Constant	−3.612*** (0.275)	−3.268 (0.278)	−2.447 (0.359)	−1.549 (0.607)	−1.329 (0.677)

Source: own calculations in Stata; *** indicates *p*-value < 0.01, ** indicates *p*-value < 0.05, * indicates *p*-value < 0.1

Table 12 MMQ regression models to explain GHG based on gender pay gap and environmental protection investments of general government.

Variable	Quantile levels (coefficients and *p*-values in brackets)				
	10th	25th	50th	75th	90th
GDP	2.342*** (<0.01)	2.202*** (<0.01)	1.942*** (<0.01)	1.792*** (<0.01)	1.664*** (<0.01)
GDP^2	−0.095*** (<0.01)	−0.089*** (<0.01)	−0.097*** (<0.01)	−0.073*** (<0.01)	−0.068*** (<0.01)
investments	−0.056 (0.311)	−0.074 (0.110)	−0.106***(0.002)	−0.125*** (<0.01)	−0.141*** (<0.01)
GPG	0.076 (0.596)	−0.003 (0.976)	−0.151* (0.092)	−0.236***(0.005)	−0.309***(0.001)
FDI	0.149*** (0.001)	0.133*** (<0.01)	0.105*** (<0.01)	0.088***(0.001)	0.074** (0.012)
Constant	−10.315*** (0.001)	−8.954*** (<0.01)	−6.437*** (<0.01)	−4.986***(0.004)	−3.751* (0.053)

Source: own calculations in Stata; *** indicates *p*-value < 0.01, ** indicates *p*-value < 0.05, * indicates *p*-value < 0.1

Moreover, income inequality was measured in this study using gender pay gap which seems to reduce pollution. Koengkan and Fuinhas (2021) showed that gender pay gap contributes to the growth of CO_2 emissions in EU countries in the period 1991–2016 using Quantile via Moments and fixed-effect models. In poorer countries, two types of explanations could be brought. First, rich people could afford expensive goods and services based on less-polluting technologies. Second, poor people will reduce the consumption which will determine the adjustment of supply to a lower demand.

The inverted U pattern revealed in this study is in line with previous studies made for New EU Member States. For example, Lazar et al., (2019) indicated an inverted U shape for Hungary and Czechia in the period 1996–2015. The inversely U pattern was shown by Simionescu (2021) for Poland. The European environmental regulations were implemented in the New EU Member States to deal with climate changes and all these countries made progress in this direction and start to implement green technologies to support green growth.

The capacity of renewable energy consumption to reduce pollution was proved in many other papers for New EU Member States (Simionescu (2021) for this sample of countries in the period 1990–2019; Lazar et al. (2019) for the CEE countries in the period 1996–2015). The penetration of renewable energy in the EU states with beneficial effects on environment is related to the goal to achieve a sustainable energy system that reduces GHG emissions and improve the air quality. Moreover, new employment opportunities are created and green technologies are supported. All the EU countries succeed in exceeding the targets established for the consumption on renewable energy and the effects are clear in terms of pollution reduction.

In most of the models that were developed in this paper, FDI enhances pollution in the New EU Member States. The result is in line with many other studies and it is explained by the fact that foreign investors are more interested in maximizing their profit rather than use green technology to protect the environment. According to Zugravu-Soilita (2017), this hypothesis is checked for states with lax regulations in the environmental field and with average capital endowments, but also in states with more capital. In this context, Mert et al. (2019) recommend more environmental regulations on FDI inflows in these countries.

Depending on the type of model, urban population has no impact or negative impact on pollution. The results are contrary to other studies (Rodríguez et al., 2016) that show more pollution in more European populated cities. Our result might be explained by the fact that population concentrated in the cities are much more careful to respect the environmental regulations.

The environmental protection investments of general government reduced pollution only in the long-run which is in line with the results of Meo, Abd Karim (2022) for the ten states with the highest investment in green finance and with the findings of Li et al. (2022) for MENT countries.

Conclusion and policy recommendations

COP 27 promotes policy stability to design the better strategies to reduce pollution and manage climate changes. Most of the previous studies are based on EKC that include various control variables to assess their impact on pollution. However, few of these papers have taken into account the tensions generated by income inequality that might have unbeneficial effects on environment. From this point of view, this is the first study that evaluates the impact of income inequality in terms of Gini index and gender pay gap on GHG emissions for New EU Member States. The results are satisfactory from one point of view, since higher income inequality reduces pollution, but the overall policy framework should take into account the reduction of pollution, but also the decrease in income inequality.

The impact of other control variables on GHG emissions has been evaluated. Two major conclusions could be drawn here. First, more environmental regulations for FDI inflows should be applied, since this type of investment proved to be harmful for environment. Second, renewable energy consumption has successfully gained the battle with pollution, but the efforts should be continued to achieve the European goals: European Green Deal's zero net pollution by 2050 and the achievement of 2030 EU air quality standards. The improvement in the legislative is required to support local authorities in monitoring and implementing air quality plans. On the other hand, more use of renewable energy will support green growth, will reduce poverty and will create job opportunities that might diminish the income inequality. Green finance reduces pollution only in the long-run which suggests that investment in environmental protection is necessary also in the future.

The results based on pollution and income inequality nexus in the context of green finance imply more practical policy recommendations. First, the implementation of better carbon pricing mechanisms is necessary. Carbon pricing, through taxes or emissions trading systems, can effectively reduce pollution and can determine revenue for environmental initiatives. However, it should be designed to consider the impact on low-income households to prevent the increase in inequality. Moreover, the revenue that results can be reinvested in green projects and social welfare programs. Second, governments should provide incentives for the adoption of clean technologies and sustainable practices to enhance renewable energy consumption, energy-efficient technologies, and green infrastructure (financial incentives, tax breaks, grants, and research funding). The support of green sectors can create new job and reduce pollution. Third, governments should implement better emission standards, pollution control measures, and waste management policies. Fourth, governments should support more investment in education and training programs that promote green skills, which can bridge income inequality gaps and prepare the workforce for a green economy. Fifth, the national policies should encourage the development of green financial products, such as green bonds and sustainability-linked loans. Sixth, policymaking processes should involve different stakeholders, including representatives of regions affected by high levels of pollution and representatives of low-income households. Governments should encourage public consultations, citizen forums, and partnerships with civil society organizations to ensure inclusive policies that address local needs and that are aligned with sustainable development goals.

Besides the valuable findings of this paper, it is still subject to few limitations. For example, a rather short period is analysed because of the data availability, which does not allow us to make a separate analysis for each country, but a panel data analysis. The models are based only on few control variables, since the main aim was to check how income inequality impacts pollution. Moreover, the research limits to the group of the New EU Member States, but a comparative analysis with the Old EU Member States is welcome. Therefore, a future study might include separate models for the Old EU Member States and more control variables in the models (index of economic freedom, globalization index, human capital index) to observe other factors that might influence pollution and might be used as key factors in the strategies to control it.

Data availability

The data included in the analysis are available in the manuscript. Links to data sources are provided in the manuscript.

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References

Arruda Filho MTD, Jacobi PR, Lauda-Rodriguez Z, Milz B (2022) Brazil and its disarranged climate policy towards COP 27. Ambiente Sociedade 25:e00002. https://doi.org/10.1590/1809-4422asoceditorialvu2022l3edeng

Baek J, Gweisah G (2013) Does income inequality harm the environment? Empirical evidence from the United States. Energy Policy 62:1434–1437. https://doi.org/10.1016/j.enpol.2013.07.097

Barra C, Zotti R (2018) Investigating the non-linearity between national income and environmental pollution: international evidence of Kuznets curve. Environ Econ Policy Studies 20:179–210. https://doi.org/10.1007/s10018-017-0189-2

Bhatnagar S, Sharma D (2022) Evolution of green finance and its enablers: a bibliometric analysis. Renew Sustain Energy Rev 162:112405. https://doi.org/10.1016/j.rser.2022.112405

Brännlund R, Ghalwash T (2008) The income–pollution relationship and the role of income distribution: an analysis of Swedish household data. Resour Energy Econ 30(3):369–387. https://doi.org/10.1016/j.reseneeco.2007.11.002

Chang BH, Sharif A, Aman A, Suki NM, Salman A, Khan SAR (2020) The asymmetric effects of oil price on sectoral Islamic stocks: new evidence from quantile-on-quantile regression approach. Resour Policy 65:101571. https://doi.org/10.1016/j.resourpol.2019.101571

Clement M, Meunie A (2010) Is inequality harmful for the environment? An empirical analysis applied to developing and transition countries. Rev Soc Econ 68(4):413–445

Coondoo D, Dinda S (2008) Carbon dioxide emission and income: a temporal analysis of cross-country distributional patterns. Ecol Econ 65(2):375–385. https://doi.org/10.1080/00346760903480590

De Maio FG (2007) Income inequality measures. J Epidemiol Commun Health 61(10):849–852. https://doi.org/10.1787/factbook-2014-table55-en

Falcone PM (2020) Environmental regulation and green investments: the role of green finance. Int J Green Econ 14(2):159–173. https://doi.org/10.1504/ijge.2020.10032078

Gassebner M, Lamla MJ, Sturm JE (2011) Determinants of pollution: what do we really know? Oxf Econ Pap 63(3):568–595. https://doi.org/10.1093/oep/gpq029

Golley J, Meng X (2012) Income inequality and carbon dioxide emissions: the case of Chinese urban households. Energy Econ 34(6):1864–1872. https://doi.org/10.1016/j.eneco.2012.07.025

Grunewald N, Klasen S, Martínez-Zarzoso I, Muris C (2017) The trade-off between income inequality and carbon dioxide emissions. Ecol Econ 142:249–256. https://doi.org/10.1016/j.ecolecon.2017.06.034

Heerink N, Mulatu A, Bulte E (2001) Income inequality and the environment: aggregation bias in environmental Kuznets curves. Ecol Econ 38(3):359–367. https://doi.org/10.1016/s0921-8009(01)00171-9

Jorgenson A, Schor J, Huang X (2017) Income inequality and carbon emissions in the United States: a state-level analysis 1997–2012. Ecol Econ 134:40–48. https://doi.org/10.1016/j.ecolecon.2016.12.016

Kasuga H, Takaya M (2017) Does inequality affect environmental quality? Evidence from major Japanese cities. J Clean Prod 142:3689–3701. https://doi.org/10.1016/j.jclepro.2016.10.099

Knight KW, Schor JB, Jorgenson AK (2017) Wealth inequality and carbon emissions in high-income countries. Soc Curr 4(5):403–412. https://doi.org/10.1016/j.jclepro.2016.10.099

Koenker R, Hallock KF (2001) Quantile regression. J Econ Perspect 15(4):143–156. https://doi.org/10.1257/jep.15.4.143

Koengkan M, Fuinhas JA (2021) Is gender inequality an essential driver in explaining environmental degradation? Some empirical answers from the CO_2 emissions in European Union countries. Environ Impact Assess Rev 90:106619. https://doi.org/10.1016/j.eiar.2021.106619

Lan J, Wei Y, Guo J, Li Q, Liu Z (2023) The effect of green finance on industrial pollution emissions: evidence from China. Resour Policy 80:103156. https://doi.org/10.1016/j.resourpol.2022.103156

Lazăr D, Minea A, Purcel AA (2019) Pollution and economic growth: evidence from Central and Eastern European countries. Energy Econ 81:1121–1131. https://doi.org/10.1016/j.eneco.2019.05.011

Li C, Sampene AK, Agyeman FO, Brenya R, Wiredu J (2022) The role of green finance and energy innovation in neutralizing environmental pollution: empirical evidence from the MINT economies. J Environ Manage 317:115500. https://doi.org/10.1016/j.jenvman.2022.115500

Liu Z, Abu Hatab A (2022) Assessing stakeholder engagement in public spending green finance and sustainable economic recovery in the highest emitting economies. Econ Change Restruct 1–26. https://doi.org/10.1007/s10644-022-09414-3

Meo MS, Abd Karim MZ (2022) The role of green finance in reducing CO_2 emissions: an empirical analysis. Borsa Istanbul Rev 22(1):169–178. https://doi.org/10.1016/j.bir.2021.03.002

Mert M, Bölük G, Çağlar AE (2019) Interrelationships among foreign direct investments renewable energy and CO_2 emissions for different European country groups: a panel ARDL approach. Environ Sci Pollut Res 26:21495–21510. https://doi.org/10.1007/s11356-019-05415-4

Mngumi F, Shaorong S, Shair F, Waqas M (2022) Does green finance mitigate the effects of climate variability: role of renewable energy investment and infrastructure. Environ Sci Pollut Res 29(39):59287–59299. https://doi.org/10.1007/s11356-022-19839-y

Muganyi T, Yan L, Sun HP (2021) Green finance fintech and environmental protection: evidence from China. Environ Sci Ecotechnol 7:100107. https://doi.org/10.1016/j.ese.2021.100107
Muller NZ, Matthews PH, Wiltshire-Gordon V (2018) The distribution of income is worse than you think: Including pollution impacts into measures of income inequality. PLoS ONE 13(3):e0192461. https://doi.org/10.1371/journal.pone.0192461
Ozili PK (2022) Green finance research around the world: a review of literature. Int J Green Econ 16(1):56–75. https://doi.org/10.1504/ijge.2022.125554
Pedroni P (2001) Fully modified OLS for heterogeneous cointegrated panels In Nonstationary panels panel cointegration and dynamic panels. Emerald Group Publishing Limited. https://doi.org/10.1016/s0731-9053(00)15004-2
Pesaran MH, Yamagata T (2008) Testing slope homogeneity in large panels. J Econom 142(1):50–93. https://doi.org/10.1016/j.jeconom.2007.05.010
Phillips PC, Hansen BE (1990) Statistical inference in instrumental variables regression with I (1) processes. Rev Econ Studies 57(1):99–125. https://doi.org/10.2307/2297545
Piketty T, Saez E (2014) Inequality in the long run Science 344(6186): 838–843. https://doi.org/10.1111/j.1467-9396.2010.00887.x
Policardo L (2016) Is democracy good for the environment? Quasi-experimental evidence from regime transitions. Environ Resource Econ 64(2):275–300. https://doi.org/10.1007/s10640-014-9870-0
Ravallion M, Heil M, Jalan J (2000) Carbon emissions and income inequality. Oxf Econ Pap 52(4):651–669. https://doi.org/10.2139/ssrn.4329837
Rodríguez MC, Dupont-Courtade L, Oueslati W (2016) Air pollution and urban structure linkages: evidence from European cities. Renew Sustain Energy Rev 53:1–9. https://doi.org/10.1787/5jrp6w9xlbq6-en
Sachs JD, Woo WT, Yoshino N, Taghizadeh-Hesary F (2019) Importance of green finance for achieving sustainable development goals and energy security. Handbook Green Finance: Energy Security Sustain Dev 10:1–10
Sager L (2019) Estimating the effect of air pollution on road safety using atmospheric temperature inversions. J Environ Econ Manag 98:102250. https://doi.org/10.1016/j.jeem.2019.102250
Simionescu M, Păuna CB, Niculescu MDV (2021) The relationship between economic growth and pollution in some new European union member states: a dynamic panel ARDL approach. Energies 14(9):2363. https://doi.org/10.3390/en14092363
Skjærseth JB, Rosendal K (2023) Implementing the EU renewable energy directive in Norway: from Tailwind to Headwind. Environ Polit 32(2):316–337. https://doi.org/10.1080/09644016.2022.2075153
Soundarrajan P, Vivek N (2016) Green finance for sustainable green economic growth in India. Agric Econ 62(1):35–44. https://doi.org/10.17221/174/2014-agricecon
Taghizadeh-Hesary F, Yoshino N (2019) The way to induce private participation in green finance and investment. Finance Res Lett 31:98–103. https://doi.org/10.1016/j.frl.2019.04.016
Tian Y, Pan X (2022) Green finance policy financial risk and audit quality: evidence from China. Eur Account Rev 1–27. https://doi.org/10.1080/09638180.2022.2109707
Torras M, Boyce JK (1998) Income inequality and pollution: a reassessment of the environmental Kuznets curve. Ecol Econ 25(2):147–160. https://doi.org/10.1016/s0921-8009(97)00177-8
Uddin MM, Mishra V, Smyth R (2020) Income inequality and CO_2 emissions in the G7 1870–2014: evidence from non-parametric modelling. Energy Econ 88:104780. https://doi.org/10.1016/j.eneco.2020.104780
Uzar U, Eyuboglu K (2019) The nexus between income inequality and CO_2 emissions in Turkey. J Clean Prod 227:149–157. https://doi.org/10.1016/j.jclepro.2019.04.169
Vandermeulen V, Verspecht A, Vermeire B, Van Huylenbroeck G, Gellynck X (2011) The use of economic valuation to create public support for green infrastructure investments in urban areas. Landsc Urban Plan 103(2):198–206. https://doi.org/10.1016/j.landurbplan.2011.07.010
Wang X, Huang J, Xiang Z, Huang J (2021) Nexus between green finance energy efficiency and carbon emission: Covid-19 implications from BRICS countries. Front Energy Res 737. https://doi.org/10.3389/fenrg.2021.786659
Wang Y, Zhi Q (2016) The role of green finance in environmental protection: Two aspects of market mechanism and policies. Energy Procedia 104:311–316. https://doi.org/10.1016/j.egypro.2016.12.053
Westerlund J, Edgerton DL (2007) A panel bootstrap cointegration test. Econ Lett 97(3):185–190. https://doi.org/10.1016/j.econlet.2007.03.003
Wolde-Rufael Y, Idowu S (2017) Income distribution and CO_2 emission: a comparative analysis for China and India. Renew Sustain Energy Rev 74:1336–1345. https://doi.org/10.1016/j.rser.2016.11.149
Yin X, Xu Z (2022) An empirical analysis of the coupling and coordinative development of China's green finance and economic growth. Resour Policy 75:102476. https://doi.org/10.1016/j.resourpol.2021.102476
Zhang C, Zhao W (2014) Panel estimation for income inequality and CO_2 emissions: a regional analysis in China. Appl Energy 136:382–392. https://doi.org/10.1016/j.apenergy.2014.09.048
Zhu H, Xia H, Guo Y, Peng C (2018) The heterogeneous effects of urbanization and income inequality on CO_2 emissions in BRICS economies: evidence from panel quantile regression. Environ Sci Pollut Res 25:17176–17193. https://doi.org/10.1007/s11356-018-1900-y
Zhu Y, Zhang J, Duan C (2023) How does green finance affect the low-carbon economy? Capital allocation green technology innovation and industry structure perspectives. Econ Res-Ekonomska Istraživanja 36(2):2110138. https://doi.org/10.1080/1331677x.2022.2110138
Zugravu-Soilita N (2017) How does foreign direct investment affect pollution? Toward a better understanding of the direct and conditional effects. Environ Res Econ 66:293–338. https://doi.org/10.1007/s10640-015-9950-9

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Author contributions

All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by MS. The first draft of the manuscript was written by MS and BG commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

This article does not contain any studies with human participants performed by any of the authors.

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