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Is the environmental Kuznets curve related to the fishing footprint? Evidence from China

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ABSTRACT

This study tests the validity of the environmental Kuznets curve (EKC) hypothesis by using the fishing grounds footprint (FGF) as the environmental degradation indicator in China from 1961 to 2017. The study also uses China's total fisheries production as a control variable. Since the results of the analysis indicate a long-run relationship between the variables, we estimate the long- and short-run coefficients that present evidence for the validity of the EKC in the long-run. We find that total fisheries production has a detrimental effect on the environment. The findings of the study have important policy implications for decision-makers: Implementing a common fishing policy at the regional and global levels to stabilize the FGF and using new technologies that are harmless to the environment at every stage of fishery production processes may be beneficial for the environment.

1. Introduction

In recent years, increasing attention has been paid to environmental pollution and its economic impacts because of climate change and global warming concerns. One outstanding approach, the environmental Kuznets curve (EKC) hypothesis, proposes an inverted U-shaped relationship between environmental pollution and economic growth; environmental pollution increases in the early stages of economic growth and then decreases as per capita income reaches its peak level. Pioneering findings presented by Grossman and Krueger (1995) support the EKC hypothesis, which means that economic growth in low-income economies will negatively affect the environment while growth does not harm the environment in high-income economies.

The EKC hypothesis has been tested by employing various econometric techniques. The vast number of empirical studies provide evidence supporting the validity of the EKC hypothesis different samples and with different indicators of environmental pollution (Apergis and Ozturk, 2015; Aslan et al., 2018; Bilgili et al., 2016; Chang, 2009; Destek et al., 2018; Lee et al., 2010; López-Menéndez et al., 2014; Markandya et al., 2006; Shahbaz et al., 2013). Different indicators, such as CO_2 emissions, ecological footprint, and water pollution rate are used in testing the validity of the EKC hypothesis. Destek et al. (2018) argued that another issue, as important as the validity of the hypothesis, is which environmental pollution indicator is employed while testing the relationship between environmental pollution and economic growth. Existing studies extensively use CO_2 emissions as the indicator while testing the existence of an inverted U-shaped relationship. However, Al-Mulali et al. (2015) and Destek et al. (2018) argued that it would be more appropriate to use the ecological footprint than an indicator that reflects just a limited dimension of environmental pollution, such as CO_2 emissions.

The ecological footprint was first introduced into the literature by Wackernagel and Rees (1996) as an indicator of sustainability and sustainable development. They constructed the ecological footprint as a computational indicator that measures the consumption of natural resources and the assimilation capacity needed for waste generated in the economy. According to the World Wildlife Fund and Kitzes et al. (2007), the ecological footprint has six components: grazing land, fishing grounds, cropland, forest area, built-up land, and carbon footprint. While testing the validity of the EKC hypothesis, employing one of the components of the ecological footprint may add a unique contribution to the existing literature.

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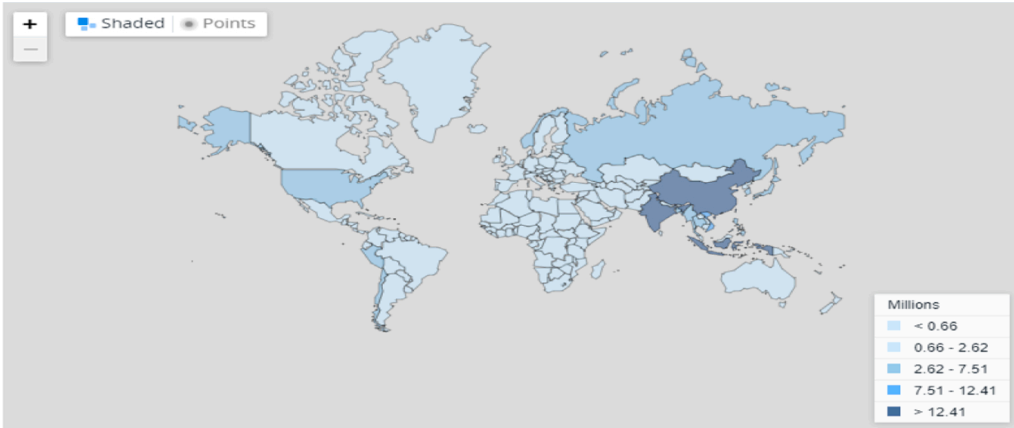

Fig. 1. Total fisheries production worldwide.
Source: World Development Indicators (World Bank)

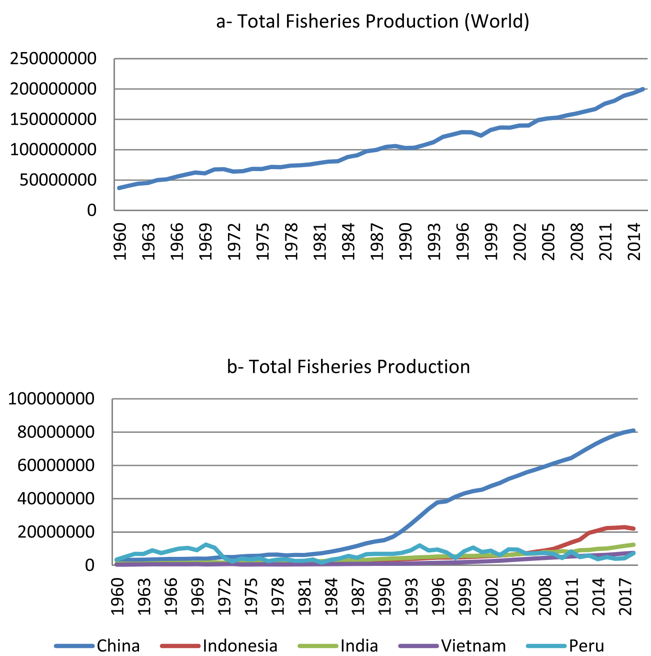

Fig. 2. Total Fisheries Production (metric tons).
Source: World Development Indicators (World Bank)

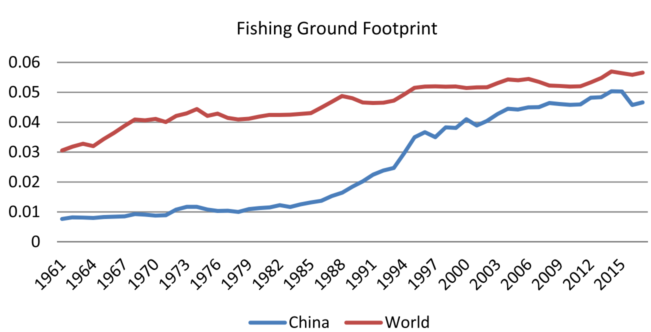

Fig. 3. : Fishing Ground Footprint (Number of Earths).
Source: Global Footprint Network

The present study deals with the fishing grounds footprint (FGF) as an environmental indicator. The FGF is the saltwater and freshwater area needed for consumed marine products. Fishing grounds are one of the main areas in terms of biological capacity. Global fish production reached approximately 179 million tons in 2018. Of this amount, 156 million tons is utilized for human consumption while 22 million for nonfood usage. In 2018, China accounted for 35% of the global fisheries production, followed by other Asian countries (34%), the Americas (14%), Europe (10%), Africa (7%), and Oceania (1%). Except for limited fluctuations in Europe and the Americas, fisheries production has increased significantly in recent years (Food and Agriculture Organization, 2020).

Fig. 1 displays the ranking of countries according to their total fisheries production. As can be seen from Fig. 1, that the top five fishery-producing countries are China, Indonesia, India, Vietnam, and Peru. Fig. 2 shows that total fisheries production has increased gradually since 1960. Panel b reveals that China has a sharply upward trend in total fisheries production when compared to the other important producers.

The Food and Agriculture Organization (2020) reported that per capita fisheries consumption has doubled globally since 1960. Considering the expectation that the world population will exceed 9 billion in 2050, one can easily predict that global fisheries consumption will continue to increase. Therefore, the need for reformative policy implementations and technological developments that will encourage sustainable fisheries production have become more urgent not only because of the increasing consumption but also because of existing challenges, such as water pollution and damage to biodiversity as a result of overfishing. The FGF can be a suitable environmental indicator for monitoring such risks to avoid any pitfalls. Fig. 3 shows that the FGF has been rising since 1961. The upward trend in the ecological footprint indicators has made testing the stationarity properties of all components, including the FGF, attractive in recent years (see Solarin et al., 2019, 2021; Ulucak and Lin, 2017; Yilanci et al., 2019).

According to Solarin et al. (2021), the nonstationary property of the FGF indicates that policy shocks created by technological innovations may reduce environmental degradation permanently. In addition, one may observe that the existing literature does not provide sufficient empirical evidence in terms of the effects of fishing activities on economic growth through the EKC hypothesis framework.

Unlike the previous studies, this study aims to investigate the validity of the EKC hypothesis using for China using the FGF from 1961 to 2017. As shown in Fig. 3, the course of the FGF in China shows that it has increased approximately from the beginning of the 1980s to 2015. To the best of our knowledge, this is the first study testing the validity of the EKC hypothesis using the FGF in China. The remaining sections of the paper deal with the following: The existing literature is discussed in Section 2, the model and the data are introduced in Section 3, and the empirical findings are reported and discussed in Section 4. Finally, the main results are evaluated in conclusion.

Table 1
Literature review on the EKC hypothesis.

Author (s)	Time / Country (Group)	Method	Environmental Indicator	Relationship
Saqib and Benhmad (2021)	1995 – 2015 / 22 European Countries	Panel Data Analysis (DOLS - FMOLS)	Ecological footprint	Yes
Udemba (2021)	1979–2018/ China	ARDL Bound Testing and VECM Granger Causality	Ecological Footprint	Yes
Yilanci and Pata (2020)	1965–2016 / China	Fourier ARDL Procedure and time-varying causality test	Ecological footprint	No
Dogan et al. (2020)	1980–2014 / BRICS-T	Panel Data Analysis (Pedroni Cointegration – FMOLS and DOLS)	Ecological footprint	No
Altintas and Kassouri (2020)	1990–2014 / 14 EU Countries	Panel Data Analysis (Westerlund Cointegration)	Ecological footprint and CO_2	EF (Yes) CO_2 (No)
Ansari et al. (2020)	GCC countries / 1991–2017	Panel Data Analysis (Westerlund Cointegration / FMOLS and DOLS)	Ecological footprint	No
Destek and Sarkodie (2019)	1977–2013 / 11 Countries	Panel Data Analysis (AMG)	Ecological footprint	Yes
Destek et al. (2018)	1980 – 2013 / EU countries	Panel Data Analysis (FMOLS-DOLS)	Ecological footprint	Yes
Abid (2017)	1990–2011 / 41 European countries	Panel Data Analysis (GMM)	CO_2	No
Almeida et al. (2017)	6 period years / 152 Countries	Panel Data Analysis	Environmental Performance Index	No
Al-Mulali et al. (2015)	1980–2008 93 Countries	Panel FE, GMM	Ecological footprint	Mixed results
Hervieux and Darné (2015)	1961–2007 / 7 Latin American countries	Time series cointegration and OLS	Ecological footprint	No
Kasman and Duman (2015)	1992–2010 / EU-15	Panel Data Analysis (FMOLS)	CO_2	Yes
López-Menéndez et al. (2014)	1996–2010 EU27	Panel Data Analysis (FE and RE)	CO_2	Yes
López-Menéndez et al. (2014)	EU countries / 1990–2008	Panel Data Analysis (OLS)	GHG	Mixed results
Lapinskienė et al. (2014)	1995–2010/ EU-27	OLS	GHG	Mixed results
Shahbaz et al. (2013)	1965–2008 South Africa	ARDL bound testing pairwise Granger causality	CO_2	Yes
Lee et al. (2010)	1980–2001 Europe and other regions	Panel GMM	Water pollution	Yes
Chang (2009)	1981–2006 / China	Johansen cointegration VECM Granger causality	CO_2	Yes
Bagliani et al. (2008)	2001 / 144 Countries	Panel Data Analysis (OLS, Weighted LS)	Ecological footprint	No
Markandya et al. (2006)	1870–2001 / EU12	Panel Data Analysis (FE and RE)	SO2	Yes

2. Literature review

Most environmental economics studies focus on the EKC hypothesis, the pollution haven hypothesis, and stationarity analysis (Yilanci et al., 2019, p. 270). Those types of studies use CO_2 emissions as an environmental indicator. However, the ecological footprint has also been referred to as an environmental indicator because it is more inclusive with many subcomponents. Yet, the ecological footprint is not used widely as an indicator of environmental degradation. Indeed, if one examines the related literature, there is a limited number of studies regarding whether the EKC hypothesis is valid for the FGF. Therefore, we employ the FGF to represent environmental degradation in this study. At this point, we divide the literature review into two parts. First, we review the studies focused on the FGF and then discuss the literature on the validity of the EKC hypothesis.

There are many studies in the literature focusing on various dimensions of the FGF (Jennings et al., 2012; Kavadas et al., 2015; Kroodsma et al., 2018; Petrossian, 2018; Pitcher and Cheung, 2013; Port et al., 2016; Russo et al., 2019; Swartz et al., 2010). However, there is a limited number of studies examining the economic and socioeconomic effects of the FGF in the literature. Solarin et al. (2021) examined the stochastic properties of the FGF of 89 countries using fractional integration analysis. The findings of this study showed that most of the series are not stationary and that overall, the policies that aim to reduce the FGF may be effective in most of the selected countries. Kassouri (2021) investigated the dynamics of the FGF in 12 countries located between the Gulf of Guinea and the Congo Basin, over the 1990–2017 period. Findings suggested poor results for the FGF convergence, which means that the degree of environmental pollution is not similar among the studies countries. In addition, the FGF is projected to increase by 2030, except in Ghana and Guinea. Yilanci et al. (2019) investigated the stationarity of the ecological footprint and its components by using a panel stationarity test with soft and sharp breaks in 25 OECD countries from 1961 to 2013. The findings suggested that the FGF is not stationary and that the environmental policy implications that focus on the FGF will have a permanent effect in the long-run. Solarin et al. (2019) investigated the convergence of six components, including the ecological footprint and FGF, in 92 countries over the 1960–2014 period. Unlike other studies, they applied a club convergence test and found ten convergence clubs for the ecological footprint and two convergence clubs for the FGF. The overall suggestion of the study is that environmental policies should be considered by all countries. Ulucak and Lin (2017), on the other hand, employed stationarity tests using all components of the ecological footprint. Using Fourier unit root tests, they concluded that neither the ecological footprint nor the FGF is stationary.

A review of the studies investigating the EKC hypothesis shows that the ecological footprint is predominantly employed as an environmental indicator. Besides, there are other studies that use the CO_2, SO_2, NO_X, and water pollution rate as proxies for environmental degradation. However, to the best of our knowledge there is not any study that tested the validity of the EKC hypothesis using the FGF.

On the one hand, Chang (2009), Destek and Sarkodie (2019), Destek et al. (2018), Kasman and Duman (2015), Lee et al. (2010), López-Menéndez et al. (2014), Markandya et al. (2006), Saqib and Benhmad (2021), Shahbaz et al. (2013), and Udemba (2021) confirmed the validity of the EKC hypothesis in different samples. On the other hand, Abid (2017), Almeida et al. (2017), Ansari et al. (2020), Bagliani et al. (2008), Dogan et al. (2020), Hervieux and Darné (2015), and Yilanci and Pata (2020) concluded that the EKC hypothesis is not valid. Moreover, Al-Mulali et al. (2015), Altıntaş and Kassouri (2020), Lapinskienė et al. (2014), and López-Menéndez et al. (2014) illustrated that the EKC hypothesis may or may not be valid, depending on the selected model and sample. A summary of the literature is presented in Table 1.

Therefore, there is no consensus in the related literature because of the conflicting results that may be stemming from the method, selected sample, and control variables. The point where our study differs from the literature is the consideration of the FGF as an environmental indicator. In addition, policy recommendations based on the selected period, sample, and the method will also contribute to the literature.

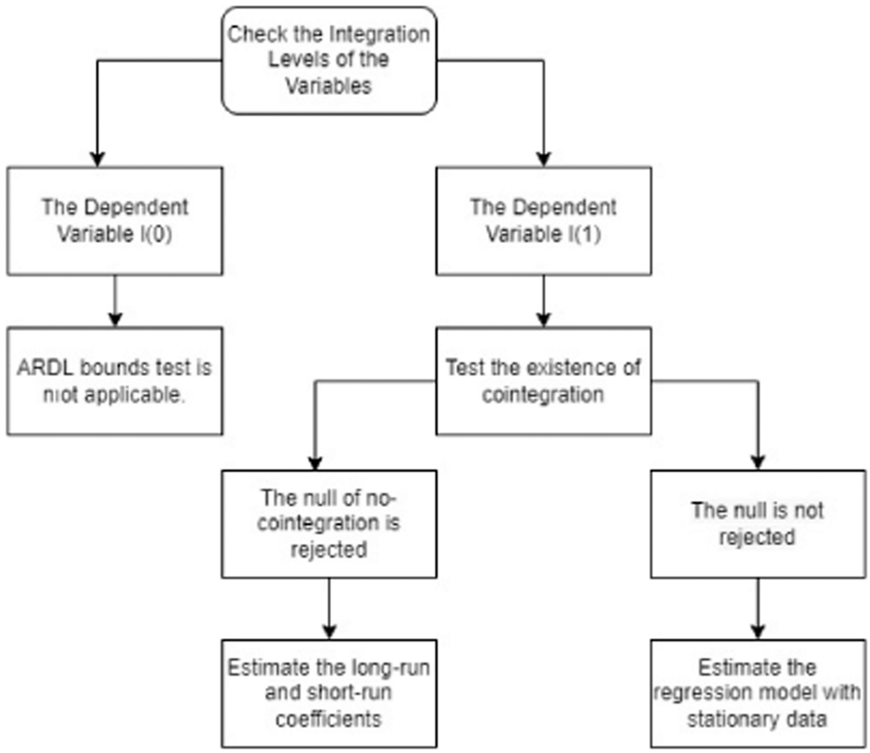

Fig. 4. Flow chart of methodology research.

3. Data and econometric method

In this study, we test the EKC by considering FGF as an environmental degradation indicator for China from 1961 to 2017 using annual data. For this purpose, we employ the following model:

$$\ln FGF_t = \beta_1 + \beta_2 \ln GDP_t + \beta_3 \ln GDP_t^2 + \beta_4 \ln FISH_t + e_t, \quad (1)$$

where FGF_t, GDP_t, GDP_t^2, and $FISH_t$ show the FGF, gross domestic product (GDP), square of GDP, and total fisheries production, respectively. The FGF series is obtained from the open data platform of the Global Footprint Network[4] and shows the demand for marine water ecosystems that is required to support aquaculture and resupply harvested seafood. GDP is measured as constant 2010 US$ and retrieved from the open data service of the World Bank.[5] The total fisheries production series describes the volume of aquatic species caught by a country for nearly all purposes, measured as metric tons, and obtained from the data service of the World Bank. We retrieved all series as per capita and in logarithmic forms.

We employ the autoregressive distributed lag (ARDL) bounds test approach to cointegration, which was introduced by Peseran et al. (2001) to test the EKC described in Eq. (1). There are several reasons for using the ARDL method. First, this test allows for flexibility in testing the long-run relationship among the variables by allowing the regressors to have mixed orders of integration. Second, it has desirable properties with small samples (see Narayan, 2005). Third, the test allows the regressors to have different lag orders (Thao and Hua, 2016). We present a flow of the method in Fig. 4.

As shown in Fig. 4, we must first test the stationarity levels of the variables. We can apply the ARDL bounds test in the case of an integrated dependent variable and estimate the long- and short-run coefficients when we reject the null of no cointegration.

We reformulate Eq. (1) in an unrestricted error correction form as follows:

$$\ln FGF_t = \delta + \beta_1 \ln GDP_{t-1} + \beta_2 \ln GDP_{t-1}^2 + \beta_3 \ln FISH_{t-1} + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln FGF_{t-i} + \sum_{i=1}^{p} \alpha_{2i} \Delta \ln GDP_{t-i} + \sum_{i=1}^{p} \alpha_{3i} \ln GDP_{t-i}^2 + \sum_{i=1}^{p} \alpha_{4i} \ln FISH_{t-i} + e_t \quad (2)$$

where p and Δ show the optimal lag length and the first backward difference operator, respectively. We can test the null hypothesis of no cointegration ($H_0 : \beta_i = 0; \forall_i = 1, 2, ., 4$) by using the usual F test statistic. The critical values can be obtained from Peseran et al.'s (2001) study, in which two sets of critical values computed: The first set was computed based on the assumption that all variables are I(1), which is the upper bound, and the second set was computed by assuming all variables are stationary at level, which is the lower bound. The null hypothesis can be rejected when the test statistic is higher than the upper bound and cannot be rejected if the test statistic is below the lower bound. There is inconclusive case when the test statistic lies between two bounds.

When we reject the null hypothesis, long-run coefficients can be estimated using Eq. (1). To compute the short-run coefficients, we estimate the following regression:

[4] https://data.footprintnetwork.org/.
[5] https://data.worldbank.org/.

Table 2
Results of unit root tests.

Series	ADF		PP		ZA	
	Constant	Constant & Trend	Constant	Constant & Trend	Model A	Model C
lnFGF	-0.592 (0.864)	-1.416 (0.845)	-0.682 (0.843)	-1.156 (0.910)	-3.432 [1989]	-2.684 [1994]
lnFISH	-0.354 (0.909)	-3.141 (0.109)	0.076 (0.961)	-1.907 (0.638)	-4.806*[1991]	-3.335 [1991]
lnGDP	2.002 (1.000)	-1.836 (0.673)	2.402 (1.000)	-2.272 (0.442)	-3.427 [1974]	-5.178** [1976]
lnGDP^2	3.360 (1.000)	-2.923 (0.165)	4.068 (1.000)	-1.681 (0.747)	-2.769 [1974]	-3.540 [1976]

Notes: ** shows the statistically significance at the 5% level. Critical values at the 1%, 5%, and 10% levels for the Model A are − 5.57, − 5.08, and − 4.82, and for the Model C are − 5.34, − 4.93, and − 4.58 for the ZA unit root test. Numbers in the parentheses show the p-values, and numbers in the brackets indicate the breakpoint dates.

Table 3
Results of the ARDL bounds test.

Model	F Test Statistics	Selected Model
LnFGF=f(LnGDP, LnGDP^2,LnFISH)	4.949*	(2, 3, 0, 4)

Note: * indicates the significance at 1% level. Critical values at the %1 level for the lower bound is − 3.65 while for the upper bound is − 4.66, respectively.

$$\Delta \ln FGF_t = \delta + \sum_{i=1}^{p_1} \alpha_{1i} \Delta \ln FGF_{t-i} + \sum_{i=0}^{p_2} \alpha_{2i} \Delta \ln GDP_{t-i} + \sum_{i=0}^{p_3} \alpha_{3i} \ln GDP^2_{t-i} + \sum_{i=0}^{p_4} \alpha_{4i} \ln FISH_{t-i} + \theta ECT_{t-1} + u_t \quad (3)$$

where ECT_{t-1} indicates the error correction term, which must have a coefficient between 0 and − 2 and be statistically significant to ensure that after a deviation from the long-run equilibrium, the dependent variable returns to equilibrium.

4. Empirical findings

The precondition for employing the ARDL bounds test is that the dependent variable must be integrated at the first difference. To determine whether variables fulfill this condition, we employ the augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Zivot-Andrews (ZA) unit root tests to examine the stationarity properties of the considered variables. Table 2 shows the results.

The results of the traditional unit root tests, which do not account for structural breaks in the data generation process, show that all series have a unit root. However, the ZA unit root test results show that FISH is stationary when we allow for a break in intercept (Model A) and that GDP is stationary when we consider a structural break in both intercept and trend (Model C). Overall, according to all test results, the findings satisfy the condition that the dependent variable (FGF) is stationary.

The breakpoint dates can be evaluated as follows:

Table 4
Long-run coefficients.

Method	Intercept	LnGDP	LnGDP^2	LnFISH
ARDL	-4.897 (−3.447)*	1.117 (3.743)*	-0.075 (−4.207)*	0.681 (9.241)*
FMOLS	-4.412 (−4.531)	0.941 (4.669)	-0.063 (−5.143)	0.669 (11.745)
DOLS	-5.73 (−5.091)	1.271 (5.261)	-0.084 (−5.769)	0.627 (10.522)

Note: * indicates the significance at the 1% level. Numbers in the parentheses show the t-statistics.

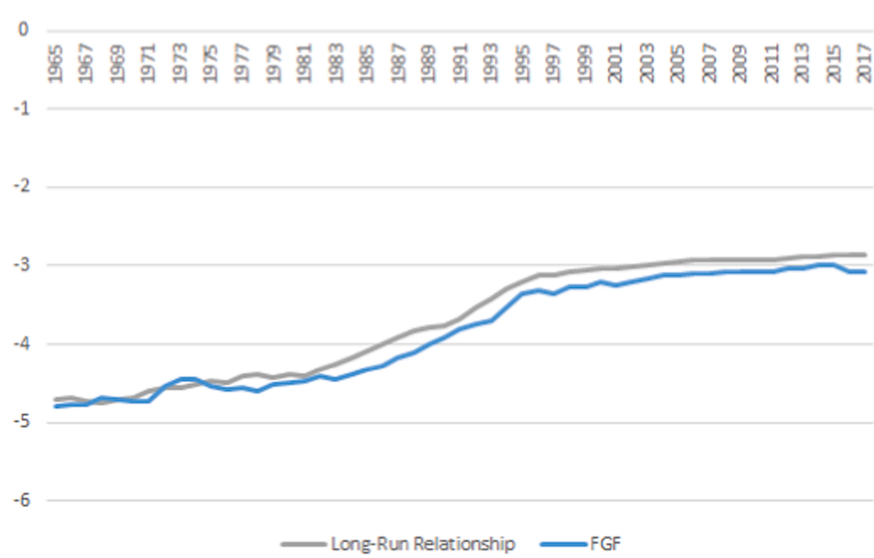

Fig. 5. Dependent variable and fitted series.

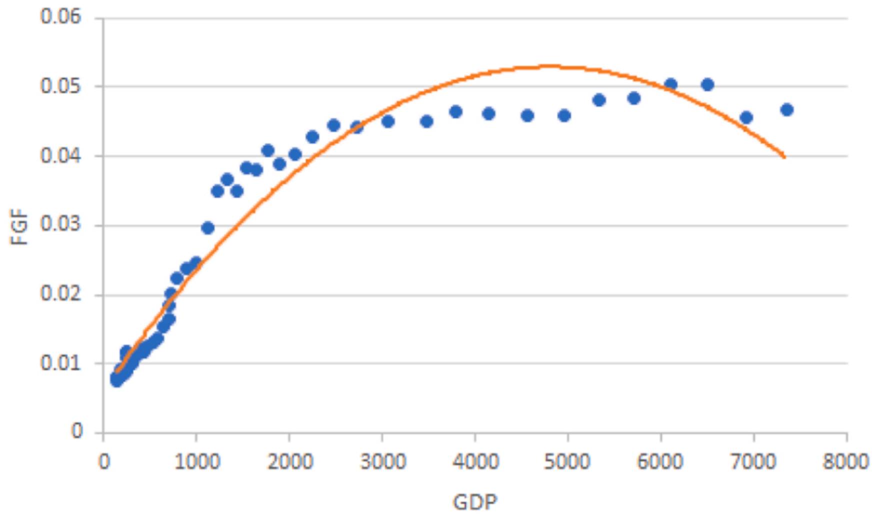

Fig. 6. Investigation of the EKC.

Table 5
Short-run coefficients.

Variables	Coefficients
$D(FGF_{t-1})$	0.328 (2.726)*
$D(GDP_t)$	0.74 (3.455)*
$D(GDP_{t-1})$	-0.44 (−2.608)**
$D(GDP_{t-2})$	0.266 (1.753)***
$D(FISH_t)$	0.399 (2.945)*
$D(FISH_{t-1})$	-0.286 (−1.807)***
$D(FISH_{t-2})$	0.193 (1.342)
$D(FISH_{t-3})$	-0.331 (−2.417)**
DU(1976)	-0.079 (−3.879)*
ECT	-0.68 (−5.223)*

Note: *, **, and *** indicate significance at the 1, 5, 10% levels, respectively. Numbers in the parentheses show the t-statistics.

- In 1974, global production costs began to fall after the OPEC countries lifted the embargo that caused the oil crisis.
- In 1976, China experienced one of the most significant earthquakes in history. Over 240,000 people lost their lives in the 7.8 magnitude earthquake, which occurred in the city of Tangshan, in northeast China.
- The year 1989 is associated with the event that occurred in Beijing's Tiananmen Square.
- The year 1991 is the end of the period known as the Cold War. The rivalry between Soviet Russia and the United States ended with the collapse of the Soviet Union in 1991. As part of the Eastern Bloc, China's siding with the Soviet Union has led to significant changes in its socioeconomic status and in many other of its sectors.
- The South China Sea region has a population of over 2 billion. In addition, more than half of the fishing boats in the world are there. The main round trip route of Pacific and Indian Ocean ports passes through the Strait of Malacca and the South China Sea. Besides, large oil and natural gas reserves, whose total value is estimated at more than $5 trillion, have been discovered in the South China Sea. *The UN Convention on the Law of the Sea* came into force, which was signed by over 160 countries in 1994 and sets up the framework for regulating the oceans and their uses. This agreement may be the reason of the breakpoint that detected in 1994.

Next, we apply the ARDL bounds test to investigate the existence of the cointegration relationship. To consider the 1976 Tangshan earthquake, we add a dummy variable to capture its effect. Table 3 presents the test results.

Based on the test results in Table 3, we can conclude that there is a long-run relationship between the considered variables for China since the test statistic is found to be higher than the critical values at the upper bound. We also visualize the fit between the equilibrating equation and the dependent variable in Fig. 5.

A visual inspection of Fig. 5 also confirms the validity of the relationship. Therefore, we can estimate the long- and short-run coefficients. Table 4 shows the results of the long-run model estimation. In addition to the long-run form of the ARDL, we also use Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) methods to reveal whether the findings are robust for the estimation method.

The findings in Table 4 show that all coefficients are statistically significant and that the results are fairly similar to each other. While the slope coefficient of GDP ranges from 0.941 to 1.271, the coefficient of GDP^2 varies between − 0.063 and − 0.084, and the coefficient of FISH ranges from 0.627 to 0.681. Taken together, we can conclude that the EKC is valid in China for the FGF because the coefficient of GDP is positive, while the coefficient of GDP^2 is negative. This result is consistent with Chang (2009), Sarkodie and Strezov (2018), and Sarkodie et al. (2020), all of whom validated the EKC hypothesis using CO_2 emissions in China as well as Udemba (2021) who confirmed the validity of the EKC hypothesis using the ecological footprint.

We also compute the turning point, which implies FGF turns from an increasing to a decreasing tendency in parallel with economic growth.[6] The findings of the long-run form of the ARDL model yield a turning point of $3207.053, which is depicted in Fig. 6. After the turning point, improvements in the environment are expected. This result shows the existence of the inverted U-shaped relationship between environmental degradation and economic growth in China. There are other studies that estimate the turning point of environmental degradation in China, such as Grossman and Krueger (1995), who estimated the turning point as $4053.

Similarly, Sarkodie and Strezov (2018) found $4874 using CO_2 emissions, and Sarkodie et al. (2020) found $5863 and $5469 using the ecological footprint and CO_2 emissions, respectively. One may infer that employing FGF yields different turning points from those found in the studies that used the other environmental indicators. It is hard to say that the estimated turning point for the FGF is consistent with the

[6] To compute the turning point, we exclude the LnFISH from the analyses and repeated all of them using LnFGF as the dependent variable and LnGDP and $LnGDP^2$ as the regressors; we also included the effect of the 1976 earthquake by adding a dummy variable to the model.

turning points estimated for the ecological footprint and CO_2 emissions. As known, China has the largest population and fisheries production in the world. One can infer that the fishing industry is one of the primary fields of activity owing to the existing production level and potential opportunities, which may prove that the FGF is prioritized in terms of environmental awareness and thus, the turning point is achieved at a much earlier level compared to the ecological footprint and CO_2 emissions. On the other hand, fisheries production is expected to be a smaller sector in terms of its GDP share compared to other industries in China. Thus, fisheries production may cause a lower environmental degradation than conventional industrial production if the FGF's turning point is lower than the CO_2 emissions and the ecological footprint.

The results in Table 4 also show that fisheries production seems to have a detrimental effect on environment in China. These findings, which show that the EKC hypothesis is valid in China in terms of the FGF, draw an image compatible with the theoretical approach and China's increasing fisheries production. In other words, the findings show that the FGF in China will continue to increase up to a certain level in GDP and then will decline. The FGF should be considered a remarkable environmental indicator in terms of environmental pollution for China because the increase in fisheries production also puts negative pressure on the environment. As to Solarin et al.'s (2021) results and to findings of unit root test of the present study, the FGF is not stationary. Therefore, policy shocks based on technological innovations to reduce the FGF can contribute to the reduction of environmental pollution (Solarin et al., 2021).

The results in Table 5 prove that the error correction mechanism is working because the ECT_{t-1} value is significant and lies between 0 and -1. One lagged value of FGF has an increasing effect on the current value itself, and lagged values of GDP and GDP^2 seem to have a decreasing impact on FGF. Moreover, FISH has an increasing effect on FGF in the short-run, which shows that FISH is harmful to the environment. Similar studies, such as Yilanci and Pata (2020), suggested that the EKC hypothesis is not valid for China. Similarly, Dogan et al. (2020) concluded that the EKC hypothesis is not valid when the ecological footprint is considered in the BRICS-T countries (except for Russia, due to data unavailability). On the other hand, Udemba (2021) suggested that the EKC hypothesis for the same environmental indicator is valid for the 1978–2018 period. Solarin et al. (2020) also argued that the EKC hypothesis is valid when the ecological footprint and CO_2 emissions are used as variables. Both the long- and short-term findings of the present study show that the production of fisheries products increases environmental pollution. Therefore, the goal should be to implement and production-oriented technological improvements as soon as possible to reduce the harmful environmental effects of fisheries production.

To check the validity of assumptions in the ARDL model, we apply several diagnostic tests and present them in the Appendix. The findings support the evidence of no first order and second-order serial correlations because the p-values of the Lagrange Multiplier (LM) autocorrelation test are higher than the traditional significance levels. The results also confirm the validity of the homoscedasticity assumption for the model due to the high p-value of the Breusch–Pagan heteroskedasticity test and since the residuals are normally distributed because the p-value of the Jarque–Berra test is higher than the significance level. There is no model specification problem because the findings show that the p-value of the RESET test is higher than the significance levels. Because R^2 is close to 1, we can conclude that the fit of the model is very good. We use the CUSUM and CUSUM-SQ tests to evaluate the stability of the coefficients. The results in Fig. A confirm that the model is stable and that the estimated coefficients are suitable for the dependent variable to predict the future.

5. Discussion

Economic growth is an essential condition for excelling in global competition. Although the World in general has been experiencing sustained economic growth, the processes carried out without environmental awareness are causing important universal disasters, such as the climate crisis and global warming. In recent years, various international agreements and protocols have been drawn up through many institutions and organizations to reduce environmental pollution with the collaboration of numerous countries. As the number of counterparties to such agreements increase and the applicability of the agreements improves, environmental quality will be enhanced by economic growth. One of the best explanations for this process in the literature is the EKC hypothesis, which argues that the relationship between environmental pollution and economic growth is in an inverted U shape.

Ecological footprint and CO_2 emissions are among the most employed environmental degradation indicators in the EKC hypothesis research. The objective of the present study was to test the EKC hypothesis by using the FGF as an indicator for the environmental degradation. As of 2018, China conducts 35% of the world's fisheries production. China's FGF has constantly been increasing, especially since 1980. Therefore, as the second-largest economy and the biggest fishery producer, by considering China as the base country, we contribute to the related literature in terms of recommending sustainable fisheries activities based on the prevention of environmental pollution. Moreover, the present study, to the best of our knowledge, is the first in the literature to test the validity of the EKC hypothesis by using the FGF as an environmental indicator.

We first checked the stationarity properties of the series. The results of the unit root tests show that the FGF series has a unit root, which indicates that implemented policies that aim to reduce the FGF will be successful. One may observe several environmental degradation problems, such as marine pollution caused by using unsustainable methods in fisheries activities and the lack of clean production technologies. Therefore, reducing the FGF depends on the comprehensive policy implications that cover the beginning of the production process and the final stage where consumers are involved.

After that, the EKC hypothesis was tested using the ARDL bounds test. The results show that the EKC hypothesis is valid for China. In other words, as economic growth increases in China, at first, the FGF increases. Then, after the growth reaches to a certain point, it begins to decrease. Similarly, Solarin et al. (2020) and Udemba (2021) confirmed the validity of the EKC in China using different environmental indicators, such as the ecological footprint and CO_2 emissions. We also revealed that the EKC hypothesis occurs at a turning point of $3207.053. This result is lower than the turning point of $4874 found by Sarkodie and Strezov (2018) and the turning point of $5469 found by Sarkodie et al. (2020), both using the CO_2 emissions. The validity of the EKC hypothesis implies that economic growth will contribute to reducing environmental degradation that occurs on fishing grounds in the medium and long-term. In recent years, the Chinese economy has experienced a high growth rate using an export-oriented policy production structure, which has made China's economy the second-largest in the world. However, it is not easy to implement precautionary policies for the environmental problems in less-developed and developing countries. Moreover, this challenge makes the emerging economies more desirable in terms of new investments in conventional sectors, thus contributing to more environmental degradation. As the validated EKC hypothesis suggests, reaching a high GDP per capita will reduce environmental degradation. Although the Chinese economy is the second-largest globally, it is hard to say that the economy achieved a high per capita income level ($10,370.40 in 2020 with constant 2015 US$). Reflecting the economic growth to the Chinese people's welfare may contribute to reducing environmental degradation. In this way, the FGF may be decreased, providing cleaner and more productive fishing activities. Furthermore, fisheries production has a detrimental effect on the FGF in China if one considers the ARDL bounds test results. This implies that environmentally harmful production techniques have a significant role in fisheries production in China. To prevent this detrimental effect, one may suggest implementing less harmful and innovative production techniques.

In summary, this study contributes to the existing literature in several ways. First, as far as our literature survey suggests, this is the first study that tests the validity of the EKC hypothesis using the FGF. Second, we believe that our study presents original findings for China the largest fisheries producer in the world. Third, the study uses various econometric techniques and estimates the turning point where the FGF is maximum. Finally, we propose some policy implications and research areas for policymakers, sector representatives, and new researchers from a multidisciplinary perspective.

As a result, the long-term findings of the current study confirm the validity of the EKC hypothesis in China. We also confirm that economic growth and more fisheries production increase the FGF in the short-term. This result implies that it is necessary to develop new policies to reduce the environmental damage caused by fisheries production. In this context, the use of technological innovations that can make a difference in fisheries production should be considered. Afterward, international cooperation should be ensured, and joint policies should be developed for the fisheries sector.

6. Conclusions

To the best of our knowledge, no study tests the validity of the EKC hypothesis using the FGF as an indicator of environmental degradation. There are studies on the FGF that are mainly focused on sectoral and technical issues (Jennings et al., 2012; Kavadas et al., 2015; Kroodsma et al., 2018; Petrossian, 2018; Pitcher and Cheung, 2013; Port et al., 2016; Russo et al., 2019; Swartz et al., 2010). One can consider that our study has the potential to make an important contribution to the literature because it deals with the economic and socioeconomic dimensions of the FGF.

The results of the unit root tests show that FGF has a unit root. This result is in line with the findings reported by Kassouri (2021), Solarin et al. (2019, 2021), Ulucak and Lin (2017), Yilanci et al., (2019, 2022). The results of the ARDL bounds test indicate that the EKC hypothesis is valid for China. As we previously discussed, many studies employ various environmental indicators to test the validity of the EKC hypothesis. Because the EKC hypothesis is not analyzed using the FGF, the literature comparison was conducted with studies that employ other environmental indicators.

The findings of this study are in line with those reported on China by Chang (2009), Sarkodie and Strezov (2018), Sarkodie et al. (2020), and Udemba (2021). Contrarily, our analysis suggests different results than those from Yilanci and Pata (2020). This contradiction may be mainly caused by the difference in the variable used as an environmental indicator, the method, and the studied period.

Based on the findings, several policy recommendations can be made separately for new research, those operating in the fishery sector, and policymakers. First, researchers have a new area to test the EKC hypothesis validity in different samples using the FGF. Also, one can investigate the effects of the fishing footprint on marine products exports to reveal the relationship between environmental degradation and foreign trade.

Second, actors operating in the fishing sector need to use new technologies that are harmless to the environment at every production stage. Therefore, the industry needs to follow and adopt innovative developments in the production stages. In this context, new technological developments, such as artificial intelligence, unmanned aerial vehicles, smart weighing at sea, big data, and blockchain, should be examined and adapted to the industry. Furthermore, fisheries producers need to use ship tracking technologies to reduce the use of environmentally damaging fishing gear and destructive fishing activities. Fishing sector representatives should take joint action regarding fishing seasons, production structuring, institutional decisions, and international cooperation.

Finally, policymakers should implement structural reforms that will increase per capita income. Indeed, studies on the EKC hypothesis show that environmental problems are constantly increasing in countries that have not yet achieved economic welfare. For this reason, policies that will increase national income and welfare, especially by increasing the production of high value-added goods, should be prioritized, and stable growth policies should be formulated since the environmental awareness of households increases after a certain economic growth performance. Therefore, it is necessary to carry out studies and projects in cooperation with public institutions, non-governmental organizations, and universities to improve environmental awareness.

Because most environmental problems occur due to the existing nonrenewable energy resources, governments should implement new policies to use more renewable energy sources, mainly to decrease environmental degradation in the production process.

Developing regional collaborative policies for the fisheries sector (i.e., establishing a common fisheries policy) will play an important role in stabilizing the FGF. Implementing a common fisheries policy at the regional and global level and protecting fishing species in the region with cross-border cooperation may reduce the FGF. Another benefit of this global cooperation would be that it might attract foreign investment in the fishing industry when we consider the increasing importance of foreign direct investment. Developing cooperation in the sector and making institutional arrangements for the stated reasons will also be a positive development leading to more economic growth.

CRediT authorship contribution statement

Veli Yilanci: Conceptualization, Methodology, Writing – review & editing. **Ibrahim Cutcu**: Writing – original draft preparation, Investigation. **Bilal Cayir**: Visualization, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A

See Table A1.
See Fig. A1.

Table A1
Results of model diagnostic tests.

LM Autocorrelation Test		Breusch-Pagan-Godfrey Het. Test	Jarque-Bera Test	RESET Test	R-Squared
First Order	Second Oder				
0.323 (0.57)	1.755 (0.416)	9.178 (0.759)	0.162 (0.922)	0.052 (0.821)	0.997083

Note: Numbers in the parenthesis show the p-values.

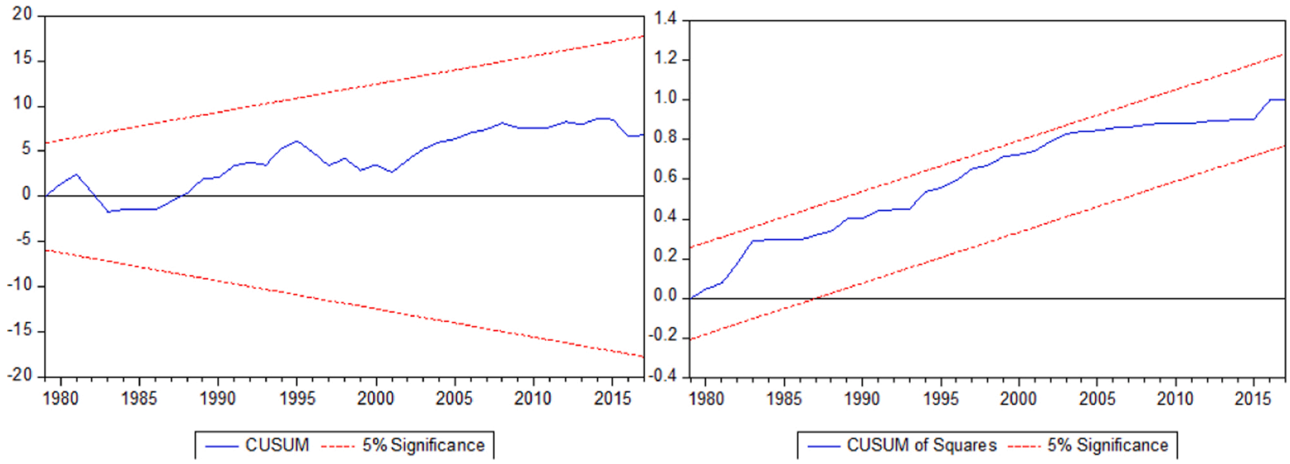

Fig. A1. CUSUM and CUSUM-SQ tests.

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