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Using Method of Moments Quantile Regression to Examine the Influences of Fishery Operations and Their Ramifications for Marine Water Contamination

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Abstract

This study aims to investigate the dynamic impact of the fishing industry on marine water contamination in 27 European countries by taking into account the roles of fisheries output, the use of fossil fuels, economic development, and governance between 1990 and 2022. The results, which used a novel technique called the Method of Moments Quantile Regression (MMQR) in addition to factors that are fixed effect, demonstrated that, at most quantiles, there was a significant positive correlation between fishing production and marine water contamination. At the earliest and latest quantiles, fishery production significantly exacerbates marine water contamination, with a smaller impact at the lowest and a larger impact at the highest. Additionally, the data indicate that affluent EU14 countries produce more fish than developing EU13 countries, which has a significant and negative impact on the contamination of marine water. Marine water contamination from the usage of fossil fuels has increased significantly in the EU13 developing countries as compared to the EU14 wealthy countries. Policymakers can reduce marine water contamination in EU14 and EU13 countries by using eco-friendly fishing gear, more sustainable fishing methods, and energy technologies like wave and tidal power.

Introduction

The sea for people. All human needs, including rainfall, drinking water, weather, climate, coastlines, a large portion of our food supply, and even the oxygen people breathe, are ultimately provided and regulated by the sea (Datta et al., 2022). Careful management of this essential global resource will be a hallmark of future sustainable development. Pollution continuously deteriorates coastal waters, and ocean acidification threatens biodiversity and ecological health (Datta et al., 2022). This has a significant effect on fish and other animal habitats as well. The protection of our ocean must always come first. Marine biodiversity is essential to the health of the ecosystem, the population, and the sea. Marine water contamination, ocean acidification, and marine protected areas must be effectively managed, adequately resourced, and governed by law in order to stop unsuitable and unhealthy fishing methods (Kroetz et al., 2022). In other words, because of human-induced increases in atmospheric CO2, more CO2 evaporation released into the ocean. The sea's pH is currently 8.1 on average, which is essential (or alkaline). However, the ocean's ability to operate as a carbon sink is diminished, and marine life is destroyed as the pH level falls and the water gets more acidic as it absorbs more CO2 (Kroetz et al., 2022). For the EU, the seas, oceans, and coastlines are valuable resources. Numerous Europeans rely on the sea for their lives, and although fisheries and tourism are essential areas of the

EU economy, so are trade and commerce. The EU's fish output ranks fourth globally, with 6.4 million tonnes of fish produced annually and more than 350,000 employees. (Kroetz et al., 2022).

One of the main barriers to blue sustainable development is the fact that fisheries and water contamination from fishing operations are the main drivers of the decline in ocean health and water quality. Water quality, which is influenced by a number of factors like as salinity, temperature, dissolved oxygen levels, and acidity/alkalinity levels, is one of the most important aspects of blue sustainability (Heneash et al., 2021). To give each species the ideal habitat, these elements must be properly balanced. Fisheries trawling reduces the removal of nitrogen pollution and deteriorates water quality by disturbing bottom microbes, according to a novel Australian experiment that illuminates a different facet of marine water contamination (Heneash et al., 2021). Similarly, methane, hydrogen sulfide, pesticides, chemical residues, and nutrients (nutrients used in food, such as growth boosters and antibiotics) are released into the ocean as a result of fisheries operations, putting fish and other marine life and species habitats at risk (Heneash et al., 2021).

The oceans absorb around 30% of the carbon dioxide produced by human activities, reducing the impacts of global warming (Turhan et al., 2021). But according to research published today by the Our Fish campaign, the EU fisheries fleet generates up to 7.3 million tonnes of CO2 from burning fuel alone and receives an annual tax break of between €759 million and €1.5 billion through fuel tax subsidies (Turhan et al., 2021). According to Turhan et al. (2021), these tax benefits from the EU jeopardize ocean health, disturb ocean biogeochemistry, fuel climate change, damage marine life, and disturb the ecological balance of the seas.

The fundamental changes in ocean biogeochemistry, such as rising sea surface and bottom temperatures, changes in primary production, decreased pH, and decreased subsurface oxygen levels (also known as hypoxia) in coastal waters, are one of the primary obstacles to marine sustainability (Hamuna et al., 2021). Standing stock biomasses were expected to drastically fall by 2050, with rising sea surface temperatures (SST) being the main contributor. Waste pollution from fisheries and marine activities is linked to the majority of these anthropogenic disturbances, and it is expected to increase in the years to come, further taxing the marine environment and the water quality of marine life (Hamuna et al., 2021).

Coastal waterways are declining as a result of pollution and eutrophication. Significant marine ecosystems are expected to see a 20% increase in coastal eutrophication by 2050 if coordinated action is not taken (Keiser and Shapiro, 2019). One of Europe's most polluted coastal waterways is the Black Sea, which has undergone multiple stages of eutrophication as a result of expanding nutrient intake, huge fisheries, and the presence of dangerous chemicals and phosphate detergents in fish production (Keiser and Shapiro, 2019). It is also mentioned that a major issue in the Mediterranean and Black Sea is the poisoning of fisheries with plastic and mercury. The chemical balance of the water is upset when the ocean absorbs a mixture of chemicals from the sediment and water. Without a doubt, this is one of the biggest threats to the ocean's ability to grow sustainably (Keiser and Shapiro, 2019). Toxins are ingested by fish and other marine life both directly through the water and sediment and indirectly through the flow of food webs.

Concerns over fish populations, water pollution, and habitat degradation are all impacted by fish production (Palomino and Pardue, 2021). According to some academics, to maintain healthy marine environments, the world's fish production needs to be significantly reduced (Prakash and Verma, 2019). The folks whose main source of income is the fish output are directly opposed to this point of view. However, the results show that wild-caught seafood would only be available by 2048 if fish production continues (Prakash and Verma, 2019). The fall was caused by a decline in the fisheries' population, which scientists attributed to overfishing, water contamination, and other environmental issues that were destroying the fisheries' ecosystems (Prakash and Verma, 2019).

(1) How will the growth in fish production affect the marine environment's long-term sustainability in European zones between 1990 and 2022? (2) Does the development of fish production make EU members more vulnerable to the impacts of water contamination? (3) Can the EU achieve its 2050 sustainable development goals and benefit the environment from greater fisheries output? (1) To examine the extent of marine water pollution brought on by the growth of fisheries production throughout EU zones from 1990 to 2022. (2) To compare the impact of fisheries production on marine water pollution in developed and developing countries from 1990 to 2022. (3) To examine how marine water contamination has been affected by the growth in global fisheries output between 1990 and 2022 in developing and developed countries.

A significant error in previous research for EU states is the assumption that disturbance terms are independent and do not exhibit cross-sectional dependency (CD) among the stated variables across the countries. These factors could include spillover, frequent or unexpected shocks, or a combination of all three (Chudik and Pesaran, 2013; Flaten et al, 2010; Breitung and Pesaran, 2005; Andrews, 2005; Cerrato, 2001). Given that a cross-sectional group of EU economies would probably rely on more economic integration in a similar way, CD must be included in the analysis. EU nations are vulnerable to combination shocks that affect economic development and fish consumption, such as resource crises and fish price shocks. According to Andrews (2005), research findings about the relationship between energy, income, and environment would be consistent and balanced if the CD were taken into consideration. The current study will help determine whether the growth-mitigating influence of natural resources will have a comparable impact on the pollution profile of countries that produce fisheries. In order to differentiate between resources with a point source and those with a diffuse source, a prior study employed natural resources as a more aggregate resource variable (Balsalobre-Lorente et al., 2018; Bekun et al., 2019).

On the other hand, this study uses the point-sourced fluctuation of a more specific natural resource (fish output). This research chose to generate fish in economies that produce fish because point-sourced resources frequently have more detrimental growth effects than diffuse ones (Isham et al. 2005; Mehlum et al. 2006). Our sample includes both developed and developing economies because it has been demonstrated that sound regulation densities reduce or even reverse resource dependency growth, mitigating. For stronger conclusions, this paper additionally incorporated governance and other regulatory control variables. Among the EU27 countries that produce fisheries are developed countries like Sweden, Germany, and Italy, as well as developing countries like Estonia, Bulgaria, and Malta. The study spans the years 1990–2022. Because the selected countries have different levels of economic development, our study investigates the feasibility of water contamination caused by income connection in the visibility of A magnificent technique known as MMQR, which is credited to Machado and Silva (2019), was used to analyze fish production with other factors referred to as control variables. This technique involves multiple transverse quantiles of the water contamination conditional distribution.

By incorporating fixed elements, this innovative method empirically provides perspectives or insights into the heterogeneous distribution of this nexus. This allows the method to capture heterogeneous income-pollution relationships at different conditional quantiles of the pollution distribution, which may be missed by conventional mean regressions. The growth idea is therefore extensively studied in fish-producing countries. This article is the first to examine how income affects fish productivity, governance, economic development, and the production of fossil fuels in nations with thriving fisheries. The growth hypothesis of the conditional population distribution should be evaluated at various quantiles for several reasons. First, it was discovered that the conditional quantile estimations are more resistant to the outliers originating from the dependent variable or the outcome variable than the conditional mean estimations. This means that the conditional quantile estimations are more vulnerable to the distorting effects of the outliers (Koenker, 2004). Conversely, the conditional mean estimate may offer a more accurate level of reflection on the distributional effects of fishing on pollution.

In contrast, quantile regression has a more intuitive appeal, particularly in panel regressions, where the distributional influence was split into quantile ranges across the factors independent of the outcome or the outcome variable. This makes the various effects of various cross-sectional groupings easier to understand when categorizing. As a result, conditional quantile estimations provide information that mean-dependent estimates rarely do. The essay's other remaining sections are organized as follows. Section 2 of the related literature provides a brief overview of the growth concept. Section 3 describes the information and methods. Section 4 presents and discusses the results of the estimates, while Section 5 draws conclusions and possible policy implications based on findings that have been empirically supported (Figure 1 in Appendix).

Unlike most previous studies, which focused primarily on fish output, this study examines the consequences of marine resource consumption on water contamination and economic development. This research also looks at how fish production affects water pollution and regional economic development in the EU in order to achieve blue sustainability. Unlike other studies, this one looks at the relationship between fish production and water contamination, and economic growth in order to achieve blue sustainable development. It does this by using both static and panel regressions. The relationship between water contamination, fish production, fossil fuels, governance, and economic development in the EU region between 1990 and 2022 is the main focus of this study. The following are some potential innovations in this article. More importantly, this paper also looks at the different ways that fish production affects water pollution and economic growth in the EU region in order to attain sustainable marine development. For the EU region, we select two different groups: emerging countries and their summation, and industrialized nations. We then employ unit root and cointegration analysis to assess the stationarity of our data, which covers the years 1990–2022, and tends to drift randomly. We also looked into the connections between fish productivity, water contamination, and economic development using the MMQR. (MMQR). Static and panel regression analysis are also used to examine the causes of pollution in the water and ocean. Lastly, we forecast the impact of future fish production on freshwater and marine pollution.

Materials and Methods

The following model was developed as a result of recent investigations by Apergis and Payne (2010), Dogan and Seker (2016a), Ehigiamusoe et al. (2020), and Anwar et al. (2022):

$$WC_{it} = f\ (FO_{it},\ FF_{it},\ ECO_{it},\ GOV_{it})$$

WC and FO represent water contamination and fish output, respectively. Furthermore, WC is the abstraction of water pollution for fishery and aquaculture operations, specified in a million cubic meters, whereas fish output (FO) refers to the total fisheries output, measured in metric tons. For these factors, information was obtained from the World Development Indicator (World Bank, 2022). The gross domestic product (ECO), which is measured in constant US dollars and represents economic growth, is available from the European Commission's database (Eurostat, 2022). The European Commission's database, which measures gasoline use in metric tons of oil equivalent, is a stand-in for fossil fuel consumption (FF) (Eurostat, 2022). Governance (GOV), which may be obtained on the official European data site, is a measure of government efficacy (Europa, 2022). The EU economies from 1990 to 2022 are the subject of the data used in this analysis. Every variable is taken to be true for each individual. The researchers used the annual parameters of the countries under consideration to gather data in order to achieve the study's objective. The data for the years 1990–2022 were collected from a variety of sources, including the European Commission's database (Eurostat), the World Bank's World Development Indicators database (WDI), and the official European data portal (Europa). The sources, data, measurement units, sources, and transformations are listed and shown in Table 1.

Summary Statistic

In this part, we discuss the findings. To start, Table 2 displays the chosen components' statistical characteristics. (i.e., maximum, minimum, mean, and standard deviation). The relative mean values for WC, FO, ECO, FF, and GOV are 1.178, 4.955, 1.274, 3.771, and 1.857. The outstanding standard deviation for each of the study's components is 0.143, 0.833, 0.196, 1.034, and 0.107, respectively. Thanks to the factors' descriptive properties, we may proceed to the unit root test.

Panel Estimation Techniques

The researchers ultimately adopted the Dynamic Ordinary Least Squares, abbreviated as DOLS, the Fixed Effects Ordinary Least Squares, OLS, and the Fully Modified Ordinary Least Squares, abbreviated as FMOLS, for comparison reasons. Also, standard errors such as those of Driscoll and Kraay (2020), with a good level of resilience, cross-section dependency, and common types with autocorrelation to a particular lag, were included in the FEOLS methodology. In line with Pedroni (2004), difficulties in heterogeneity with variations in cross-sectional adjustment and cross-sectional averages to the cointegrating equilibrium level portend as the primary sources of concern in making the cointegrated panel's dynamism estimations. To address these issues, Individual-specific intercepts were

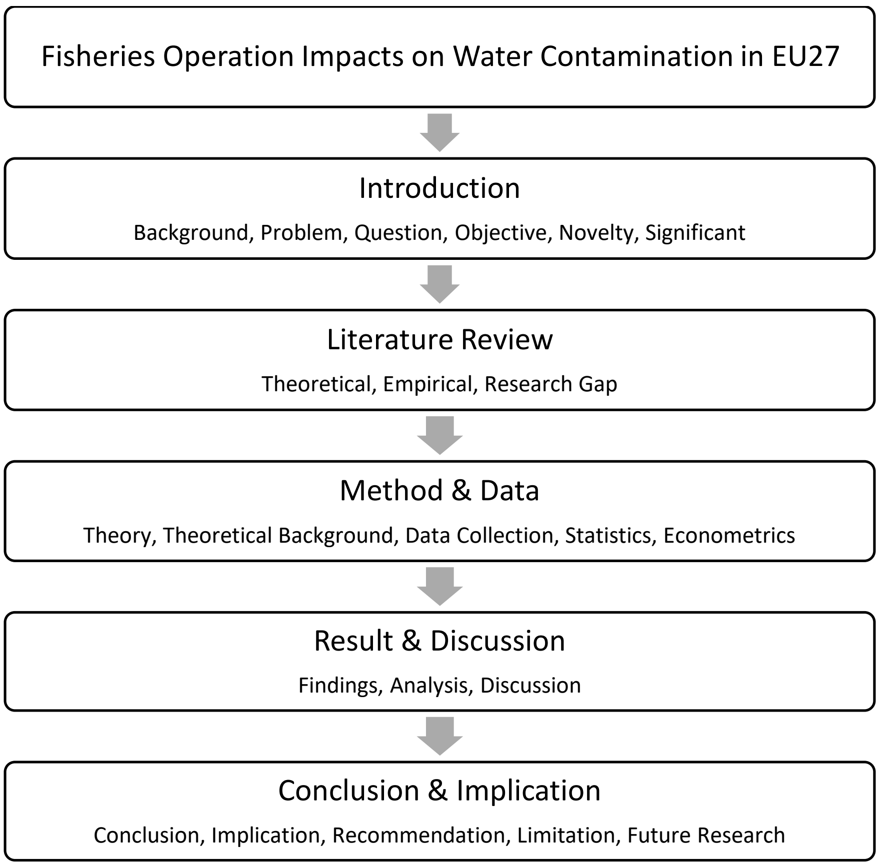

Figure 1. Research method flow chart.

included by Pedroni's FMOLS model, which permits serial relationships in various features of the processing errors within the different panelists. As a result of simulations from Monte Carlo, the estimations of the DOLS were ascertained as being impartial compared to those of the FMOLS with OLS estimators in finite samples. This motivated Kao and Chiang (2001) to make an extension of the estimator DOLS to panel data settings. This estimator (DOLS) additionally suppresses endogenous feedback through lag and lead differences, which creates room for endogeneity. A regression strategy, panel quantile, was adopted to evaluate the influence heterogeneously and distributionally in the range of quantiles; after all, there are a series of shortcomings or limitations of earlier estimating approaches (Sarkodie and Strezov, 2019).

In a seminal study by Koenker and Bassett (1978), the Panel quantile regression technique was introduced. This technique differs from the least-squares variant, which is thought to be more akin to regular regressions, in that it generates conditional mean estimations of those parameters that are thought to be endogenous to specific values of the exogenous ones. The dependent means were accurately estimated using quantile regressions to assess the conditioned median or a number of different response variable quantiles. Outliers in the estimate are less likely to arise in regressions using the quantile scale. Furthermore, it works best when there is little to no connection or nexus between the conditional means of two variables (Binder & Coad, 2011). However, in addition to fixed factors, the researchers used Machado and Silva's (2019) Method of Moments Quantile Regression (MMQR) in this study. Quantile regression does not consider any potential unobserved heterogeneity between the individuals in a panel, even if there is resilience to the outliers. Together with other researchers, Koenker (2004) and Canay (2011) found that the MMQR method allows for effects analysis at individual levels, demonstrating effects on the distribution as a whole rather than just shifting the means. This allows for the identification of the covariance-conditioned heterogeneous effects of determining factors of water pollution.

The Methods of Moments quantile regression estimate methodology is highly relevant when the panel data model is integrated, in conjunction with impact at individual levels, and when the model contains endogenous explanatory factors. The MMQR approach is also easy to understand because it generates the regression quantile non-crossing estimates. In the model of the location-scale variations, such an assessment of the conditioned quantiles *QY(τ|X)* has the following form:

$$Y_{it} = \alpha_i + X_{it}{}^{/}\acute{\beta} + (\delta_i + Z_{it}\,\acute{\gamma})\,U_{it} \text{ (Eq.1)}$$

Where the probability, $P(\delta_i + Z_{it}\,\acute{\gamma}>0)= 1.(\alpha, \acute{\beta}, \delta, \acute{\gamma})$ are parameters to be estimated. (α_i, δ_i),i = 1,…, n, designates the individual i fixed effects, and Z is a k-vector of identified components of X which are differentiable transformations with element l given by:

$$Z_l= Z_l(X), l = 1,\ldots, k \text{ (Eq.2)}$$

For every fixed i, X_{it} is identifiably and independently distributed, and over time, it shows independence (t). In Machado and Silva's (2019) moment criteria, which, among other things, do not necessitate stringent homogeneity, U_{it} is orthogonal to X_{it}, identically as well as independently distributed crosswise individuals (i) with over time (t), which is normalized in fulfilling these constraints. Eq. (1) suggests what follows;

$$Q_Y(\tau|X_{it})= (\alpha_i + \delta_i q(\tau)) + X_{it}\,\acute{\beta} + Z_{it}\,\acute{\gamma} q(\tau) \text{ (Eq.3)}$$

Examining it from the third equation, the natural logarithm of FO (LFO), the economic growth logarithm,

Table 1. Data, units, transformation, and source

Data	Measurement Unit	Transformation	Source
Water contamination	million cubic metres	Natural logarithm Transformation	WDI
Fish output	metric tons	Natural logarithm Transformation	WDI
Fossil Fuel	metric tons of oil equivalent	Natural logarithm Transformation	Eurostat
Economic Growth	constant US dollars	Natural logarithm Transformation	Eurostat
Governance	% of confidence for governance	Natural logarithm Transformation	Europa

Source: Alsaleh & Abdul-Rahim (2024)

Table 2. Results of descriptive-statistics

Variable	Observations	Mean	Std. Dev.	Min	Max
WC	864	1.178	0.143	0.425	1.419
FO	864	4.955	0.833	2.902	6.310
ECO	864	1.274	0.196	0.436	5.713
FF	864	3.771	1.034	0.185	1.612
GOV	864	1.857	0.107	1.205	1.989

Source: Alsaleh & Abdul-Rahim (2024)

which is also natural (LECO), the fossil fuel production natural logarithm (LFF), and the natural logarithm of governance make up the independent variables vectors $X_{it}^{/}$ in this current research. (LGOV). The scalar coefficient, $Q_Y(\tau|X_{it})$, represents the quantile -τ fixed effect for individual $X_{it} - \alpha_i(\tau) \equiv \alpha_{i} + \delta_i q(\tau)$ and displays the distributional quantile of the outcome variable Y_{it} (water contamination natural logarithm), which is dependent on the independent variable location X_{it}. Unlike the typically fixed effects of least-squares, the individual impact does not pinpoint a shift in the intercepts. Their heterogeneous effects are allowed to make variance crosswise the conditioned distribution quantile of the variable, categorized as endogenous Y. These parameters, time-wise, are invariant parameters. The τ-th quantile sample, denoted as *Y. q(τ)*, is calculated by resolving the following optimization problem:

$$\min_q \sum_i \sum_t P_\tau (R_{it} - (\delta_i + Z_{it}\acute{\gamma})q) \text{ (Eq.4)}$$

Where P_τ (A)= $(\tau - 1)$ AI {A $\leq$ 0} + TAI {A>0} denotes the check function.

Results

Cross-sectional Dependence and Unit Root Tests

Before estimating the unknown parameters, a few common preliminary experiments are carried out to ascertain the parameters' time series characteristics. The researchers ascertain whether there is cross-sectional dependency (CD) inside the panel's boundaries. The cross-sectioned dependence may be distorted as a result of these precise variable coefficient estimates. Ignoring cross-sectional dependency may result in standard variables going unnoticed, which might significantly lower the potential for panel data (Phillips & Sul, 2003). Consequently, this issue needs to be taken into account in order to get accurate coefficient estimations. To assess the panel and the cross-sectional dependency, the researchers used the Pesaran (2004) CD testing analysis. Except for fisheries productivity, the remaining quantitative characteristics significantly predict cross-sectional dependency among the countries under consideration, as indicated in Table 3. Techniques for our cointegration testing analysis and unit root test analysis using panel estimate processes that demonstrate a strong degree of resistance to cross-sectional dependency effects must be adopted in order to avoid occurrences of size distortion.

To objectively assess the integrating characteristics of the variables being studied, we employ the unit root tests developed by Levin, Lin, and Chu (2002) (LLC) and Im, Pesaran, and Shin (2003) (IPS). By integrating cross-sectional and time-series data, the panel unit root tests seek to improve test efficiency. To evaluate the unit root null hypothesis with opposing hypotheses, several panel unit roots have been built. The homogeneous alternative, in which every series in the panel is stationary with the same rate of reversion, is examined by Levin, Lin, and Chu (2002) in opposition to the unit root null hypothesis. The alternative—at least one series in the panel is stationary—is tested against the unit root null hypothesis by Im, Pesaran, and Shin (2003). The LLC architecture is the obvious focus of the new test introduced in this study, which focuses on the stationarity of the panel. The Im-Pesaran-Shin (IPS) (2003) test panel relaxes this assumption, allowing each individual to have their own autoregressive parameter. The Levin, Lin, and Chu (2002) (LLC) panel unit root testing methodology has been found to outperform other similar unit root tests in terms of power for moderately small panel datasets, such as the one employed in the current study. To find out how cross-sectional dependency affects the panel unit root tests, we employ these two testing analyses. Table 4 shows that all of the parameters for the unit root testing specifications are non-stationary at levels and stationary at starting differences. The estimate's variables are listed in order I (1).

Table 3. Cross-sectional dependence results

Variables	WC	FO	ECO	FF	GOV
Pesaran (2004)	(4.26)***	(18.82)***	(83.55)***	(65.35)***	(31.30)***

Remark: *** refer importance at the 1%, scale. Source: Alsaleh & Abdul-Rahim (2024)

Table 4. Panel unit root test results

Variable	Difference		First Difference	
	LLC	IPS	LLC	IPS
WC	-0.711	2.658	-8.721***	-17.947***
FO	-3.076	-3.700	-24.136***	-22.737***
ECO	-1.571	-0.210	-18.74***	-68.362***
FF	-9.255	-4.970	-20.610***	-21.409***
GR	-1.090	-0.254	-23.471***	-23.479***

Remark: *** refer importance at the 1%, scale. Levin, Lin & Chu test (LLC), and Im, Pesaran, and Shin W-stat test (IPS). Source: Alsaleh & Abdul-Rahim (2024)

Panel Cointegration Test

To determine whether there is a true long-term relationship between the variables under consideration, the researchers used the Pedroni (2004) panel cointegration testing study in conjunction with the Westerluns (2007) Bootstrapped panel cointegration testing, as indicated in Table 5. Pedroni (2004) presents a thorough methodology for panel cointegration testing based on the Granger 2-step and Engle technique. By eliminating short-term deterministic patterns that are person-specific during the initial processing stage, the technique accounts for Pedroni heterogeneity. Tests that assume single-process processing, also known as "pooled" or "within-dimension" tests, or tests that assume individual processes, also known as "grouped" or "between-dimension" tests, in Table 5, are among the seven alternative testing statistics that are derived from residual estimations. The Westerluns (2007) technique is used to give four new tests, using the null hypothesis that there is no cointegration. This is because the dynamics are not merely residual but rather have structure; the test removes the typical factor constraints that are imposed on tests that rely on residual dynamics. The effectiveness of residual-based cointegration investigations may be significantly reduced if common factor limits are not met. Structural dynamics are therefore necessary (Kremers et al. 1992).

The short-term and long-term processes no longer require the same changes after this restriction is removed. Using the bootstrap process developed by Westerluns (2007), we can obtain robust values while minimizing the effects of cross-sectional dependency distortions. The results in Table 5 show that cointegration is strongly supported by both Westerlun's (2007) testing analysis of bootstrapped cointegration and Pedroni's (2004) testing technique.

Panel Estimation Results

The results of the FMOLS, DOLS, and FEOLS estimation procedures are shown in Table 6. The coefficient estimates generated from the three parameters for Model 1 in Table 6 show an average value that is comparable to others, despite differences in statistical significance. The usage of fossil fuels and fish production in these EU regions is the most stable of the three characteristics in terms of the statistical significance level and the coefficient size. A percentage increase in fish production lowers water contamination by 0.03%, 0.02%, and 0.19%, respectively, according to the FEOLS estimate, the FMOLS estimator, and the DOLS estimator. This conclusion is supported by the key findings of Datta et al. (2022), Kroetz et al. (2022), Heneash et al. (2021), and Prakash and Verma (2019). Marine water contamination results from the introduction of hazardous materials and dangerous toxins into the ocean's waters, including plastic waste, chemicals used on ships, rubbish from fisheries activities, and oil consumption. Numerous marine animal and plant species, as well as the people who depend on them, have been negatively impacted by irresponsible fishing techniques that have seriously endangered the ocean environment and water quality. According to earlier research, this is consistent with Alsaleh et al. (2024), Alsaleh (2023), and Alsaleh et al. (2023a).

Additionally, as expected, there is a statistically significant positive correlation between the usage of fossil fuels in the EU region and the contamination of marine water. For every percentage increase in the use of fossil fuels, marine water contamination rises by 0.02%, 0.09%, and 0.12%, respectively, according to the FEOLS, FMOLS, and DOLS estimators. These findings align with previous research by Shapiro et al. (2021),

Table 5. Panel cointegration test is EU countries

Test	Without Trend	With Trend
A) Pedroni Residual Cointegration Test:		
Alternative hypothesis: common AR coefficients (within dimension):		
Panel v-Statistic	1.277	0.969
	(0.100)	(0.833)
Panel rho-Statistic	-2.948***	-3.229***
	(0.001)	(0.000)
Panel PP-Statistic	−10.579***	-11.225***
	(0.000)	(0.000)
Panel ADF-Statistic	-3.662***	-2.182**
	(0.000)	(0.014)
Alternative hypothesis: common AR coefficients (between dimension)		
Group rho-Statistic	-2.196**	(0.014)
Group PP-Statistic	−14.165***	(0.000)
Group ADF-Statistic	−1.069***	(0.142)

B) Westerlund (2007) Bootstrap Panel Cointegration:

Statistics	Value	Z-Value	p-value	Robust p-value
Gt	-3.415	-3.218	0.001	0.000**
Ga	-9.377	-4.889	1.023	0.145
Pt	-16.956	-3.045	0.001	0.000***
Pa	-11.328	-1.574	0.942	0.236

Remark: ***, ** and * refer importance at the 1%, 5%, and 10% scales respectively. Values in parentheses are *p*-values. Source: Alsaleh & Abdul-

Wang et al. (2022), Mohite et al. (2022), Moosavian et al. (2022), Shafeeque et al. (2021), Chia et al. (2022), Wang et al. (2022b), and Kalair et al. (2021). Even though the main source of CO2 emissions in wild fishing activities is the powering of vessel equipment with diesel and gasoline. Furthermore, the ocean absorbs and dissolves 70% of these pollutants, lowering water quality and contributing to pollution. Surprisingly, fisheries operations are not included in the EU's approved Emissions Trading Scheme (ETS), which releases the sector from accountability for climate policy. These results were consistent with those of Alsaleh et al. (2023b), Alsaleh et al. (2023c), and Alsaleh et al. (2023d) earlier studies.

Additionally, as expected, there is a statistically significant positive correlation between the usage of fossil fuels in the EU region and the contamination of marine water. For every percentage increase in the use of fossil fuels, marine water contamination rises by 0.02%, 0.09%, and 0.12%, respectively, according to the FEOLS, FMOLS, and DOLS estimators. These findings align with previous research by Shapiro et al. (2021), Wang et al. (2022), Mohite et al. (2022), Moosavian et al. (2022), Shafeeque et al. (2021), Chia et al. (2022), Wang et al. (2022b), and Kalair et al. (2021). Even though the main source of CO2 emissions in wild fishing activities is the powering of vessel equipment with diesel and gasoline. Furthermore, the ocean absorbs and dissolves 70% of these pollutants, lowering water quality and contributing to pollution. Surprisingly, fisheries operations are not included in the EU's approved Emissions Trading Scheme (ETS), which releases the sector from accountability for climate policy. These results were consistent with those of Alsaleh et al. (2023b), Alsaleh et al. (2023c), and Alsaleh et al. (2023d) earlier studies.

On the other hand, it is thought that the governance of the EU region negatively affects marine water contamination. Although it is consistent with the modernization hypothesis proposed by Andrews et al. (2022), Kelkar and Arthur (2022), and Pandit et al. (2022), this result contradicts it. While the DOLS estimate specification only has moderate statistically significant support, the growth hypothesis in the FMOLS and FEOLS specifications has high statistically significant support. A coalition of companies, civil society organizations, and local and regional governments enters into a mutual agreement or covenant under private law to measure ship-generated marine debris, the fishery for a clean marine environment, and pristine beaches in European countries. This is done to keep the ocean healthy and the marine water quality excellent. These findings were consistent with earlier findings from important studies like Alsaleh and Yang (2023) and Alsaleh and Abdul-Rahim (2021).

The impact of fishery production on marine water contamination is statistically significant at the first and ninth quantiles (between the first and third quantiles and between the eighth and ninth quantiles), but not at the median quantiles, according to Table 7's estimations regarding panel quantile regression. The effectiveness of marine water regulations for fish production in countries with higher levels of marine water contamination is supported by this research. The results show that the growth hypothesis is only supported by the first and last quantiles of marine water contamination in the EU27. This implies that in countries that are in the middle, the expansion of fisheries takes precedence over the contamination of marine water. Additionally, countries at the median level with lower levels of water contamination could find it simpler to switch from non-recycled to recycled fish output due to the accompanying investment expenditures. Fish production has little positive effect on ocean water quality in countries with the highest levels of marine contamination. This could be due to the disparity in extraction methods between the developed EU14 nations and the developing EU13 economies. These

Table 6. Model 1. Panel Estimation for the EU-27 Region from 1990-2022

Long-run coefficient	DOLS		FMOLS		FEOLS	
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
FO	0.387	(0.192)**	0.071	(0.022)***	0.038	(0.097)***
ECO	0.236	(0.067)*	0.021	(0.012)*	0.022	(0.017)
FF	0.121	(0.114)**	0.093	(0.022)***	0.022	(0.093)**
GOV	-0.504	(0.431)	-0.109	(0.022)***	-1.100	(0.047)***

Note: ***, ** and * indicate significance at the 1%, 5%, and 10% levels respectively. Values in parentheses are P-values. Source: Alsaleh & Abdul-Rahim (2024)

Table 7. Panel Quantile Estimation Results for EU27 countries

Variables	Method of Moments Quantile regression with fixed effects										
	Location	Scale	Quantiles								
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
FO	(0.097)***	(0.090)*	(0.050)*	(0.027)**	(0.031)**	(0.059)	(0.064)	(0.071)	(0.069)	(0.026)**	(0.062)***
ECO	(0.017)	(0.318)	(0.049)	(0.077)	(0.043)	(0.035)	(0.065)***	(0.061)***	(0.061)***	(0.043)	(0.066)
FF	(0.093)**	(0.064)**	(0.089)***	(0.073)***	(0.057)***	(0.049)***	(0.055)***	(0.059)***	(0.061)***	(0.018)	(0.021)
GR	(0.047)***	(0.012)***	(-0.530)*	(-0.261)	(-0.589)***	(-0.509)***	(-0.553)***	(-0.461)***	(-0.403)***	(-0.546)***	(-0.423)***

Notes: *,** and *** indicate significance at 10%, 5% and 1% levels, respectively. Source: Alsaleh & Abdul-Rahim (2024) investigations could have a significant impact on the policies that Datta et al. (2022), Kroetz et al. (2022), and Heneash et al. (2021) advocated, which result in extraordinarily high levels of marine water contamination.

The growth hypothesis, another significant factor influencing the quality of marine waters, was supported by a recent empirical study conducted by Turhan et al. (2021), which is also consistent with our findings. Hamuna et al. (2021) showed that the growth hypothesis for the primary source of marine water quality was valid, and the results are consistent with their findings. Additionally, there is a strong and positive correlation between the effects of economic expansion as evaluated by ECO and marine water contamination in the median (5th, 6th, and 7th) quantiles. Likewise, as quantiles rise, so does the degree to which ECO reflects the influence of economic expansion. Fossil fuel use significantly contributes to marine water contamination from the first to the seventh quantiles, but economic expansion has less effect in the eighth and ninth quantiles. This result demonstrates the effectiveness of energy-use policies that benefit marine ecology in countries with higher pollution levels. Nonetheless, the governance-based results showed that it harms marine water contamination across all quantiles and is statistically significant in countries with high water contamination levels (those in the first to ninth quantiles). One of the main tenets of the modernization hypothesis, the negative correlation between governance and water contamination, may help to explain this conclusion. According to Luo et al. (2022) and Kelkar and Arthur (2022), the effectiveness of marine policies forces the government and its management to support and encourage ecologically friendly fisheries practices. This is compatible with their theories and hypotheses discussed previously.

The results of the FMOLS, DOLS, and FEOLS estimation procedures are shown in Table 8. Fish output and governance in the EU14 developed nations are the most stable across all three parameters, both in terms of coefficient sizes and size statistical significance, although differentiations look at their significance level. The estimation coefficient produced out of these three specifications going on Model 2 in Table 8 is, on average, relatively similar to others. A percentage increase in fish production lowers marine water contamination by 0.03 percent, 0.04 percent, and 0.07 percent, respectively, according to the FEOLS, FMOLS, and DOLS estimators. This conclusion is supported by the key findings of Keiser and Shapiro (2019), Prakash and Verma (2019), Hamuna et al. (2021), and Turhan et al. (2021). The problem of the invisible saltwater illustrates how a mixture of bacteria, garbage, chemicals, and plastics can deplete the water's oxygen content and make it toxic to ecosystems and marine life. Economic growth considerably lowers the level of marine water pollution in the developed EU14 countries. Likewise, economic growth is shown to have increased by the FEOLS and FMOLS estimators as a percentage increase of 0.14% and 0.07%, respectively; however, the coefficient appears to be inconsistent among DOLS specifications.

According to the panel of developed EU14 countries, the growth theory is supported. This result runs counter to the findings of Shapiro (2022) and Radelyuk et al. (2021), who were unable to discover a discernible, elastic, and positive effect of economic growth on marine water contamination in industrialized nations. Additionally, it repeats the key findings of Mumbi and Watanabe (2022), Pan and Tang (2021), Zhou et al. (2021), and Wang et al. (2021). Fishery economic activities that could harm marine water contamination include shipping, fishing, aquaculture, and leisure activities. To clean up polluted streams and stop marine disasters, inefficient fishing methods could cost billions of dollars.

However, every assessed metric indicates that governance in the industrialized EU14 countries has a significant negative influence. The modernization ideas proposed by Okafor-Yarwood et al. (2022), Bender et al. (2022), and Hou et al. (2022) are supported by this conclusion, although it contradicts Andrews et al. (2022). A percentage increase in governance harms marine water contamination of 0.33 percent, 0.32 percent, and 0.91 percent, respectively, according to the FELS, FMLS, and DOLS estimators. The FEOLS, FMOLS, and DOLS estimate specifications all provide strong statistically significant support for the growth hypothesis.

The panel quantile regression results in Table 9 show that the effects of fish output on marine water contamination are statistically significant from the first to the sixth quantiles. The effectiveness of marine water policy in increasing fish production in the developed EU14 countries is supported by this conclusion. The growth hypothesis of developed EU14 countries with lower and median levels of marine water contamination is supported by these findings. This implies that marine

Table 8. Model 2. panel estimation for the EU-14 region from 1990-2022

Long-run coefficient	DOLS		FMOLS		FEOLS	
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
FO	0.132	(0.077)*	0.169	(0.047)***	0.116	(0.036)***
ECO	0.023	(0.049)	0.072	(0.036)**	0.142	(0.038)***
FF	0.023	(0.026)	0.079	(0.017)	0.040	(0.013)
GOV	-0.913	(0.270)***	-0.326	(0.169)*	-0.334	(0.129)**

Note: ***, ** and * indicate significance at the 1%, 5%, and 10% levels respectively. Values in parentheses are P-values. Source: Alsaleh & Abdul-Rahim (2024) water policy is prioritized over fish production in the developed EU14 countries in the older and median quantiles, but not in the more recent quantiles. Furthermore, established EU14 nations that are now ranked as having significant levels of water contamination may find it more difficult to transition from traditional to recycled and ecologically friendly fishing methods due to the related investment expenses. Fish production has a less positive effect on water contamination in the EU14 countries with the highest levels of marine water contamination. The different extraction methods utilized in the fisheries of the EU14 developed economies could be the cause of this. Since they corroborate Turhan et al.'s (2021) validation of the growth hypothesis for a number of wealthy countries that produce extremely high levels of marine water contamination, these findings have important policy implications. Our results are consistent with a recent empirical study by Hamuna et al. (2021) that validated the growth hypothesis, another major cause of marine pollution.

Furthermore, the results are consistent with those of Prakash and Verma (2019) and Keiser and Shapiro (2019), who established the validity of the growth hypothesis as the main cause of marine water contamination. According to ECO, the influence of economic expansion on marine water contamination is significant from the first to the ninth quantiles. This research lends credence to the idea that environmental laws could boost economic growth in countries with higher pollution levels. This implies that in the developed EU14 countries, economic expansion comes before marine water quality. Additionally, the consequences of using fossil fuels and the pollution of marine water were significantly correlated from the first to the ninth quantiles. Similarly, the impact of using fossil fuels is becoming less significant at higher quantiles. Nonetheless, the governance-based results showed that it significantly and negatively affected marine water contamination in every quantile (except for the seventh and ninth quantiles). Similar to this, the extent of governance practices' influence is diminishing as quantiles rise. The efficiency of governance forces government representatives and their management to support ecologically friendly practices in fish production.

The results of the several panel estimate techniques (FMOLS, DOLS, and FEOLS) are listed in Table 10 of Model 3. The coefficient values produced by both methods are nearly the same. The findings show that fish production has a significant and positive impact on marine water contamination in the developing EU13 countries. A 1% increase in fish production raises marine water contamination by 0.03%, 0.8%, and 0.12% for FEOLS, FMLS, and DOLS, respectively. The positive and significant sign of the fish output coefficients in each of the three approaches confirms the presence of the growth hypothesis in the EU13 developing countries. This outcome is in line with the findings of Hamuna et al. (2021) and Turhan et al. (2021), who claim that when fish output increases throughout the early stages of growth, marine water contamination increases as well. Fossil fuel consumption is directly linked to marine water contamination in the FEOLS, FMOLS, and DOLS techniques. Marine water contamination rises by 0.03 percent for FEOLS, 0.09 percent for FMOLS, and 10.06 percent for DOLS for every 1% increase in the usage of fossil fuels. Fossil fuel use exacerbates water contamination in developing countries, according to Alsaleh et al. (2022a) in the case of Malta and Alsaleh et al. (2022b) in the case of Estonia. Their findings are in line with this conclusion.

The outcome shows that ECO has a significant and positive impact on marine water contamination in the developing EU13 countries. A 1% rise in ECO results in a 0.17% increase in marine water contamination, according to DOLS, albeit the coefficient appears to vary depending on the FEOLS and FMOLS estimation factors. The existence of the growth hypothesis in the EU13

Table 9. Panel quantile estimation results for EU14 countries

Variables	Location	Scale	Method of Moments Quantile regression with fixed effects								
			Quantiles								
			0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
FO	(0.036)***	(0.026)***	(0.057)***	(0.042)***	(0.036)***	(0.037)***	(0.031)***	(0.019)**	(0.003)	(0.001)	(0.001)
ECO	(0.038)***	(0.096)	(0.213)***	(0.233)***	(0.237)***	(0.249)***	(0.241)***	(0.249)***	(0.197)***	(0.125)**	(0.094)*
FF	(0.013)	(0.068)***	(0.217)	(0.302)	(0.073)	(0.002)	(0.078)	(0.031)	(0.062)	(0.137)	(0.074)
GR	(0.129)**	(0.567)	(-0.057)***	(-0.026)***	(-0.013)***	(-0.020)***	(-0.004)***	(-0.005)**	(0.018)	(-0.008)*	(-0.022)

Notes: *,** and *** indicate significance at 10%, 5% and 1% levels, respectively. Source: Alsaleh & Abdul-Rahim (2024)

Table 10. Model 3. panel estimation for the EU-13 region from 1990-2022

Long-run coefficient	DOLS		FMOLS		FEOLS	
	Coefficient	Std. Error	Coefficient	Std. Error	Coefficient	Std. Error
FO	0.127	(0.023)***	0.081	(0.030)***	0.032	(0.013)**
ECO	0.173	(0.034)***	0.021	(0.019)	0.030	(0.019)
FF	0.067	(0.011)***	0.096	(0.028)***	0.039	(0.011)***
GR	-0.670	(0.082)	-0.109	(0.025)***	-0.178	(0.065)***

Note: ***, ** and * indicate significance at the 1%, 5%, and 10% levels respectively. Values in parentheses are P-values. Source: Alsaleh & Abdul-Rahim (2024) developing countries is confirmed by the positive and substantial sign of the ECO coefficients in the DOLS approach. These results are consistent with those of Zhang et al. (2021), He et al. (2021), and Faroque and South (2022). The empirical data from the EU13 developing countries explain why marine water and governance have a negative association. Even while FEOLS and FMOLS show 0.17% and 0.10% reductions in marine water contamination, respectively, if governance increases by 1%, its coefficient appears to be inconsistent across DOLS estimate settings. This conclusion is supported by studies by Alsaleh et al. (2020a/b) for underdeveloped countries and Alsaleh and Abdul-Rahim (2021; 2022) for EU economies, which demonstrate that managed governance lowers marine water contamination. The outcomes of the Method of Movement Quantile regression are shown in Table 11. First, it is feasible to verify that fish production has a beneficial effect on the contamination of marine water. The data shows that fish output significantly varies in marine water for all quantiles, decreasing from 0.216 to 0.124 as the quantile increases (from the 1st to the 9th quantile).

Furthermore, the impacts of using fossil fuels and the pollution of marine water are significantly and favorably correlated in all quantiles. In a similar vein, the degree of fossil fuel influence rises for lower quantiles (first quantile) and then falls for higher quantiles. Ninth quantile. Governance harms the lowest and highest quantiles of marine water contamination, and this relationship is statistically significant in the first, the second, and the ninth quantiles. Unlike previous examples, the degree of governance influence diminishes when higher quantiles are attained. Economic growth is known to have a beneficial effect on marine water contamination. As the quantile rises for all quantiles (from 1st to 9th), the table demonstrates that the rise in marine water contamination caused by economic expansion is substantial, rising from 0.086 to 0.172.

Discussion

The estimates from the FEOLS panel have been confirmed by Panel FMOLS and DOLS. The panel FMOLS and DOLS coefficients and the panel FEOLS coefficients are shown to have the same sign and level of significance. This proves that panel FMOLS and DOLS data are trustworthy and useful for concluding. The FEOLS coefficients have the same sign as the panel FMOLS and DOLS coefficients, but with a little different significant threshold. Panel DOLS estimates, however, are trustworthy and free from problems with endogeneity and serial correlation. Based on their levels of marine pollution, the EU 27 countries were divided into two groups: 14 developed countries and 13 developing countries. The purpose of this study was to investigate the impact of fish output on water contamination. Tables 8 and 9 illustrate the anticipated effects of fish production on hazardous waste in the developed EU14 countries.

Tables 10 and 11 forecast the impact of fish production on marine water pollution in the emerging nations of the EU-14. The results in Tables 8 and 10 show that fish output has a major effect on water contamination. The findings also imply that developed EU14 countries have a more significant and significant influence on the pollution of marine water than do developing EU13 countries. The precise impacts on the governments of the EU13 and EU14 are 0.032 and 0.116, respectively. This demonstrates that by using fisheries regulation and a marine taxation approach to the fish output, established EU14 countries may significantly reduce marine water contamination more than emerging EU13 nations. The data also indicates that the use of fossil fuels has a significant impact on marine water contamination, but only in the developing countries of the EU13 and not at all in the developed countries of the EU14. The exact size of the effect for the EU13 countries is 0.039. This indicates that by enacting energy regulations and energy levies on the use of fossil fuels in fish production, developing countries in the EU13 may considerably reduce marine water contamination in comparison to developed nations in the EU14. Marine water contamination is significantly and seriously impacted by the fact that developed EU14 countries have more significant economic development than growing EU13 nations, according to the data.

The exact magnitude of the effect for the EU14 countries is 0.142. This indicates that EU14 developed countries may see a greater reduction in marine water contamination as a result of investments in green and ecologically friendly fisheries than EU13 developing countries. Nonetheless, the data also indicates that the EU14 developed countries have lower levels of marine water contamination attributable to governance than the EU13 developing countries. The precise magnitudes of the impact are -0.178 for the EU14 wealthy countries

Table 11. Panel quantile estimation results for EU13 countries

	Method of moments quantile regression with fixed effects										
			Quantiles								
Variables	Location	Scale	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
FO	(0.013)**	(0.021)***	(0.216)***	(0.182)***	(0.134)***	(0.125)***	(0.091)***	(0.088)***	(0.085)***	(0.113)***	(0.124)***
ECO	(0.019)	(0.048)	(0.086)***	(0.091)***	(0.097)***	(0.114)***	(0.112)***	(0.122)***	(0.143)***	(0.127)***	(0.171)***
FF	(0.011)***	(0.067)***	(0.071)***	(0.084)***	(0.087)***	(0.081)***	(0.082)***	(0.076)***	(0.080)***	(0.059)***	(0.048)**
GR	(0.065)***	(0.506)***	(-0.302)***	(-0.224)***	(-0.090)	(-0.078)	(-0.030)	(-0.036)	(-0.044)	(-0.038)	(-0.182)***

Notes: *,** and *** indicate significance at 10%, 5% and 1% levels, respectively. Values in parentheses are P-values. Source: Alsaleh & Abdul-Rahim (2024) and -0.334 for the EU13 underdeveloped countries. By applying an ocean governance approach to fish production, developing countries in the EU13 may significantly reduce marine water pollution faster than developed countries in the EU14. This might be a result of the current tax law modifications in the developed EU14 countries, which exclude fish production from taxes.

A visual analysis of Table 7 showed that the MMQR estimates of the dynamics of fish production and fossil fuel use are identical. The coefficient for assessing the consumption of fossil fuels and fisheries output was highest in the lowest quantile. Fossil fuel use and fish production coefficients decrease from the lowest to the highest quantile. This implies that when marine water contamination is at its worst, the effects of fish production and fossil fuel consumption are at their lowest quantile levels. There is proof that improving governance would reduce marine water contamination from the experiences of Egypt (Heneash et al., 2021), Turkey (Turhan et al., 2021), Indonesia (Hamina et al., 2021), and the USA (Keiser and Shapiro, 2019). As a result, we support the necessity of improving governance in fish-producing countries, especially in the developed EU14 states with notable water contamination indicators. In addition, fish output had a positive link with marine water contamination at the earlier and later quantiles. Fossil fuel use was positive and significant throughout all quantiles except the eighth and ninth quantiles. This finding supports the growth concept in the body of previous research. The results suggest various explanations for various quantiles in the context of fishery-producing nations in the EU27 area. At median quantiles, deindustrialization, which happens when fisheries output supplants all other tradable sectors of the economy reliant on water contamination, might be a contributing factor. As a result, they become increasingly dependent upon imports, which means that a significant portion of these countries' economic development will constitute fish imports and exports.

Since fossil fuel use impacts every productive sector of the economy, there should be a positive correlation between it and marine water contamination at all quantiles. The impact of fish output on marine water contamination was found to be most prominent at the minor level of quantile and the least at the peak or greatest quantile. It does not mean a boost in energy utilization from the least to the peak quantile can decrease marine water contamination for each produced energy unit due to more energy consumption from renewable and sustainable sources.

Conclusion

Taking the growth theory into consideration, this study investigates the empirical relationships among fish production, economic growth, governance, consumption of fossil fuels, and marine water contamination. It contributes to our understanding of environmental pollution related to fisheries and sustainable development. We employed panel cointegration analysis, panel unit roots testing analysis, and panel estimate approaches on data spanning 31 years across 27 EU countries. The model used the quantitative variable governance (% of confidence for governance) to account for marine water contamination and measure the degree of sustainable development. Using panel cointegration techniques and panel unit root testing, all the parameters have a non-spurious long-run relationship and follow an I(1) process. Traditional panel cointegration estimation approaches revealed discrepancies in coefficient significance, although the sizes produced from the various requirements are similar. The researchers used the moment's regression quantile approach, which enables studies of the various effects of exogenous factors on the cross-sectional conditional distribution of multiple quantiles of marine water contamination, in order to have a thorough evaluation or investigation of the connection empirically. The coefficient estimates of DOLS, FMOLS, and FEOLS confirmed the growth assumptions for the fish-producing economies of the EU27 member states.

According to our MMQR data, fish production is felt at the median quantile of pollution in marine water but is favorably significant at the earlier and most recent conditioned distribution quantiles. This indicates that there is a positive association between the conditional distribution of marine water contamination at different quantiles and the use of fossil fuels in fisheries, even though the relationship is significant and positive from the first to the seventh quantiles. Except for the second quantile, governance statistically reduced marine water contamination in quantiles from the first to the ninth quantiles. This could indicate that fisheries output benefited EU27 countries during both their early and mature phases of transitional development. It should be emphasized that nations with more diverse economies and fisheries are more economically diversified than rising economies, which depend far more on imported seafood. This implies that a far larger percentage of the marine water contamination profile in wealthy countries may be attributable to fish production.

Dependency in this case does not necessarily mean plenty. This lends more credence to the deindustrialization-induced resource curse. The severity of the negative consequences of governance in the earlier and median quantiles may be related to the most recent environmental actions taken by the government in the continuous battle against marine water contamination. Residents of EU14 developed countries place a higher importance on environmental quality than those in EU13 developing countries, which have less contaminated marine water. Therefore, a government efficiency that satisfies popular desire would execute more initiatives to prevent marine water contamination to gain the favor of the electorate. The need for fisheries output at the lowest water contamination quantiles is highlighted by the possibility that fish output in the developed EU14 countries with the highest emissions may likewise be subject to numerous compromises. Strategies for reducing marine water contamination could be detrimental to growth. Since the effects of environmental degradation can be observed right away, residents of these EU countries may be overly concerned about environmental regulations because the quantile value is so close to the median when fisheries output has a very small but significant impact on marine water contamination. As a result, voters and elected officials might not place a higher value on economic development based on fish production activities that rely on contaminated seawater.

Because sustainable operations are more common in fish production and the sustainability approach adaptation is more prevalent, the influence of governance efficiency may be bigger at higher quantiles in EU13 developing and EU14 developed countries. The positive and significant influence seen in the upper quantiles of fish yield in Table 9 indicates that fisheries practices have improved in the industrialized EU14 countries. In order to increase profit margins, the labor-intensive export-oriented fish production from the EU13 developing economies may move to the EU14 developed markets. This could significantly reduce water contamination levels in the EU13 countries and shift economic growth dynamics in favor of imports at higher quantiles. Furthermore, because of the stringent environmental rules imposed on export-oriented and clean seawater-dependent sectors of the economy, the growth theory may be directly applicable in the industrialized EU14 countries. This situation might compel the onshore fishery to produce less marine debris. Due to the financial consequences of switching to fuels and employing more energy-efficient technologies in the EU13 emerging countries, many enterprises may decide to relocate to a country with less stringent environmental regulations and taxation.

This suggests that from the lowest to the highest quantile, the fish output will become more efficient. The impact of developed EU14 countries that can afford the financial expenses of switching from traditional fishing gear to sustainable, environmentally friendly gear is also suggested. Given that fish production is far higher than marine water contamination, it can be inferred that the fisheries gear used in the EU13 developing and EU14 developed countries comes from conventional sources. This study implies that in order to reduce marine water contamination in the developed EU14 countries, a greater effort should be made to transition the fish output's operations from conventionally unfriendly to sustainably friendly sources. Stated differently, it is imperative to encourage the growth of fisheries using eco-friendly techniques, including eco-friendly angling, eco-friendly fisheries lines, and biodegradable lures. Even better, if the EU13 developing countries are unable to implement eco-friendly fishing gear, they could implement equitable environmental tax rules for fish production. According to these regulations, fish production that is impacted by contaminated marine water must be fairly taxed. These taxes ought to bring in money for long-term infrastructure and technology improvements that support sustainable fishing resources.

Lastly, by incorporating additional elements that affect the sustainability of fish production and marine development in the EU region, such as tourism, globalization, and economic expansion, this analysis might be made more thorough. Additionally, this research may be conducted at the national level (for example, the Republic of China) or at other regions (for example, ASEAN, BRICS, the Group of Seven, or the Next 11 countries) using innovative and state-of-the-art econometric methodologies. There are definitely limitations to this type of modeling, and this study is no different. The simulation was unable to assess the potential benefits of marine water contamination due to data limitations, which still require further research. Furthermore, depending on the constraints of the current study, the model might be tested in many countries to understand a wide-ranging contextual viewpoint. Despite using contemporary econometric techniques to show these associations, the study had a number of limitations. For example, the current findings only encompassed a limited set of characteristics from 1990 to 2022 and were only assessed using econometrics. Using the current dataset and additional parameter metrics, future studies could look at how public-private investments in fisheries and ocean energy affect fish production. Second, although the existing framework only applies to EU countries, it might be extended to encompass several non-EU countries. Thirdly, researchers may examine the economic complexity of marine water contamination over multiple time periods to account for structural gaps in the data.

Ethical Statement

The authors declare the provided manuscript has not been published before nor submitted to another journal or preprint server for consideration of publication.

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Author Contribution

M.A. (Mohd Alsaleh) gathered the data and estimated the panel cointegration model and the competitive advantage of the external factors on the fishery industry in the EU27 region; M.A. presented the EU27's water pollution and fishery industry and put together all the numerical results; M.A. contributed with conclusions and recommendations as well as with the limitations of the study and further research; M.A. conducted the literature review; and was responsible for the overall writing process.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

References

Alsaleh, M., Yuan, Y., Longqi, S., Abdul-Rahim, A.S. (2024). Do worldwide governance drivers affect the blue sustainability practices? An empirical study of the fish output. Journal of Coastal Conservation 28, 7 (2024). https://doi.org/10.1007/s11852-023-01001-6

Alsaleh, M. (2023). The role of the fish output in the shift towards sustainable food security: a critical study of blue food. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-023-29747-4

Alsaleh, M., Wang, X., & Nan, Z. (2023a). Estimating the impact of fish output on marine pollution: New insights from Method of Moments Quantile Regression. Energy & Environment. https://doi.org/10.1177/0958305X231200572

Alsaleh, M., Wang, X., Nan, Z., Liu, R., & Sun, Q. (2023b). Impact of coastal tourism demand on fish output sustainability: A suggested framework for blue growth. Natural Resources Forum. https://doi.org/10.1111/1477-8947.12332

Alsaleh, M., Abdul-Rahim, A. S., Liu, R., & Sun, Q. (2023c). Nature of property rights and motivation for blue growth: An empirical evidence from the fish output. Natural Resources Forum. https://doi.org/10.1111/1477-8947.12317

Alsaleh, M., Wang, X., & Nan, Z. (2023d). Toward marine sustainability: Unveiling the effect of the fish output on blue carbon sequestration. Sustainable Development. https://doi.org/10.1002/sd.2659

Alsaleh, M., Yang, Z. (2023). The evolution of information and communications technology in the fish output: The pathway for marine sustainability. Marine Pollution Bulletin. https://doi.org/10.1016/j.marpolbul.2023.115231

Alsaleh, M., Abdul-Rahim, A.S. (2021). Does Hydropower Growth Threaten Fish Security Under the Pathway of Sustainable Development? Evidence from in EU Economies. Energy & Environment. https://doi.org/10.1177/0958305X2110463

Alsaleh, M., Abdul-Rahim, A.S. (2024). What are the influence of fishery activities and their implication on marine water pollution? an empirical analysis. Environ Dev Sustain (2024). https://doi.org/10.1007/s10668-024-05561-x

Andrews, D. W. (2005). Cross-section regression with common shocks. Econometrica, 73(5), 493 1551-1585. https://www.jstor.org/stable/3598883

Andrews, N., Bennett, N. J., Le Billon, P., Green, S. J., Cisneros-Montemayor, A. M., Amongin, S., ... & Sumaila, U. R. (2021). Oil, fisheries and coastal communities: A review of impacts on the environment, livelihoods, space and governance. Energy Research & Social Science, 75, 102009. https://doi.org/10.1016/j.erss.2021.102009

Anwar, A., Siddique, M., Dogan, E., & Sharif, A. (2021). The moderating role of renewable and non-renewable energy in environment-income nexus for ASEAN countries: Evidence from Method of Moments Quantile Regression. Renewable Energy, 164, 956-967. https://doi.org/10.1016/j.renene.2020.09.128

Apergis, N., & Payne, J. E. (2010). The emissions, energy consumption, and growth nexus: evidence from the commonwealth of independent states. Energy policy, 38(1), 650-655. https://doi.org/10.1016/j.enpol.2009.08.029

Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D., Farhani, S., (2018). How economic growth, renewable electricity and natural resources contribute to CO2 emissions?. Energy Policy 113, 356–367. https://doi.org/10.1016/j.enpol.2017.10.050

Bekun, F.V., Alola, A.A., Sarkodie, S.A. (2019). Toward a sustainable environment: Nexus between CO2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. Science of Total Environment. 657, 1023–1029. https://doi.org/10.1016/j.scitotenv.2018.12.104

Bender, M., Bustamante, R., & Leonard, K. (2022). Living in relationship with the Ocean to transform governance in the UN Ocean Decade. PLoS Biology, 20(10), e3001828. https://doi.org/10.1371/journal.pbio.3001828

Breitung, J., & Pesaran, M. H. (2005). Unit roots and cointegration in panels. https://doi.org/10.1007/978-3-540-75892-1_9

Cerrato, M., & Sarantis, N. (2002). The cross sectional dependence puzzle. Royal Economic Society Annual Conference 2002 42, Royal Economic Society. London Guildhall 555 University.

Chia, S. R., Nomanbhay, S., Ong, M. Y., Chew, K. W., & Show, P. L. (2022). Renewable diesel as fossil fuel substitution in Malaysia: A review. *Fuel*, *314*, 123137. https://doi.org/10.1016/j.fuel.2022.123137

Chudik, A., & Pesaran, M. H. (2013). Large panel data models with cross-sectional dependence: a survey. Globalization Institute Working Papers 153, Federal Reserve Bank of Dallas.

Datta, S., Sinha, D., Chaudhary, V., Kar, S., & Singh, A. (2022). Water contamination of wetlands: a global threat to inland, wetland, and aquatic phytodiversity. In Handbook of Research on Monitoring and Evaluating the Ecological Health of Wetlands (pp. 27-50). IGI Global. https://doi.org/10.4018/978-1-7998-9498-8.ch003

Dogan, E., & Seker, F. (2016a). Determinants of CO2 emissions in the European Union: The role of renewable and non-renewable energy. Renewable Energy, 94, 429-439. https://doi.org/10.1016/j.renene.2016.03.078

Ehigiamusoe, K. U., Lean, H. H., & Smyth, R. (2020). The moderating role of energy consumption in the carbon emissions-income nexus in middle-income 588 countries. Applied Energy, 261, 114215. https://doi.org/10.1016/j.apenergy.2019.114215

Faroque, S., & South, N. (2022). Water contamination and environmental injustices in Bangladesh. International Journal for Crime, Justice and Social Democracy, 11(1), 1-13. https://doi.org/10.5204/ijcjsd.2006

Flaten, O., Lien, G., Koesling, M., & Løes, A. K. (2010). Norwegian farmers ceasing certified organic production: characteristics and reasons. Journal of environmental management, 91(12), 2717–2726.

https://doi.org/10.1016/j.jenvman.2010.07.026

Hamuna, B., & Tanjung, R. H. R. (2021). Heavy metal content and spatial distribution to determine the water contamination index in depapre waters, Papua, Indonesia. Current Applied Science and Technology, 1-11. https://doi.org/10.14456/cast.2020.36

He, M., Xu, Z., Hou, D., Gao, B., Cao, X., Ok, Y. S., ... & Tsang, D. C. (2022). Waste-derived biochar for water contamination control and sustainable development. Nature Reviews Earth & Environment, 3(7), 444-460. https://doi.org/10.1038/s43017-022-00306-8

Heneash, A. M., Alprol, A. E., El-Hamid, A., Hazem, T., Khater, M., & El Damhogy, K. A. (2021). Assessment of water contamination induced by anthropogenic activities on zooplankton community in Mariout-Lake using statistical simulation. Arabian Journal of Geosciences, 14(7), 1-21. https://doi.org/10.1007/s12517-021-06977-9

Hou, N., Zhu, Q., Yang, J., Zhang, D., Liu, W., & Chang, H. (2021). The Impact of Environmental Governance on the Development of Fishery Economy—The Intermediary Role of Technological Innovation. Sustainability, 13(20), 11378. https://doi.org/10.3390/su132011378

Huang, Y., Mi, F., Wang, J., Yang, X., & Yu, T. (2022). Water contamination incidents and their influencing factors in China during the past 20 years. Environmental Monitoring and Assessment, 194(3), 1-13. https://doi.org/10.1007/s10661-022-09838-4

Im, K.S., Pesaran, M.H., Shin, Y., 2003. Testing for unit roots in heterogeneous panels. Journal of econometrics 115 (1), 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7

Isham, J., Woolcock, M., Pritchett, L., Busby, G., (2005). The Varieties of Resource Experience: Natural Resource Export Structures and the Political Economy of Economic Growth. The World Bank Economic Review 19 (2), 141–174. https://doi.org/10.1093/wber/lhi010

Kalair, A., Abas, N., Saleem, M. S., Kalair, A. R., & Khan, N. (2021). Role of energy storage systems in energy transition from fossil fuels to renewables. *Energy Storage*, *3*(1), e135. https://doi.org/10.1002/est2.135

Keiser, D. A., & Shapiro, J. S. (2019). Consequences of the Clean Water Act and the demand for water quality. The Quarterly Journal of Economics, 134(1), 349-396. https://doi.org/10.1093/qje/qjy019

Kelkar, N., & Arthur, R. I. (2022). A review of governance and tenure in inland capture fisheries and aquaculture systems of India. FAO Fisheries and Aquaculture Circular, (C1230), 0_1-84. https://doi.org/10.4060/cb8615en

Koenker, R. (2004). Quantile regression for longitudinal data. Journal of Multivariate Analysis 91 (1), 74–89. https://doi.org/10.1016/j.jmva.2004.05.006

Kremers, J.J., Ericsson, N.R., Dolado, J.J., (1992). The power of cointegration tests. Oxford Bulletin of Economics and Statistics. 54 (3), 325–348. https://doi.org/10.1111/j.1468-0084.1992.tb00005.x

Kroetz, K., Nøstbakken, L., & Quaas, M. (2022). The future of wild-caught fisheries: Expanding the scope of management. Review of Environmental Economics and Policy, 16(2), 241-261.

Leite, C., Weidmann, J. (1999). Does Mother Nature Corrupt: Natural Resources, Corruption, and Economic Growth IMF Working Papers. International Monetary Fund.

Levin, A., Lin, C.F. and Chu, C.S.J. (2002) Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties. Journal of econometrics, 108, 1-24. https://doi.org/10.1016/S0304-4076(01)00098-7

Luo, Y., Wu, J., & Xu, Y. (2022). Can self-governance tackle the water commons?—Causal evidence of the effect of rural water contamination treatment on farmers' health in China. Ecological Economics, 198, 107471. https://doi.org/10.1016/j.ecolecon.2022.107471

Machado, J.A., Silva, J.S., (2019). Quantiles via moments. Journal of Econometrics. https://doi.org/10.1016/j.jeconom.2019.04.009.

Mehlum, H., Moene, K., Torvik, R., (2006). Institutions and the Resource Curse. Economic Journal 116, 1–20. https://doi.org/10.1111/j.1468-0297.2006.01045.x

Mohite, V. T. (2022). Pollution and Pollution Control. In *Emerging Trends in Environmental Biotechnology* (pp. 11-21). CRC Press. https://doi.org/10.1201/9781003186304

Moosavian, S. F., Borzuei, D., Zahedi, R., & Ahmadi, A. (2022). Evaluation of research and development subsidies and fossil energy tax for sustainable development using computable general equilibrium model. *Energy Science & Engineering*, *10*(9), 3267-3280. https://doi.org/10.1002/ese3.1217

Mumbi, A. W., & Watanabe, T. (2022). Cost Estimations of Water contamination for the Adoption of Suitable Water Treatment Technology. Sustainability, 14(2), 649. https://doi.org/10.3390/su14020649

Okafor-Yarwood, I., Kadagi, N. I., Belhabib, D., & Allison, E. H. (2022). Survival of the Richest, not the Fittest: How attempts to improve governance impact African small-scale marine fisheries. Marine Policy, 135, 104847. https://doi.org/10.1016/j.marpol.2021.104847

Palomino, E., Pardue, J. (2021). Alutiiq Fish Skin Traditions: Connecting Communities in the COVID-19 Era. *Heritage* 2021, *4*, 4249-4263. https://doi.org/10.3390/heritage4040234

Pan, D., & Tang, J. (2021). The effects of heterogeneous environmental regulations on water contamination control: Quasi-natural experimental evidence from China. Science of The Total Environment, 751, 141550. https://doi.org/10.1016/j.scitotenv.2020.141550

Pandit, D., Shefat, S. H. T., & Kunda, M. (2022). Fish diversity decline threatens small-scale fisheries in the haor basin of Bangladesh. Small in Scale, Big in Contributions: Advancing Knowledge of Small-Scale Fisheries in Bangladesh. TBTI Global Publication Series, St. John's, NL, Canada. https://doi.org/10.1016/j.heliyon.2022.e11875

Pedroni, P. (2004). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. Econometric theory 20 (3), 597–625. https://doi.org/10.1017/S0266466604203073

Pesaran, M.H. (2004). General diagnostic tests for cross-sectional dependence in panels. Empirical Economics 60, 13–50 (2004). https://doi.org/10.1007/s00181-020-01875-7

Phillips, P.C., Sul, D., (2003). Dynamic panel estimation and homogeneity testing under cross section dependence. The Econometrics Journal 6 (1), 217–259. https://doi.org/10.1111/1368-423X.00108

Prakash, S., & Verma, A. K. (2019). Effect of arsenic on lipid metabolism of a fresh water cat fish, Mystus vittatus. Liver, 10(20), 30.

Radelyuk, I., Tussupova, K., Klemeš, J. J., & Persson, K. M. (2021). Oil refinery and water contamination in the context of sustainable development: Developing and developed countries. Journal of Cleaner Production, 302, 126987. https://doi.org/10.1016/j.jclepro.2021.126987

Rahim, A., & Soeprobowati, T. R. (2019). Water contamination index of Batujai reservoir, Central Lombok regency-Indonesia. Journal of Ecological Engineering, 20(3). https://doi.org/10.1093/qje/qjy019

Sarkar, B., & Islam, A. (2022). Assessing poverty and livelihood vulnerability of the fishing communities in the context of pollution of the Churni River, India. Environmental Science and Pollution Research, 29(18), 26575-26598. https://doi.org/10.1007/s11356-021-17719-5

Shafeeque, M., Arshad, A., Elbeltagi, A., Sarwar, A., Pham, Q. B., Khan, S. N., ... & Al-Ansari, N. (2021). Understanding temporary reduction in atmospheric pollution and its impacts on coastal aquatic system during COVID-19 lockdown: a case study of South Asia. *Geomatics, Natural Hazards and Risk*, *12*(1), 560-580. https://doi.org/10.1080/19475705.2021.1885503

Shapiro, J. S. (2022). Pollution trends and US environmental policy: Lessons from the past half century. *Review of Environmental Economics and Policy*, *16*(1), 42-61. https://doi.org/10.1086/718054

Shapiro, J. S. (2022). Pollution trends and US environmental policy: Lessons from the past half century. Review of Environmental Economics and Policy, 16(1), 42-61. https://doi.org/10.1086/718054

Tang, W., Pei, Y., Zheng, H., Zhao, Y., Shu, L., & Zhang, H. (2022). Twenty years of China's water contamination control: Experiences and challenges. Chemosphere, 295, 133875. https://doi.org/10.1016/j.chemosphere.2022.133875

Turhan, D. Ö. (2021). Evaluation of microplastics in the surface water, sediment and fish of Sürgü Dam Reservoir (Malatya) in Turkey. Turk. J. Fish Aquat. Sci, 22. http://doi.org/10.4194/TRJFAS20157

Wang, M., Janssen, A. B., Bazin, J., Strokal, M., Ma, L., & Kroeze, C. (2022). Accounting for interactions between Sustainable Development Goals is essential for water contamination control in China. *Nature communications*, *13*(1), 1-13. https://doi.org/10.1038/s41467-022-28351-3

Wang, M., Janssen, A. B., Bazin, J., Strokal, M., Ma, L., & Kroeze, C. (2022). Accounting for interactions between Sustainable Development Goals is essential for water contamination control in China. Nature communications, 13(1), 1-13. https://doi.org/10.1038/s41467-022-28351-3

Wang, S. (2022). Sustainable Development of Atmosphere and Water Resources: A Case Study of the UK. In *2022 International Conference on Urban Planning and Regional Economy (UPRE 2022)* (pp. 185-189). Atlantis Press. https://doi.org/10.2991/aebmr.k.220502.034

Wang, Y., Wei, H., Wang, Y., Peng, C., & Dai, J. (2021). Chinese industrial water contamination and the prevention trends: An assessment based on environmental complaint reporting system (ECRS). Alexandria Engineering Journal, 60(6), 5803-5812. https://doi.org/10.1016/j.aej.2021.04.015

Westerluns, J., (2007). Testing for error correction in panel data. Oxford Bulletin of Economics and Statistics 69 (6), 709–748. https://doi.org/10.1111/j.1468-0084.2007.00477.x

Zhang, Y., Liu, W., Cai, Y., Khan, S. U., & Zhao, M. (2021). Decoupling analysis of water use and economic development in arid region of China–based on quantity and quality of water use. Science of The Total Environment, 761, 143275. https://doi.org/10.1016/j.scitotenv.2020.143275

Zhou, Z., Liu, J., Zhou, N., Zhang, T., & Zeng, H. (2021). Does the" 10-Point Water Plan" reduce the intensity of industrial water contamination? Quasi-experimental evidence from China. Journal of Environmental Management, 295, 113048. https://doi.org/10.1016/j.jenvman.2021.113048