

## The moderating role of energy consumption in the relationship between trade openness and environmental degradation in Pakistan and China

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**Abstract:** Every country wants to accomplish the sustainable development goal. For this reason, each country protects the environment, expressing widespread concern over environmental degradation. Furthermore, trade is the most essential component of economic growth, and energy is the primary source of production and environmental degradation. Therefore, the study aims to investigate the moderating effect of energy consumption on the link between trade openness and environmental degradation in the case of China and Pakistan. It will utilise data from 1990 to 2020 and employ ARDL and Granger causality estimation techniques. This study revealed that energy consumption and GDP growth are constructive. At the same time, inflow, FDI, and trade openness have negative consequences on CO<sub>2</sub> emission in China, while all the variables have positive effects on CO<sub>2</sub> emission in the case of Pakistan. This study confirms the existence of the Environmental Kuznets Curve and the moderation effect of energy consumption in both countries. This study also found that there exists a one-way causality running from CO<sub>2</sub> to energy consumption and trade openness to CO<sub>2</sub> in the case of China. This study suggested focusing on screening and identifying environmentally friendly enterprises.

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## 1. Introduction

Protecting the environment has been of global importance in recent decades, reflecting broad worries about environmental degradation. In this setting, trade's environmental impact is becoming a rising importance of trade policy. A growing number of empirical researches have been conducted to study the link between trade openness (later on TO) and environmental quality (later on EnQ) (Boulatoff & Jenkins, 2010; Shahbaz et al., 2013). The past literature, both theoretical and empirical findings, are varied, with some indicating a favorable association and others indicating a negative link. Both theory and empirical literature indicate that commerce stimulates growth. To provide one example, China's spectacular ascent was largely driven by its incorporation into the global commercial system. If TO leads to economic growth (later on GDPg), which leads to environmental degradation, impacted nations may adopt stricter environmental rules. They anticipate the use of more ecologically friendly industrial processes to improve environmental quality (Le et al., 2016).

Furthermore, Antweiler et al. (2001) discovered that increased economic openness is related to lower pollution levels as assessed by SO<sub>2</sub>. Baek et al. (2009) demonstrated that commerce and affluence favour EnQ in developed nations and China. However, Boulatoff and Jenkins (2010) discovered an indication of an adverse long-term (later on LR) association between TO and oil-related CO<sub>2</sub> across various socioeconomic categories of nations. However, many scholars revealed that increasing openness might have an adverse impact on EnQ. Theoretically, a country with a competitive advantage in pollution-intensive items may specialize in their production. However, doing so will raise pollutant emissions and negatively impact EnQ. China's development as a universal manufacturing powerhouse is a prime example of fast export expansion accompanied by widespread environmental degradation. This unfavorable assessment of trade's impact on the EnQ is similar to (Kindo et al., 2024).

Energy is a critical source of clean fuels and technology utilized in domestic cooking, power generating, heating, lighting, and everyday monotonous activities. The industrial division entailed more energy to carry out its economic activities, and energy is also a quantitative production input. The job of energy is to meet the market economy's supply and demand to normalize economic activities and produce exportable goods (Ali et al., 2015). Fossil fuel is directly utilized as energy-sources such as petroleum, gas, and coal. The advantage of renewable energy consumption (later on REC) sources is that they are less susceptible to CO<sub>2</sub>, improving air quality and moderating the consequences of climate change (Lau et al., 2016). Following the industrial rebellion, all nations have attempted to achieve high GDPg by energy consumption (*later on EC*); however, the widespread energy use has created an upsetting condition due to high mass CO<sub>2</sub>, which has raised sea levels by approximately 10-20 cm higher than anticipated. The mean global temperature will climb from 1.00° to 3.50° in the 21<sup>st</sup> century. This dire situation has forced the governments to concentrate their planning and efforts on REC, which is a key component of attaining global sustainable development (Nnaji et al., 2013).

Greenhouse Gas emissions (later on GHG) are viewed as an obstacle to attaining sustainable development since they are principally responsible for CO<sub>2</sub>. These gases enter the atmosphere as a result of burning fossil fuels and using agricultural practices (IPCC, 2014). One of the most important facts is that air quality is heavily influenced by fast industrialization (later on IND), flexible environmental criteria, insufficient cleaner production technologies (later on Protech), and un-sustainable consumption and output, all of which are liable on developed economies as they strive for higher GDPg through extreme level of energy-demand, which harms the world's natural plants. China, Russia, the US, Japan, and India were among the significant CO<sub>2</sub> emitters in 2014 (Boden et al., 2016).

Pakistan is a developing economy in Asia. Pakistan is presently ranked sixth among the world's most populous countries. The diminishing contribution of hydro energy was attributed to climatic conditions and a drop in the volume of water in the river (Ministry of Energy-Power Division, 2017). Hydroelectricity is a safe energy source since it emits minimal CO<sub>2</sub>. Chashma, Turbela, Jhelum, Neelum, and a few more tiny dams are examples of free hydro plants operating in the nation. Pakistan's energy consumption from fossil fuels accounted for around 59.70% of overall EC in 2014. The total renewable power generation was around 31% in 2013 and 30.20% in 2014. In 2014, renewable internal freshwater amounted to 55 billion cubic meters. Hydro-energy accounts for around 42.0% of global power output. Coal, oil, and gas all produce thermal energy. Thermal power plants provide over 58% of all electricity in Pakistan. Thermal power plants exist in Multan, Kotaddu, Faisalabad, Jemshoro, Rohri, Karachi, and Hyderabad. Pakistan's overall hydropower resources are estimated to be around 50,000 megawatts (Naz et al., 2019).

Pakistan is an intriguing case study in which TO has increased GDPg and CO<sub>2</sub> during the previous 20 (twenty) years. As a result, establishing whether trade and industrial processes have caused environmental deterioration is critical (Khan et al., 2023). There is no clear consensus about the link between trade and environmental degradation (CO<sub>2</sub>), both empirically and theoretically. One group of researchers argues that trade positively induces environmental deterioration (Awan et al., 2018; Lv & Xu, 2019; Salman et al., 2018). However, another group supports an adverse link between trade and environmental damage (Ozturk & Acaravci, 2010). Moreover, A rising number of empirical researchers have attempted to reveal the size of the link between TO and environmental deterioration (Baek et al., 2009; Hao et al., 2020; Zomorodi & Zhou, 2017). Similarly, the link between REC, FDI inflows, GDPg, and its impression on CO<sub>2</sub> is extensively discussed in EC and EnQ literature; however, there is an unseen area of the moderation and mediation effect of GDPg and IFDI with REC on CO<sub>2</sub> in developing economies like Pakistan (Naz et al., 2019).

Trade liberalization boosts energy consumption by directing funds toward manufacturing expansion. FDI inflows into the industrial industry raise waste emissions and contribute to overall CO<sub>2</sub>. FDI inflows into the host economy as a result of trade were identified as the cause of environmental damage (Qamruzzaman, 2021)Therefore, this study was conducted to

investigate the effect of trade openness on environmental degradation in China and Pakistan. Moreover, it investigates the moderating role of energy consumption in the relationship between trade and environmental degradation.

This research assists policymakers in removing the negative impact of trade on EnQ by using proper policy instruments and promoting Pakistan's commerce in the international market. The main motivation for the study is that too few studies are available on the link between trade and CO<sub>2</sub>. Moreover, this study uses energy consumption as a moderating variable, which was not yet used by the prior studies in the case of Pakistan. This study has significantly contributed to the existing body of literature. This study is different from other studies in many ways. Firstly, this study used an updated data set in the case of Pakistan and China, and the ARDL technique was used for estimation, which is more reliable than other techniques. Secondly, this study used energy consumption as a moderating variable, which was ignored by prior studies to investigate the link between trade and CO<sub>2</sub> emission in the case of China and Pakistan. Thirdly, this study also tests the EKC hypothesis using an updated data set in the case of China and Pakistan. Fourthly, this study significantly contributes to the existing body of literature and opens new areas for researchers.

## **2. Literature review**

### **2.1. Theoretical literature**

Ethnic diversity exists in many nations, which can impact various socioeconomic aspects such as TO and CO<sub>2</sub>. It is more difficult for nations when ethnic variety undermines confidence among nations, obstructs economic agreements, and may impact the environment. Various theoretical models have investigated the link between international commerce and ethnic diversity, with diverse and contentious results, making the current subject more fascinating to investigate (Amin et al., 2021). Mundell (1957) proposed a link between ethnic clusters and commerce, which was later investigated by Samuelson's factor-value equalization. Markusen (1983) changes Mundell's (1957) assumptions to create a more correct and realistic model. The Ricardian model describes trade patterns based on technological differences, as the Comparative Advantage Model states. In contrast, the Heckscher-Ohlin (H-O) model is based on production factors rather than a based-on-technology differential like the Ricardian theory. Two paths clarify the ethnic cluster's trade connection: the 1<sup>st</sup> affects imports, while the 2<sup>nd</sup> affects both exports and imports, but imports to a lesser amount. Gould (1994) uses a gravity model of commerce that includes migration variables to investigate the relationship between bilateral trade and among UK residents and immigrants. Anderson (2011) uses a bilateral trade model to illustrate the influence of migrants on commerce.

According to Alesina et al. (2003), ethnic assortment has been quantified in previous research, mostly just by Ahlerup et al. (2009) using the fractionalization index. Most of the theoretical effort on commerce migration connections regards labour mobility as hazy from the capital.

Allowing immigrants to buy commodities produced in their home nation creates a very clear link between trade and the movement of different ethnic groups. Later, demand for these commodities is projected to rise in home nations due to demonstration effects (Amin et al., 2021). Trefler (1995) advocates for a significant investigation into the function of trade costs and links as a reaction to these trade costs (Combes et al., 2005). The gravity model is a typical method for demonstrating the effects of trade charges. Their model takes the following approach: instead of bilateral commerce (i.e., trade volume of both countries, migrant categories are substituted by ethnic groupings (Amin et al., 2021).

Furthermore, as mentioned by Girma and Yu (2002), the social links of migrants boost international trade as a unified unit, whereas the learned knowledge is group-specific. To save costs, international companies require an understanding of their partners' markets, languages, and cultures. Achieving knowledge is a difficult undertaking owing to geographical distance, both physically and symbolically, and learning about culture is impossible. This raises costs for the foreign countries if other countries have different cultures. The migrants serve as a conduit for the information and expertise that businesses entail for trading with the migrant's nation. Egger et al (2012) concur that the ethnic groupings influence market formation, i.e., the ability to develop new international markets. As a result, a diverse pool of migrants boosts the global trade.

Previous research has shown an enigma related to ethnic diversity, TO, and CO<sub>2</sub> is preferred for investigating this mystery based on cross-sectional or panel data (Montalvo & Reynal, 2005). Ethnic diversity has both detrimental and beneficial effects on GDP. The unfavourable consequences of ethnically diverse economies are attributed to fragile social cohesiveness as a consequence of differences in ethnic group values (Amin et al., 2021) Vigdor (2004) discovered that ethnic groups frequently encounter difficulties in achieving unity and collaborative efforts while spending minimally on items such as the environment. Milem (2003) discovered that students from varied ethnic backgrounds who connect with heterogeneous groups are more active participants in society than those who do not interact. Society must work together to achieve peace and cooperation because the environment is a public benefit that cannot be given without collaborative effort.

Esty (2008) incorporates a variety of environmental factors into his model. Regional ozone, CO<sub>2</sub>, and SO<sub>2</sub> emissions are used to quantify air pollution. Das and DiRienzo (2009) find a nonlinear connection between EnQ and ethnic assortment. Alesina et al. (2003) fractionalization metrics are used in this work to calculate EnQ. Furthermore, the metric of fractionalization and CO<sub>2</sub> emissions per capita are key contributors to air pollution. Das and DiRienzo (2009) have captured SO<sub>2</sub> and water quality. Most research employs CO<sub>2</sub>, such as Newton et al. (2016), regressing the ethnic diversity on CO<sub>2</sub> storage. Among other researchers, Agarwal (2009) and Hossain et al (2010) employ the Simpson's-index to assess the effect of ethnic diversity on the EnQ. The Mauro (1996) contends that political instability and civil war are proxies.

## 2.2. Empirical literature

Antweiler et al. (2001) examine how access to international goods markets influences pollution levels. They create a theoretical model that divides trade's influence on CO<sub>2</sub> into size, method, and composition impacts and then test it using data on SO<sub>2</sub> levels. They discovered that changing the mix of national production through foreign commerce causes only little changes in pollutant concentrations. Evaluations of trade-induced technology and scale effects indicate a net reduction in CO<sub>2</sub>. Combining all three (3) estimates of impacts provides a rather surprising conclusion: free trade looks to be beneficial to the environment. Similarly, He (2006) developed a simultaneous model to investigate the FDI-CO<sub>2</sub> nexus in China, examining both the FDI entrance choice and the connection from FDI entry to ultimate SO<sub>2</sub> outcomes while accounting for size, composition, and method impacts. The model is then calculated using panel data representing China's twenty-nine (29) provinces' SO<sub>2</sub> emissions.

Their findings reveal that, when viewed via several pathways, the cumulative impact of FDI on SO<sub>2</sub> emissions is quite minor. With a 1% surge in FDI, SO<sub>2</sub> emissions will rise by 0.0980%, cancelling the emission reduction resulting from FDI's influence on economic development and composition shift. Their model also gives persuasive support for the 'pollution haven' concept by integrating recursive dynamism into the simultaneous system, which assumes that FDI entrance decisions are influenced by economic development. Although FDI inflow in China often produces improved pollution efficiency, nevertheless, has a moderately restrictive effect on FDI inflows. Besides, the composition impact of FDI in China appears to be dominated by seeking a 'production platform' with reduced environmental regulatory compliance costs.

Baek et al. (2009) use a co-integration approach to inspect the dynamic links between trade, GDPg, and the environment. Their findings imply that while trade and wealth growth improve environmental quality in rich nations, they have an adverse impact on EnQ in the bulk of developing countries. They also discovered that in industrialized nations, the causal link appears to go from commerce and income to CO<sub>2</sub>, with a change in trade and GDPg resulting in a change in EnQ. Most developing nations, on the other hand, find that causation runs from CO<sub>2</sub> to commerce and GDPg; however, China has the reverse causal link. Boulatoff and Jenkins (2010) investigate the dynamic link between wealth, trade, and EnQ as evaluated by CO<sub>2</sub> emissions by energy sources (gas, oil, and coal). Using data from 1980–2006 from 21 nations, including the G7, and BRIC economies, they consistently establish an LR association between GDPg, TO, and CO<sub>2</sub>.

This is significant since the Environmental Protection Agency (later EPA) has ruled that CO<sub>2</sub> does represent a risk to the health and well-being. Zomorodi and Zhou (2017) define the significance of environmental quality in terms of sulphur dioxide and water pollutants emissions due to the increased FDI. The period considered for this study was 2003–2014. The research found a substantial but modest positive relationship between FDI and sulphur dioxide

but denied the link between water pollutant emissions and the latter. On the aggregate level, the panel data analysis reveals comparable relationships among all provinces in the investigation.

Shahbaz et al. (2018) use French data from 1955-2016 and apply the bootstrapping bounds testing technique. They discovered that FDI benefits French CO<sub>2</sub>, but energy research discoveries have a negative influence. Financial development reduces carbon emissions, therefore enhancing French EnQ. FDI harms the EnQ, supporting France's pollution-haven concept. Similarly, economic development (later on FD) indicates that financial stability (later on FS) is a requirement for enhancing EnQ, as are energy-research advancements. In contrast, EC is positively correlated with CO<sub>2</sub>. However, the link between economic development and CO<sub>2</sub> is an inverted U, supporting the EKC.

Lv and Xu (2019) Used the PMG technique to empirically examine the varied impacts of TO and urbanization (later on URB) on CO<sub>2</sub> in fifty-five (55) middle-income countries from 1992-2012. They discovered that TO positively influences the CO<sub>2</sub> in the short-term (later on SR), but an adverse impact in the LR. Meanwhile, their findings suggest that URB has influenced CO<sub>2</sub>. Therefore, the panel data from 30 (thirty) African nations using GMM estimation approaches were used to study the impact of trade liberalization on EnQ. They discovered that TO is related to higher levels of CO<sub>2</sub> owing to comparative gain derived from factor endowment; the inclusive benefits of TO are observed to have some positive effects on EnQ. Also, the relative economic expansion reduces CO<sub>2</sub> (scaling impact), maybe owing to the technology transfer.

Hao et al. (2020) examine the influence of FDI and technological innovation on CO<sub>2</sub> using panel data from thirty (30) provinces of China from 1998-2016. Their findings demonstrate that more significant FDI can reduce CO<sub>2</sub>, proving the existence of the "pollution-haven-hypothesis (*later on PHH*)"; technical innovation can lower SO<sub>2</sub> emissions while increasing chemical-oxygen consumption. Ali et al. (2021) examine the extent to which TO influences EnQ using several indicators for the environment from 1991-2018. They employed GHG, CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O levels, as well as ecological footprint (*later on EcGFP*), to assess EnQ. They bear an adverse link between TO and CO<sub>2</sub>, N<sub>2</sub>O, and CH<sub>4</sub> but a positive link with the EcGFP in all high-income OIC-countries. Trade openness, on the other hand, correlates positively with all environmental indices in OIC nations with lower incomes.

Qamruzzaman (2021) used ARDL, CS-ARDL, and NARDL to determine whether the link between EnQ, institutional quality, and trade openness is symmetric or asymmetric, with FDI acting as a mediating factor, from 1982 to 2019. Furthermore, directional causation is evaluated using the Granger-causality (later on the G-C) test, which includes EnQ, institutional quality, and FDI in corresponding equations. His studies using ARDL show that beneficial consequences range from EnQ and FDI, particularly over a long period. Furthermore, it identifies shocks in EnQ and IFDI that are optimistically correlated with TO, particularly in

the extended period. Moreover, the Wald test findings demonstrate the occurrence of asymmetry. The casualty with symmetry-possession of EnQ, institutional quality, and IFDI disclosure feedback theory explains the causative impacts of trade openness. Furthermore, an asymmetric causality test reveals a feedback hypothesis between EnQ and TO and the institutional quality and TO, with unidirectional causation flowing from optimistic shocks in FDI to TO.

Nwani et al. (2022) reveal that remittances and TO raise CO<sub>2</sub>, regardless of accounting technique. TO has a greater impact on consumption. However, the effect is negligible for lower quintile nations but substantial for medium and upper quintile countries. Duodu and Mpuure (2023) investigated the environmental impact of foreign commerce in 33 SSA countries between 1990 and 2020. The extended approach of moment estimation and the D-H causality test were used. They discovered that trade decreases environmental degradation by around 0.1% and 0.790% in the SR and LR, respectively. Again, they find that in the SR and LR, exports and imports reduce CO<sub>2</sub> by around 0.070% and 0.450% (0.080% and 0.580%). D-H findings discovered bidirectional causation between total commerce and environmental pollution but uni-directional causality from CO<sub>2</sub> to exports and imports. Kindo et al. (2024) investigate the link between commerce, ecological issues, and sustainable development in Ghanaian settings. Using the ARDL error correction estimating approach, they discovered that trade benefits sustainable development in Ghana while having adverse environmental consequences.

### **2.3. Empirical literature based on Pakistan**

Nasir and Rehman (2011) explore the link between Pakistan's CO<sub>2</sub>, income, EC, and TO from 1972-2008. Using the Johansen approach of co-integration, they discovered a quadratic long-period connection between CO<sub>2</sub> and income, proving the presence of the EKC in Pakistan. Furthermore, both energy use and international commerce are shown to have a favourable impact on CO<sub>2</sub>. The near-run results, however, have ruled out the presence of the EKC. Awan et al. (2018) inspect the link among TO, FDI, GDPg, and EnQ in Pakistan (1971 to 2016). They used an ARDL-bounds testing technique for their study. They found a positive and strong LR link between TO, FDI, and CO<sub>2</sub> in Pakistan. However, GDP has no link with environmental quality. Salman et al (2018) studied the long-period link between GDPg, TO, and EC with CO<sub>2</sub> in Pakistan between 1980-2014. Their findings demonstrate that GDPg has a large beneficial impression on CO<sub>2</sub>. This advises that a rise in GDPg raises CO<sub>2</sub>, showing a scale impact. Moreover, an LR-positive link between EC and CO<sub>2</sub> and a negative link between TO and FTAs were found.

Naz et al (2019) used consistent data from 1975-2016 in Pakistan. They reveal that economic development and IFDI raise CO<sub>2</sub>, but REC significantly reduces CO<sub>2</sub>. They did not confirm the EKC theory. Their findings validated the PHH, which holds that IFDI harms the country's natural plants. The inclusion of the moderation effect of GDPg and IFDI with the REC on CO<sub>2</sub>

reversed the REC's positive impression. It converted it into an adverse externality, in which the unsustainable production methods that boost the country's GDPg. They conclude that incorporating REC assists in reducing CO<sub>2</sub>, whereas stringent CO<sub>2</sub> ignores the adverse externalities of unsustainable production and enhances the achievement of green development initiatives in a nation. Amin et al. (2021) investigate the unique links between ethnic diversity, foreign trade, and the environment in Pakistan, using data from 1970-2015. They use the NARDL approach to scrutinize the effects of ethnic diversity on EnQ and TO. They discovered that GDPg is more unswerving for TO in both negative and positive shocks, causing CO<sub>2</sub> emissions to rise. However, an adverse shock to social exclusion may reduce CO<sub>2</sub> emissions through a constant consumption pattern. They argue that diversity issues may be mitigated by ensuring equal opportunities for society to make it more united.

Khan et al (2023) used data from 1984-2019, and the dynamic ARDL simulation framework was used to investigate Pakistan's trade-environment solid relationship. Their findings reveal that the scale impact increases CO<sub>2</sub> while the method effect reduces them, demonstrating the existence of the EKC. The composition effect adds to rising CO<sub>2</sub>. Trade openness harms the environment by encouraging the growth of polluting export industries. The concept of the pollution hypothesis has also been confirmed. According to frequency domain causality results, economic development, TO, urbanization, and CO<sub>2</sub> are all bi-directional. Khaliq et al. (2024) analyzed data from 1993 to 2020 in Pakistan and used the NARDL and ARDL bounds testing methodologies. The findings demonstrate that fossil fuel use for energy generation and consumption damages the environment. Furthermore, combining energy diversity with a focus on REC can cut emissions while considerably advancing long-term sustainability. Deliberately leveraging natural resource rent and trade skills can contribute to Pakistan's environmental sustainability.

#### **2.4. Empirical literature based on China**

Chai (2002) evaluates the CO<sub>2</sub> impact of TO in China. His findings indicate that China's experience with the TO- CO<sub>2</sub> nexus is consistent with previous research. On the one hand, TO has produced a variety of environmental benefits. First, it encouraged specialization in areas of comparative advantage, which often featured businesses that contributed less to CO<sub>2</sub>. Second, it enabled China to obtain and use the finest worldwide techniques in pollution abatement technologies. Third, it allowed China to shift environmental costs onto other nations by purchasing intermediate items whose manufacturing contributed to CO<sub>2</sub>. Dean (2002) includes many effects of TO on CO<sub>2</sub> and shows that free trade exacerbates environmental harm through trade terms while mitigating it through GDP.

Jalil and Mahmud (2009) explore the link between CO<sub>2</sub>, EC, GDPg, and TO in China, using data from 1975-2005. The estimates indicate that TO has an optimistic influence on CO<sub>2</sub>. Yunfeng and Laike (2010) estimate the quantity of CO<sub>2</sub> embodied in China's overseas commerce from 1997 to 2007. They classify trade-embodied emissions into magnitude,

content, and technological effect. It was discovered that the size and composition effects increased the CO<sub>2</sub> incorporated in commerce, while the technological impact countered only a portion of them. Jayanthakumaran et al. (2012) used the ARDL test to compare CO<sub>2</sub>, EC, TO, and GDP<sub>g</sub> in China and India from 1971-2007. They discovered that trade did not influence the environment in China and India. Most of the experts' findings were ambiguous, emphasizing the need for more studies to better understand the impact of commerce on environmental damage.

During their research, Onafowora and Owoye (2014) discovered that trade negatively influenced Brazil's, China's, and Japan's carbon dioxide emissions. They argue for transforming international commerce to reduce CO<sub>2</sub>. Boamah et al. (2018) investigated the causative influence of urban population expansion and foreign commerce on CO<sub>2</sub> in China from 1980-2014. For the instance of China, the Johansen co-integration revealed an LR co-integration among variables used. The direction of causation among the variables was then explored using the most current boot-strapped Granger-causality test. They discovered a bi-directional causal link between imports and urban populations.

According to IRF, the three most important variables illuminating China's CO<sub>2</sub> are imports, urbanization, and energy use. They also discovered an N-shaped EKC in China. As a result, they urge China to follow stricter environmental rules in commerce and implement policies that encourage EC efficiency to reduce CO<sub>2</sub> as the GDP. He (2019) estimates trade's various effects on environmental performance. The systematic analysis of literary sources and methods for tackling trade and environmental problems reveals that they overlooked country-specific characteristics and varied phases of economic growth. He employs panel regression of data at the province level throughout the period from 1997-2008. He observed that commerce itself had considerable favourable benefits on the environment. He experimentally validates and analytically explains the consequences of TO on EnQ.

Jun et al. (2020) use wavelet-coherence analysis, the phase-difference approach, and a causality test to evaluate the influence of TO on CO<sub>2</sub> in China. Their findings imply that TO has worsened CO<sub>2</sub> in China, particularly after 2001, when China joined the WTO. They contend that the "PHH" exists in China. Their findings suggest that TO have bigger exports, which has augmented domestic output by expanding the scope of industries, resulting in more significant CO<sub>2</sub>. The results of the spectral domain-causality test point out that liberalization causes CO<sub>2</sub> emissions. Ma and Wang (2021) investigated the impacts of TO involvement on both CO<sub>2</sub> and SO<sub>2</sub> emission intensity using panel data from 179 (one hundred and seventy-nine) major countries throughout 20 years when globalization blossomed, including China. Empirically, international trade involvement decreases the intensity of CO<sub>2</sub> but not SO<sub>2</sub> emissions. Furthermore, trading in products is more effective than in services.

Dou et al (2021) investigate the prospective impact of TO on this region's CO<sub>2</sub> between 1970-2019. They separately examined the effects of imports and exports on CO<sub>2</sub> and concluded that

TO positively influences the GHG effect. Similarly, their results found that the imports increase CO<sub>2</sub>, but the exports considerably reduce CO<sub>2</sub>; thus, improving TO impacts CO<sub>2</sub>. Wu et al (2022) employ an input-output analysis approach to determine how TO influences the China's CO<sub>2</sub>. They also examine the reasons contributing to the discrepancy between potential no-trade CO<sub>2</sub> and the actual CO<sub>2</sub>, as well as the presence of the "PHH" in China. Their findings demonstrate that from 2000-2017, the hypothetical no-trade CO<sub>2</sub> was 2.430%-14.670% which is lower than the actual CO<sub>2</sub>.

Butt et al (2023) investigate the effects of EC on CO<sub>2</sub> in China, utilizing TO and economic development as moderators, from 1971-2019. Their findings reveal that the primary energy supply has a considerable influence on the EcGFP. Energy usage and TO have an impact on the EcGFP, but to a smaller level. Economic development has a positive relationship with the EcGFP. Availability of Energy benefits the EnQ in China; however, EC harms the ecosystem. Wang et al. (2024) utilized the China data between 2000-2020. Regions experiencing more export expansion saw a more severe early decrease in local air quality, followed by a more noticeable following EnQ improvement, demonstrating that the CO<sub>2</sub> impact of trade changes over time.

## 2.5. Summary of the literature

According to Zarsky (1999), FDI facilitates the efficient implementation of environmental legislation through cleaner manufacturing processes and a better EnQ in the host country. According to the PHH theory, advanced countries want to locate their manufacturing facilities in states with cheaper taxes. It implies that commercial openness may be enhanced with foreign money at the expense of CO<sub>2</sub> (Baek et al., 2009). According to the PHH, investing in the host economy creates a favourable environment because implementing environmental regulations deepens and encourages everyone to follow the guidelines (Hayek 2018). A rising number of empirical research have attempted to reveal the size of the link between TO and environmental deterioration (Baek et al., 2009; Shahbaz et al., 2018). The empirical research provides two explanations for the FDI-EnQ connection.

First, FDI inflows are largely driven by important economic characteristics of home nations, such as countries attempting to encourage FDI into the economy at the expense of less severe environmental standards. As a result, they get significant ecological advantages. Investors reallocate their investments to less environmentally friendly countries. According to the population haven theory, lax environmental rules attract long-term foreign investment while having a negative long-term impact on local industry (Nathaniel et al., 2020). Second, FDI is a key avenue for acquiring innovative industrial technologies. Energy competence is one of the advantages of adopting new technology in the manufacturing process since it decreases environmental hazards. The pollution halo theory proposes that economic success through energy-efficient and cleaner production considerably improves environmental deterioration (Wang & Luo, 2020).

The relationship between TO and the EnQ has been thoroughly explored in empirical research using a clear consensus has emerged that trade openness in the LR indeed induces environmental deterioration (Lv & Xu, 2019). Ali et al. (2021) findings indicated that ecological imbalances caused by the surge of domestic commerce as a result of IND are among the apparent repercussions in the economy, as is the excessive NREC, and degradation of air quality, etc., However, investigations found a negative relationship between TO and CO<sub>2</sub> (Ozturk & Acaravci, 2010). They proposed that increased TO in emerging and developed nations increased industrial productivity and energy consumption, resulting in environmental deterioration via increasing carbon emissions. The empirical literature shows that researchers transmitted their sentiments using CO<sub>2</sub>. They aimed to focus on a different approach to describing the relationship between EnQ and trade, rather than trade openness and environment (Qamruzzaman, 2021). Twerefou et al (2019) discovered that the free trade harms countries' environmental status resulting in climate change. Lv and Xu (2019) found that TO helps to improve EnQ in the near run. However, as time passes, the long-term negative impacts of TO on CO<sub>2</sub> become clear.

### 3. Empirical methodology and data sources

#### 3.1. Model specification

This study used CO<sub>2</sub> emissions as a proxy for environmental degradation as the dependent variable and energy use, GDP growth, inflow of FDI, and trade as independent variables. This study used the following modified model (given in Eq. 1), which is also used by Azam et al (2022), Baek & Koo (2009), He (2006), and Hoffmann et al (2005). In the Eq. (1)  $\beta_1$ ,  $\beta_2$ ,  $\beta_3$ ,  $\beta_4$ ,  $\beta_5$ , and  $\beta_6$ , show the estimated coefficients,  $t$  stands for the truth period, correspondingly ( $t = 1, 2, \dots T$ ).

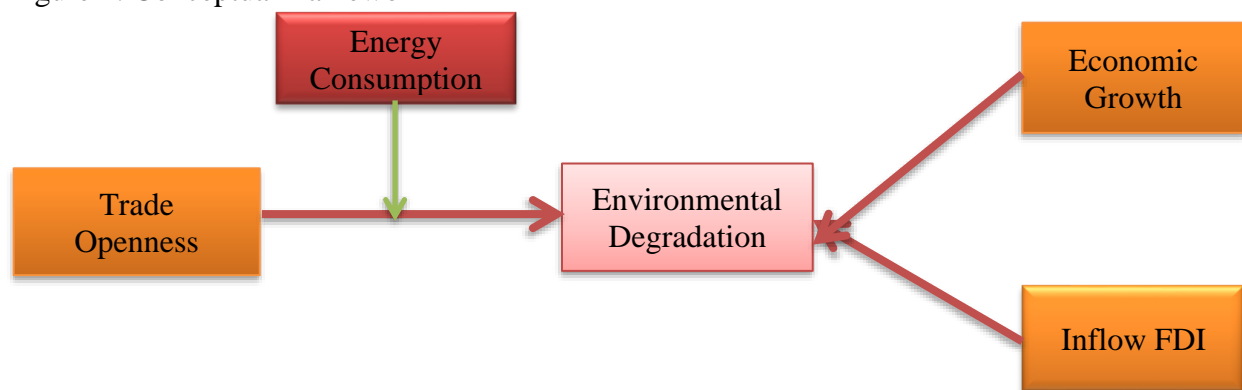
$$CO_{2t} = \beta_0 + \beta_1 EC_t + \beta_2 GDPg_t + \beta_3 GDPg_t^2 + \beta_4 IFDI_t + \beta_5 TO_t + \beta_6 EC_t * TO_t + \mu_t \dots (1)$$

#### 3.2. Conceptual framework

According to Copeland and Taylor (2013), TO can impact the CO<sub>2</sub>. The scale effect is the impression of commerce on the level of GDPg. Specifically, higher TO leads to more GDPg. Because these actions naturally have environmental consequences, one may argue that more GDPg spurred by TO degrades EnQ. In contrast, the composition consequence refers to the impact of TO on the production arrangement between countries. Unambiguously, the impoverished nations with relaxed environmental rules specialize in making dirty goods, whereas affluent states with the strict policies specialize in the clean goods. This causes a shift in polluting industries from the advanced to unindustrialized nations. This viewpoint is congruent with Baek et al (2009), who scrutinize that TO and money had an optimistic inspiration on EnQ in the industrialized countries. However, the analyses scrutinize TO as having an adverse EnQ.

Dirty industrial economies are progressively suffering the environmental liabilities of wealthy economies (Copeland & Taylor, 2013). However, there are conceptual reasons to believe that commerce has an optimistic impression on the EnQ. Antweiler et al. (2001) contend that more TO may be beneficial to EnQ. Specifically, if increased real wealth as a result of TO leads to higher levels of GDP, which is often linked with a stronger ability and desire to enact and enforce rules, EnQ might improve. Furthermore, if increasing economic activity drives research into cleaner industrial processes, pollutant emissions will be reduced. In other words, trade liberalization may improve the environment by generating revenue benefits that allow certain nations to concentrate on relatively clean industries (Copeland & Taylor, 2013).

Figure 1: Conceptual framework



### 3.3. Data sources and justification of the variable

This study used the time-series data of China and Pakistan from 1990 to 2020. The data period was selected based on its use and comprised World Development Indicators (WDI) (2024).

Table-1: Variables Descriptions

S.No.	Variable	Symbol	Source
	CO <sub>2</sub> emissions (metric tons per capita) (log)	CO <sub>2t</sub>	(Dou et al., 2021)
	Energy use (kg of oil equivalent per capita) (log)	EC <sub>t</sub>	(Lau et al., 2016)
	GDP growth (annual %)	GDP <sub>g,t</sub>	(Le et al., 2016)
	Foreign direct investment (FDI), net inflows (% of GDP)	IIFDI <sub>t</sub>	(Naz et al., 2019)
	Trade (% of GDP)	TO <sub>t</sub>	(Dou et al., 2021)

Source: WDI-World Development Indicators (2024)

#### 3.3.1. Estimation strategy

##### a) Autoregressive Distributed Lag (ARDL) Test

Unlike the other methodologies, this study used ARDL techniques based on the behavior of the data. The ARDL approach is preferable to other techniques for a variety of reasons, including its acceptance of heterogeneous order of integration and automated handling of autocorrelation and endogeneity (Ahmad & Wajid, 2013).

$$CO_{2t} = \beta_0 + \sum_{i=1}^n \beta_{1i}CO_{2t-i} + \sum_{i=0}^n \beta_{2i}EC_{t-i} + \sum_{i=0}^n \beta_{3i}GDPg_{t-i} + \sum_{i=0}^n \beta_{4i}GDPg_{t-i}^2 + \sum_{i=0}^n \beta_{5i}IFDI_{t-i} + \sum_{i=0}^n \beta_{6i}TO_{t-i} + \sum_{i=0}^n \beta_{7i}EC * TO_{t-i} + \mu_t \dots\dots\dots (2)$$

$$\Delta CO_{2t} = \beta_0 + \sum_{i=1}^n \beta_{1i}\Delta CO_{2t-i} + \sum_{i=0}^n \beta_{2i}\Delta EC_{t-i} + \sum_{i=0}^n \beta_{3i}\Delta GDPg_{t-i} + \sum_{i=0}^n \beta_{4i}\Delta GDPg_{t-i}^2 + \sum_{i=0}^n \beta_{5i}\Delta IFDI_{t-i} + \sum_{i=0}^n \beta_{6i}\Delta TO_{t-i} + \sum_{i=0}^n \beta_{7i}\Delta (EC * TO)_{t-i} + \gamma_1 EC_t + \gamma_2 GDPg_t + \gamma_3 GDPg_t^2 + \gamma_4 IFDI_t + \gamma_5 TO_t + \gamma_6 (EC * TO)_t + \mu_t \dots\dots\dots (3)$$

**b) Granger causality test**

Granger (1988) developed a practical test for Granger causality between two variables. The underlying premise is that if changes in X occur before changes in Y, then X might cause Y. The test also requires a constrained regression, which only regresses Y against prior Y values. This is to see if adding prior X values as an independent variable may significantly explain differences in Y (Pindyck & Rubinfeld, 1998).

**4. Results and discussion**

**4.1. Unit root test results**

Table 2 shows that all the variables have the 1st degree of order of integration (1(1)) in China, while the variables GDPg and IFDI have (1(0)), and the rest of the variables have (1(1)) in Pakistan. Overall, the order of integration is mixed in Pakistan, while it is 1(1) in China. Therefore, the ARDL technique is appropriate to the current behaviour of data.

Table 2: Unit Root Tests Results

Variables	China			Pakistan		
	ADF Test t-value (p-value)	PP test Adj t-value (p-value)	Judgment	ADF Test t-value (p-value)	PP test Adj t-value (p-value)	Judgment
CO <sub>2t</sub>	-0.1221 (0.9381)	-0.1223 (0.9380)	1(1)	-1.4882 (0.5258)	-1.4882 (0.5258)	1(1)
D(CO <sub>2t</sub> )	-5.6661* (0.0001)	-5.6580* (0.0001)		-4.6138* (0.0010)	-4.6307* (0.0009)	
EC <sub>t</sub>	-0.4270 (0.8897)	-0.9057 (0.7724)	1(1)	-2.1233 (0.2374)	-2.0824 (0.2527)	1(1)
D(EC <sub>t</sub> )	-8.9083* (0.0001)	-12.642* (0.0001)		-4.3865* (0.0001)	-4.3843* (0.0001)	

	(0.0000)	(0.0000)		(0.0017)	(0.0017)	
GDP <sub>g<sub>t</sub></sub>	-1.7582 (0.3931)	-2.2912 (0.1811)	1(1)	-2.9759** (0.0488)	-2.8916 (0.0582)	1(0) & 1(1)
D(GDP <sub>g<sub>t</sub></sub> )	-4.0307* (0.0042)	-4.0403* (0.0041)		-----	-6.3156* (0.0000)	
IIFDI <sub>t</sub>	-2.0111 (0.2807)	-2.1843 (0.2157)	1(1)	-2.9767** (0.0491)	-1.8518 (0.3494)	1(0) & 1(1)
D(IFDI <sub>t</sub> )	-4.1220* (0.0034)	-4.0714* (0.0038)		-----	-3.5896** (0.0124)	
TO <sub>t</sub>	-1.7754 (0.3846)	-1.8026 (0.3721)	1(1)	-1.6448 (0.4481)	-1.7733 (0.3859)	1(1)
D(TO <sub>t</sub> )	-4.0941* (0.0036)	-4.0980* (0.0036)		-5.0404* (0.0003)	-5.0389* (0.0003)	

Note: \* & \*\* indicate the consequence level at 1, and 5%.

## 4.2. Regression results

Table 3 shows that in the case of China, in the long-term, the EC, and GDPg have positive and significant effects on CO<sub>2</sub>. A per cent increase in EC and GDP leads to an increase the CO<sub>2</sub> by 0.4164 and 0.7674%, respectively. However, the inflow FDI and TO have adverse and significant effects on CO<sub>2</sub>. A per cent increase in the inflow of FDI and TO leads to a decrease in CO<sub>2</sub> by 0.2329 and 0.7540%, respectively. Some scholars found that trade openness positively induces environmental deterioration (Chai, 2002). In the case of China, some research has determined that TO harms the EnQ (He, 2019), but others have initiated that trade benefits the EnQ (Jalil & Mahmud, 2009). According to Shen (2008), TO has varying effects on pollutant variables, and TO has augmented CO<sub>2</sub> in China. Fang et al. (2020) found that TO reduces discarded water emissions while increasing SO<sub>2</sub> in China. Similarly, in the short term, the GDP growth and TO have a negative and noteworthy effect on CO<sub>2</sub>, while the rest of the variables are insignificant. A per cent increase in GDP growth and TO leads to a decrease in CO<sub>2</sub> emission by 0.0741 and 0.2774 per cent, respectively. Moreover, there exists long-run cointegration and a 51% level of correction to LR equilibrium.

The empirical results confirm the existence of EKC in the LR, while there is U-shape link between GDPg and CO<sub>2</sub> in the SR. The prior scholar confirmed the EKC in China (Jalil & Mahmud, 2009), but it was not confirmed (Azam et al., 2024). Moreover, the coefficients TO and interaction variables were found to be significant, which means that EC has a moderation effect on the link of TO and CO<sub>2</sub> in the LR only. This study found that the interaction of EC with the TO causes CO<sub>2</sub> emission to increase by 0.05% in the LR. The interaction impact of TO and EC on CO<sub>2</sub> is positive, implying that more trade openness undermined the benefits of EC on CO<sub>2</sub> emissions, which significantly increased CO<sub>2</sub> in a nation. The results further confirmed that China's trade is associated with energy consumption, and during the trade, the environment is jeopardised due to the large trading of energy-related CO<sub>2</sub>. Furthermore, in the case of Pakistan, all the variables have a positive and noteworthy effect on CO<sub>2</sub> in the LR. A % increase in EC, GDP growth, inflow FDI, and trade openness leads to an increase in CO<sub>2</sub> emission by 0.7213, 0.0079, 0.0240, and 0.3101 per cent, respectively.

Table 3: Regression Results

Description	China		Pakistan	
	Coefficient [Std. Error] (t-statistics)	p-value	Coefficient [Std. Error] (t-statistics)	p-value
EC <sub>t</sub>	0.4164* [0.0837] (4.9764)	0.0000	0.7213* [0.2093] (3.4461)	0.0026
GDP <sub>g</sub> <sub>t</sub>	0.7674* [0.1666] (4.6066)	0.0000	0.0079* [0.0022] (3.6188)	0.0017
GDP <sub>g</sub> <sup>2</sup> <sub>t</sub>	-0.0337* [0.0082] (-4.1303)	0.0012	-0.0007** [0.0003] (-2.1846)	0.0410
IFDI <sub>t</sub>	-0.2329*** [0.1230] (-1.8942)	0.0807	0.0240* [0.0033] (7.1828)	0.0000
TO <sub>t</sub>	-0.7540* [0.0526] (-14.3465)	0.0000	0.3101* [0.0339] (9.1569)	0.0000
TO <sub>t</sub> *EC <sub>t</sub>	0.1090* [0.0060] (18.0191)	0.0000	0.0525* [0.0057] (9.2161)	0.0000
C	-4.3712* [1.0061] (-4.3447)	0.0008	-12.1602* [1.1850] (-10.2619)	0.0000
F-Bound Test	5.0664 *		10.5544*	
D(EC <sub>t</sub> )	0.0104 [0.0313] (0.3323)	0.7429	0.8130 [0.5385] (1.5096)	0.1460
D(GDP <sub>g</sub> <sub>t</sub> )	-0.0741** [0.0324] (-2.2849)	0.0328	0.0147** [0.0053] (2.8025)	0.0107
D(GDP <sub>g</sub> <sup>2</sup> <sub>t</sub> )	0.0039** [0.0016] (2.4903)	0.0212	-0.0015** [0.0006] (-2.3772)	0.0270
D(IFDI <sub>t</sub> )	0.0168 [0.0263] (0.6365)	0.5313	0.0359* [0.0097] (3.6841)	0.0014
D(TO <sub>t</sub> )	-0.2774** [0.1267] (-2.1889)	0.0400	0.2333** [0.1027] (2.2706)	0.0338
D(TO <sub>t</sub> *EC <sub>t</sub> )	0.0429** [0.0192] (2.2364)	0.0363	-0.0396** [0.0173] (-2.2902)	0.0325
ECM <sub>t-1</sub>	-0.5089* [0.0436] (-11.668)	0.0000	-0.5540* [0.1166] (-4.7528)	0.0001
C	0.1280** [0.0461] (2.7778)	0.0113	0.0163* [0.0048] (3.3884)	0.0028
Diagnostic tests	F-statistics	p-value	F-statistics	p-value
B-G Serial Correlation LM Test	1.8546	0.1983	1.4509	0.2605
H <sub>0</sub> :No Serial Correlation				

B-P-G Heteroskedasticity Test	0.3972	0.9549	0.7253	0.6812
H <sub>0</sub> : Homoskedasticity				
Ramsey RESET Test	1.7595	0.2094	0.0246	0.8771
H <sub>0</sub> : No Specification Error				
J-B test	1.7978	0.4070	0.2840	0.8676
H <sub>0</sub> : Residuals are Normally Distributed.				
CUSUM test	Stable**		Stable**	

Note: \*, \*\* & \*\*\* indicate the consequence level at 1, 5 and 10% and the critical values for the Bound test for 1% is 2.88-3.99.

Some scholars found that trade openness positively induces environmental deterioration (Lv & Xu, 2019). However, some scholars found a negative link between openness and environmental damage (Ozturk & Acaravci, 2010). In the case of Pakistan, some scholars found that trade has a Positive like Awan et al. (2018), while others found a Negative like Salman et al. (2018) effect on CO<sub>2</sub>. Similarly, in the SR, the GDP growth, inflow FDI, and TO have an optimistic and noteworthy consequence on CO<sub>2</sub>, while the rest of the variables are insignificant. A per cent increase in GDP growth, inflow FDI, and TO led to an increase in CO<sub>2</sub> emission by 0.0147, 0.0359, and 0.2333 per cent, respectively. Moreover, there exists long-term co-integration and a 55% level of correction to LR equilibrium. Furthermore, the results confirm the existence of EKC in Pakistan in both terms. The prior scholars also confirmed the EKC, like Azam et al. (2024). Moreover, the coefficients of trade openness and interaction variables were found significant, which means that EC has a moderation effect on the relationship of TO and CO<sub>2</sub> in the LR only. This study found that the interaction of EC with the TO, then CO<sub>2</sub> emission increases by 0.05% in the LR. The interaction impact of TO and EC on CO<sub>2</sub> is positive, implying that more trade openness undermined the benefits of EC on CO<sub>2</sub>, which significantly increased CO<sub>2</sub> in a nation. The results further confirmed that Pakistan's trade is associated with energy consumption, and during the trade, the EnQ is jeopardized due to the large trading of energy-related CO<sub>2</sub>.

### 4.3. Granger Casualty Test Results

Table 4 demonstrates the G-C test consequences, which show in China, that there exists one-way causality running from CO<sub>2</sub> to EC and IFDI, from EC to GDP growth and IFDI, and from trade openness to CO<sub>2</sub>, while there exists no causality among the rest of the variables. Furthermore, in the case of Pakistan, there exists one-way causality running from EC to CO<sub>2</sub> and GDP growth to IFDI, while there exists no causality among the rest of the variables as shown in Figure 2 as well.

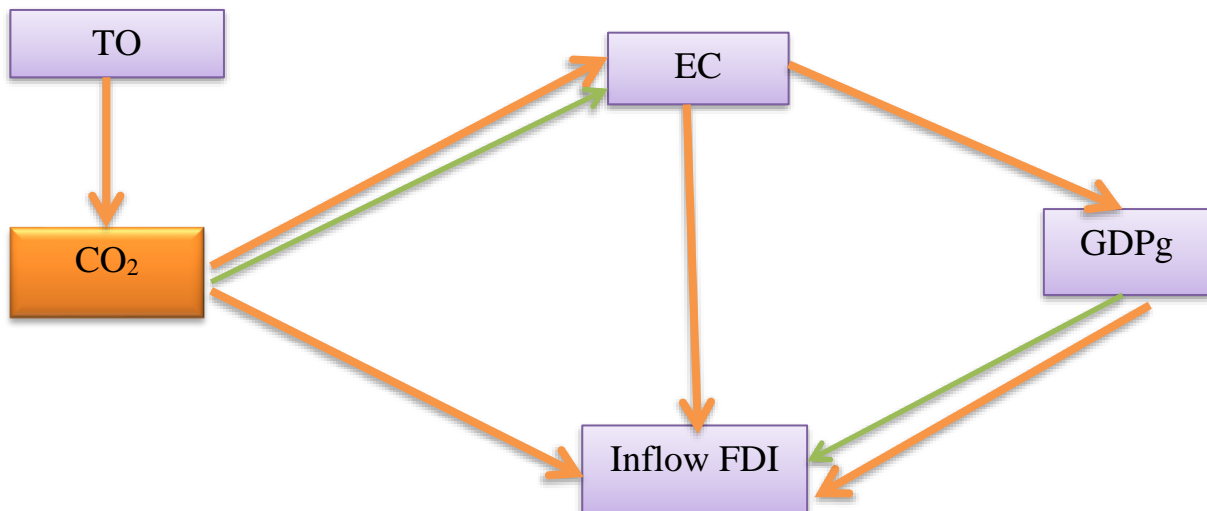
Table 4: Casually results

Country	Variables	CO <sub>2t</sub>	EC <sub>t</sub>	GDPg <sub>t</sub>	IFDI <sub>t</sub>	TO <sub>t</sub>
China	CO <sub>2t</sub>	---	4.6835** (0.0192)	2.1632 (0.1368)	5.8266* (0.0087)	1.3887 (0.2687)
	EC <sub>t</sub>	0.0103 (0.9897)	---	3.1348*** (0.0617)	5.9595* (0.0079)	1.1913 (0.3212)
	GDPg <sub>t</sub>	0.4451	0.0276	---	5.2871**	0.6094

Country	Variables	CO <sub>2t</sub>	EC <sub>t</sub>	GDP <sub>gt</sub>	IFDI <sub>t</sub>	TO <sub>t</sub>
Pakistan		(0.6459)	(0.9728)		(0.0125)	(0.5519)
	IFDI <sub>t</sub>	0.3085 (0.7374)	0.3142 (0.7334)	0.4330 (0.6535)	---	0.1016 (0.9038)
	TO <sub>t</sub>	3.3786*** (0.0510)	0.4756 (0.6272)	0.0446 (0.9564)	0.6984 (0.5072)	---
	CO <sub>2t</sub>	---	0.6902 (0.5112)	1.4530 (0.2537)	0.8968 (0.4211)	0.1538 (0.8582)
	EC <sub>t</sub>	7.0573* (0.0039)	---	0.0456 (0.9555)	0.0794 (0.9239)	1.1179 (0.3434)
	GDP <sub>gt</sub>	2.0273 (0.1536)	0.3082 (0.7376)	---	3.9858** (0.0320)	2.4373 (0.1087)
	IFDI <sub>t</sub>	1.8523 (0.1718)	0.2803 (0.7580)	0.6335 (0.5394)	---	0.3840 (0.6853)
	TO <sub>t</sub>	0.7369 (0.4891)	1.1734 (0.3264)	0.7221 (0.4960)	0.2402 (0.7884)	---

Note: \*& \*\* indicate the consequence level at 1, and 5%.

Figure-2: Graphical Representation of Casualty Results



Note: The orange colour line shows the one-way causality in China, and the green colour line shows the one-way causality in Pakistan.

### 5. Conclusion and recommendations

The main objective of the study was to investigate the moderating effect of energy consumption on the link between trade openness and environmental degradation in China and Pakistan. It used data from 1990 to 2020 and employed ARDL and granger-causality procedures for estimations. This study found that in the case of China, in the LR, the EC, and GDP growth have positive and noteworthy effects on CO<sub>2</sub> emission. However, the inflow of FDI and trade openness have negative and noteworthy effects on CO<sub>2</sub> emissions. Similarly, in the short term, GDP growth, and trade have a negative and noteworthy effect on CO<sub>2</sub>, while the rest of the variables are insignificant. Moreover, there exists the long run cointegration and a 51% level of correction. Furthermore, the empirical results confirm the existence of EKC in the LR, while there is a U-shaped relationship between GDP growth and CO<sub>2</sub> in the SR. Moreover, energy

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consumption has a moderating effect on the relationship of trade openness and CO<sub>2</sub> in the long period only. Furthermore, the interaction impact of TO and EC on CO<sub>2</sub> is positive, implying that more trade openness undermined the benefits of energy consumption on CO<sub>2</sub>, which significantly increased CO<sub>2</sub> in a nation. This study also found that in the case of Pakistan, in the LR, all the variables have a positive and noteworthy effect on CO<sub>2</sub> emission. Similarly, in the SR, the GDP growth, inflow FDI, and trade have an optimistic and noteworthy effect on CO<sub>2</sub> emission, while the rest of the variables are insignificant. Moreover, there is a 55% level of correction to LR stability. Furthermore, the empirical results confirm the existence of EKC in Pakistan in both terms. Moreover, energy consumption has a moderating effect on the relationship between trade and CO<sub>2</sub> in the long period only.

This study found that the interaction impact of trade openness (TO) and energy use (EC) on CO<sub>2</sub> is positive; implying that more trade openness undermined the benefits of EC on CO<sub>2</sub> emissions, which significantly increased CO<sub>2</sub>. This study also found that there exists one-way causality running from CO<sub>2</sub> to EC and IFDI, from energy consumption to GDP growth and IFDI, and from trade openness to CO<sub>2</sub>, in the case of China while, from EC to CO<sub>2</sub> and GDP growth to IFDI, in the case of Pakistan. This study concluded that both countries trade associated energy consumption, and during the trade, the environment is exposed due to the large trading of energy-related CO<sub>2</sub> emissions, damaging the process of GES. This study suggested that vigorous foreign capital inflows are beneficial to government sustainability, to focus on environmentally friendly initiatives that have been phased out in developed countries. Furthermore, governments need to carefully establish and actively implement environmental policies to retain greener products and technology through trade policy. Similarly, the policymakers must address environmental deterioration as a result of trade openness and FDI; moreover, environmental quality should not be overlooked. It is further advised that Pakistan maintain trade openness policies and energy sector reforms, as well as the sustainable use of biocapacity, to tackle environmental challenges while increasing wealth. Moreover, China must continue to adopt more energy-saving technologies in its businesses.

**Declaration of conflict of interest**

The author(s) declared no potential conflicts of interest(s) with respect to the research, authorship, and/or publication of this article. There is no conflict of interests, whether financial or non-financial. The researchers do not have any personal bias or affiliation in the matter under study.

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## References

- Agarwal, B. (2009). Gender and forest conservation: The impact of women's participation in community forest governance. *Ecological Economics*, 68(11), 2785-2799. <https://doi.org/10.1016/j.ecolecon.2009.04.025>
- Ahlerup, P., Olsson, O., & Yanagizawa, D. (2009). Social capital vs institutions in the growth process. *European Journal of Political Economy*, 25(1), 1-14. <https://doi.org/10.1016/j.ejpoleco.2008.09.008>
- Ahmad, K., & Wajid, S. (2013). What matters for economic growth in Pakistan: fiscal policy or its composition? *Asian Economic and Financial Review*, 3(2), 196-215. <https://archive.aessweb.com/index.php/5002/article/view/986>
- Alesina, A., Devleeschauwer, A., Easterly, W., Kurlat, S., & Wacziarg, R. (2003). Fractionalization. *Journal of Economic Growth*, 8(2), 155-194. <https://doi.org/10.1023/A:1024471506938>
- Ali, A., Khatoon, S., Ather, M., & Akhtar, N. (2015). Modeling energy consumption, carbon emission and economic growth: empirical analysis for Pakistan. *International Journal of Energy Economics and Policy*, 5(2), 624-630. <https://dergipark.org.tr/en/pub/ijeeep/issue/31913/350919>
- Ali, S., Yusop, Z., Kaliappan, S. R., & Chin, L. (2021). Trade-environment nexus in OIC countries: fresh insights from environmental Kuznets curve using GHG emissions and ecological footprint. *Environmental Science and Pollution Research*, 28(4), 4531-4548. <https://doi.org/10.1007/s11356-020-10845-6>
- Amin, S., Ahmad, N., Iqbal, A., & Mustafa, G. (2021). Asymmetric analysis of environment, ethnic diversity, and international trade nexus: empirical evidence from Pakistan. *Environment, Development and Sustainability*, 23(8), 12527-12549. <https://doi.org/10.1007/s10668-020-01181-3>
- Anderson, J. E. (2011). The gravity model. *Annual Review Of Economics*, 3(1), 133-160. <https://doi.org/10.1146/annurev-economics-111809-125114>
- Antweiler, W., Copeland, B. R., & Taylor, M. S. (2001). Is Free Trade Good for the Environment? *American Economic Review*, 91(4), 877-908. <https://doi.org/10.1257/aer.91.4.877>
- Awan, S. A., Muhammad Saeed, M., Amogh, G., Ra-Yan, W., & Pei-Fen, Z. (2018, 2018/05). *Is trade openness good or bad for environment in Pakistan; an ARDL bounds testing approach*. Paper presented at the Proceedings of the 4th Annual International Conference on Management, Economics and Social Development (ICMESD 2018). <https://www.atlantispress.com/proceedings/icmesd-18/25898719>.
- Azam, M., Rehman, Z. U., & Ibrahim, Y. (2022). Causal nexus in industrialization, urbanization, trade openness, and carbon emissions: empirical evidence from OPEC

- economies. *Environment, Development and Sustainability*, 24(12), 13990-14010. <https://doi.org/10.1007/s10668-021-02019-2>
- Azam, M., Rehman, Z. U., Khan, H., & Haouas, I. (2024). Empirical testing of the environmental Kuznets curve: evidence from 182 countries of the world. *Environment, Development and Sustainability*. <https://doi.org/10.1007/s10668-024-04890-1>
- Baek, J., Cho, Y., & Koo, W. W. (2009). The environmental consequences of globalization: a country-specific time-series analysis. *Ecological Economics*, 68(8), 2255-2264. <https://doi.org/10.1016/j.ecolecon.2009.02.021>
- Baek, J., & Koo, W. W. (2009). A dynamic approach to the FDI-environment nexus: the case of China and India. *East Asian Economic Review*, 13(2), 87-106. [https://papers.ssrn.com/sol3/papers.cfm?abstract\\_id=3077770](https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3077770)
- Boamah, K. B., Du, J., Boamah, A. J., & Appiah, K. (2018). A study on the causal effect of urban population growth and international trade on environmental pollution: evidence from China. *Environmental Science and Pollution Research*, 25(6), 5862-5874. <https://doi.org/10.1007/s11356-017-0882-5>
- Boden, T., Andres, R., & Marland, G. (2016). Global, Regional, and National Fossil-Fuel CO2 Emissions (1751-2013): Environmental System Science Data Infrastructure for a Virtual Ecosystem. [http://cdiac.ornl.gov:8080/xml/cdp/metadata/Tom\\_Boden/Global\\_Regional\\_National\\_CO2\\_Emissions.xml](http://cdiac.ornl.gov:8080/xml/cdp/metadata/Tom_Boden/Global_Regional_National_CO2_Emissions.xml)
- Boulatoff, C., & Jenkins, M. (2010). Long-term Nexus between Openness, Income, and Environmental Quality. *International Advances in Economic Research*, 16(4), 410-418. <https://doi.org/10.1007/s11294-010-9283-y>
- Butt, H. M. M., Khan, I., & Xia, E. (2023). How do energy supply and energy use link to environmental degradation in China? *Environmental Science and Pollution Research*, 30(40), 92891-92902. <https://doi.org/10.1007/s11356-023-28960-5>
- Chai, J. C. (2002). Trade and environment: evidence from China's manufacturing sector. *Sustainable Development*, 10(1), 25-35. <https://doi.org/10.1002/sd.174>
- Combes, P.-P., Lafourcade, M., & Mayer, T. (2005). The trade-creating effects of business and social networks: evidence from France. *Journal of International Economics*, 66(1), 1-29. <https://doi.org/10.1016/j.jinteco.2004.07.003>
- Copeland, B. R., & Taylor, M. S. (2013). *Trade and the Environment, Theory and Evidence* (Student edition). Princeton University. <http://www.jstor.org/stable/j.ctt5hznzk>.
- Das, J., & DiRienzo, C. E. (2009). Is Ethnic Diversity Good for the Environment? A Cross-Country Analysis. *The Journal of Environment & Development*, 19(1), 91-113. <https://doi.org/10.1177/1070496509355274>

- 
- Dean, J. M. (2002). Does trade liberalization harm the environment? A new test. *Canadian Journal of Economics/Revue canadienne d'économique*, 35(4), 819-842. <https://doi.org/10.1111/0008-4085.00155>
- Dou, Y., Zhao, J., Malik, M. N., & Dong, K. (2021). Assessing the impact of trade openness on CO2 emissions: Evidence from China-Japan-ROK FTA countries. *Journal of Environmental Management*, 296, 113241. <https://doi.org/10.1016/j.jenvman.2021.113241>
- Duodu, E., & Mpuure, D. M.-N. (2023). International trade and environmental pollution in sub-Saharan Africa: do exports and imports matter? *Environmental Science and Pollution Research*, 30(18), 53204-53220. <https://doi.org/10.1007/s11356-023-26086-2>
- Egger, P. H., Von Ehrlich, M., & Nelson, D. R. (2012). Migration and trade. *The World Economy*, 35(2), 216-241. <https://doi.org/10.1111/j.1467-9701.2011.01429.x>
- Esty, D. C. (2008). Rethinking Global Environmental Governance to Deal with Climate Change: The Multiple Logics of Global Collective Action. *American Economic Review*, 98(2), 116-121. <https://doi.org/10.1257/aer.98.2.116>
- Fang, Z., Huang, B., & Yang, Z. (2020). Trade openness and the environmental Kuznets curve: evidence from Chinese cities. *The world economy*, 43(10), 2622-2649. <https://www.adb.org/sites/default/files/publication/464116/adbi-wp882.pdf>
- Girma, S., & Yu, Z. (2002). The link between immigration and trade: evidence from the United Kingdom. *Weltwirtschaftliches Archiv*, 138(1), 115-130. <https://doi.org/10.1007/BF02707326>
- Gould, D. M. (1994). Immigrant Links to the Home Country: Empirical Implications for U.S. Bilateral Trade Flows. *The Review of Economics and Statistics*, 76(2), 302-316. <https://doi.org/10.2307/2109884>
- Granger, C. W. J. (1988). Causality, cointegration, and control. *Journal of Economic Dynamics and Control*, 12(2), 551-559. [https://doi.org/10.1016/0165-1889\(88\)90055-3](https://doi.org/10.1016/0165-1889(88)90055-3)
- Hao, Y., Wu, Y., Wu, H., & Ren, S. (2020). How do FDI and technical innovation affect environmental quality? Evidence from China. *Environmental Science and Pollution Research*, 27(8), 7835-7850. <https://doi.org/10.1007/s11356-019-07411-0>
- He, J. (2006). Pollution haven hypothesis and environmental impacts of foreign direct investment: The case of industrial emission of sulfur dioxide (SO<sub>2</sub>) in Chinese provinces. *Ecological Economics*, 60(1), 228-245. <https://doi.org/10.1016/j.ecolecon.2005.12.008>
- He, S. (2019). The impact of trade on environmental quality: a business ethics perspective and evidence from China. *Business Ethics and Leadership*, 3(4), 43-48. [https://doi.org/10.21272/bel.3\(4\).43-48.2019](https://doi.org/10.21272/bel.3(4).43-48.2019)
-

- Hoffmann, R., Lee, C. G., Ramasamy, B., & Yeung, M. (2005). FDI and pollution: a granger causality test using panel data. *Journal of International Development: The Journal of the Development Studies Association*, 17(3), 311-317. <https://doi.org/10.1002/jid.1196>
- Hossain, N., Byrne, B., Campbell, A., Harrison, E., McKinley, B., & Shah, P. (2010). *The impact of the global economic downturn on communities and poverty in the UK*: Foundation JR, editor. <https://research.manchester.ac.uk/en/publications/the-impact-of-the-global-economic-downturn-on-communities-and-pov>
- IPCC. (2014). Climate Change 2014, Synthesis report summary for policymakers: Intergovernmental panel on climate change (IPCC). [https://www.ipcc.ch/site/assets/uploads/2018/02/AR5\\_SYR\\_FINAL\\_SPM.pdf](https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf).
- Jalil, A., & Mahmud, S. F. (2009). Environment Kuznets curve for CO2 emissions: a cointegration analysis for China. *Energy Policy*, 37(12), 5167-5172. <https://doi.org/10.1016/j.enpol.2009.07.044>
- Jayanthakumaran, K., Verma, R., & Liu, Y. (2012). CO2 emissions, energy consumption, trade and income: A comparative analysis of China and India. *Energy Policy*, 42, 450-460. <https://doi.org/10.1016/j.enpol.2011.12.010>
- Jun, W., Mahmood, H., & Zakaria, M. (2020). Impact of trade openness on environment in China. *Journal of Business Economics and Management*, 21(4), 1185-1202. <https://doi.org/10.3846/jbem.2020.12050>
- Khaliq, A., Atique, A., Hina, H., & Bilal, A. (2024). Impact of electricity generation, consumption, energy trade, and ICT on the environment in Pakistan: a NARDL and ARDL analysis. *International Journal of Sustainable Development & World Ecology*, 31(3), 279-297. <https://doi.org/10.1080/13504509.2023.2277918>
- Khan, A., Safdar, S., & Nadeem, H. (2023). Decomposing the effect of trade on environment: a case study of Pakistan. *Environmental Science and Pollution Research*, 30(2), 3817-3834. <https://doi.org/10.1007/s11356-022-21705-w>
- Kindo, M. D., Adams, A. A., & Mohammed, J. (2024). The impact of trade on environmental quality and sustainable development in Ghana. *World Development Sustainability*, 4, 100134. <https://doi.org/10.1016/j.wds.2024.100134>
- Lau, E., Tan, C.-C., & Tang, C.-F. (2016). Dynamic linkages among hydroelectricity consumption, economic growth, and carbon dioxide emission in Malaysia. *Energy Sources, Part B: Economics, Planning, and Policy*, 11(11), 1042-1049. <https://doi.org/10.1080/15567249.2014.922135>
- Le, T. H., Chang, Y., & Park, D. (2016). Trade openness and environmental quality: International evidence. *Energy Policy*, 92, 45-55. <https://doi.org/10.1016/j.enpol.2016.01.030>

- Lv, Z., & Xu, T. (2019). Trade openness, urbanization and CO2 emissions: dynamic panel data analysis of middle-income countries. *The Journal of International Trade & Economic Development*, 28(3), 317-330. <https://doi.org/10.1080/09638199.2018.1534878>
- Ma, T., & Wang, Y. (2021). Globalization and environment: effects of international trade on emission intensity reduction of pollutants causing global and local concerns. *Journal of Environmental Management*, 297, 113249. <https://doi.org/10.1016/j.jenvman.2021.113249>
- Markusen, J. R. (1983). Factor movements and commodity trade as complements. *Journal of International Economics*, 14(3), 341-356. [https://doi.org/10.1016/0022-1996\(83\)90009-0](https://doi.org/10.1016/0022-1996(83)90009-0)
- Mauro, P. (1996). The effects of corruption on growth, investment, and government expenditure. *IMF Working Papers*, 1996(098), A001. <https://doi.org/10.5089/9781451852097.001.A001>
- Milem, J. F. (2003). The educational benefits of diversity: evidence from multiple sectors. *Compelling interest: examining the evidence on racial dynamics in higher education*, 126-169. [http://web.stanford.edu/~hakuta/www/policy/racial\\_dynamics/Chapter5.pdf](http://web.stanford.edu/~hakuta/www/policy/racial_dynamics/Chapter5.pdf)
- Ministry of Energy-Power Division. (2017). Ministry of energy-power division, government of Pakistan. <https://power.gov.pk/>
- Montalvo, J. G., & Reynal, M. Q. (2005). Ethnic polarization, potential conflict, and civil wars. *American Economic Review*, 95(3), 796-816. <https://doi.org/10.1257/0002828054201468>
- Mundell, R. A. (1957). International Trade and Factor Mobility. *The American Economic Review*, 47(3), 321-335. <https://www.jstor.org/stable/1811242>
- Nasir, M., & Rehman, F. U. (2011). Environmental Kuznets curve for carbon emissions in Pakistan: an empirical investigation. *Energy Policy*, 39(3), 1857-1864. <https://doi.org/10.1016/j.enpol.2011.01.025>
- Nathaniel, S., Agueboh, E., Iheonu, C., Sharma, G., & Shah, M. (2020). Energy consumption, FDI, and urbanization linkage in coastal Mediterranean countries: re-assessing the pollution haven hypothesis. *Environmental Science and Pollution Research*, 27(28), 35474-35487. <https://doi.org/10.1007/s11356-020-09521-6>
- Naz, S., Sultan, R., Zaman, K., Aldakhil, A. M., Nassani, A. A., & Abro, M. M. Q. (2019). Moderating and mediating role of renewable energy consumption, FDI inflows, and economic growth on carbon dioxide emissions: evidence from robust least square estimator. *Environmental Science and Pollution Research*, 26(3), 2806-2819. <https://doi.org/10.1007/s11356-018-3837-6>
- Newton, P., A Oldekop, J., Brodnig, G., Karna, B. K., & Agrawal, A. (2016). Carbon, biodiversity, and livelihoods in forest commons: synergies, trade-offs, and implications

- for REDD+. *Environmental Research Letters*, 11(4), 044017. <https://doi.org/10.1088/1748-9326/11/4/044017>
- Nnaji, C. E., Chukwu, J. O., & Nnaji, M. (2013). Electricity supply, fossil fuel consumption, Co2 emissions and economic growth: implications and policy options for sustainable development in Nigeria. *International Journal of Energy Economics and Policy*, 3(3), 262-271.
- Nwani, C., Alola, A. A., Omoke, C. P., Adeleye, B. N., & Bekun, F. V. (2022). Responding to the environmental effects of remittances and trade liberalization in net-importing economies: the role of renewable energy in Sub-Saharan Africa. *Economic Change and Restructuring*, 55(4), 2631-2661. <https://doi.org/10.1007/s10644-022-09403-6>
- Onafowora, O. A., & Owoye, O. (2014). Bounds testing approach to analysis of the environment Kuznets curve hypothesis. *Energy Economics*, 44, 47-62. <https://doi.org/10.1016/j.eneco.2014.03.025>
- Ozturk, I., & Acaravci, A. (2010). CO2 emissions, energy consumption and economic growth in Turkey. *Renewable and Sustainable Energy Reviews*, 14(9), 3220-3225. <https://doi.org/10.1016/j.rser.2010.07.005>
- Pindyck, R. S., & Rubinfeld, D. L. (1998). *Econometric models and economic forecasts* (4th ed.). Irwin/McGraw-Hill. [https://esploro.libs.uga.edu/permalink/01GALI\\_UGA/182omg4/alma9925480263902\\_959](https://esploro.libs.uga.edu/permalink/01GALI_UGA/182omg4/alma9925480263902_959)
- Qamruzzaman, M. (2021). Nexus between environmental quality, institutional quality and trade openness through the channel of FDI: an application of common correlated effects estimation (CCEE), NARDL, and asymmetry causality. *Environmental Science and Pollution Research*, 28(37), 52475-52498. <https://doi.org/10.1007/s11356-021-14269-8>
- Salman, A., Sethi, B., Aslam, F., & Kahloon, T. (2018). Free trade agreements and environmental nexus in Pakistan. *Policy Perspectives*, 15(3), 179-195. <https://doi.org/10.13169/polipers.15.3.0179>
- Samuelson, P. A. (1948). International trade and the equalisation of factor prices. *The Economic Journal*, 58(230), 163-184. <https://doi.org/10.2307/2225933>
- Shahbaz, M., Kumar Tiwari, A., & Nasir, M. (2013). The effects of financial development, economic growth, coal consumption and trade openness on CO2 emissions in South Africa. *Energy Policy*, 61, 1452-1459. <https://doi.org/10.1016/j.enpol.2013.07.006>
- Shahbaz, M., Nasir, M. A., & Roubaud, D. (2018). Environmental degradation in France: The effects of FDI, financial development, and energy innovations. *Energy Economics*, 74, 843-857. <https://doi.org/10.1016/j.eneco.2018.07.020>

- 
- Shen, J. (2008). Trade liberalization and environmental degradation in China. *Applied Economics*, 40(8), 997-1004. <https://doi.org/10.1080/00036840600771148>
- Trefler, D. (1995). The Case of the Missing Trade and Other Mysteries. *The American Economic Review*, 85(5), 1029-1046. <https://www.jstor.org/stable/2950973>
- Twerefou, D. K., Akpalu, W., & Mensah, A. C. E. (2019). Trade-induced environmental quality: the role of factor endowment and environmental regulation in Africa. *Climate and Development*, 11(9), 786-798. <https://doi.org/10.1080/17565529.2018.1562868>
- Vigdor, J. L. (2004). Community composition and collective action: analyzing initial mail response to the 2000 Census. *The Review of Economics and Statistics*, 86(1), 303-312. <https://doi.org/10.1162/003465304323023822>
- Wang, H., Zhang, Z., & Zhang, Z. (2024). The dynamic impact of trade on environment. *Journal of Economic Surveys*, 1-29. <https://doi.org/10.1111/joes.12624>
- Wang, X., & Luo, Y. (2020). Has technological innovation capability addressed environmental pollution from the dual perspective of FDI quantity and quality? Evidence from China. *Journal of Cleaner Production*, 258, 120941. <https://doi.org/10.1016/j.jclepro.2020.120941>
- World Development Indicators (WDI). (2024). *World Development Indicators (WDI)*, The World Bank. <https://databank.worldbank.org/source/world-development-indicators>.
- Wu, R., Ma, T., Chen, D., & Zhang, W. (2022). International trade, CO2 emissions, and re-examination of “Pollution Haven Hypothesis” in China. *Environmental Science and Pollution Research*, 29(3), 4375-4389. <https://doi.org/10.1007/s11356-021-15926-8>
- Yunfeng, Y., & Laike, Y. (2010). China's foreign trade and climate change: a case study of CO2 emissions. *Energy Policy*, 38(1), 350-356. <https://doi.org/10.1016/j.enpol.2009.09.025>
- Zarsky, L. (1999). Havens, halos and spaghetti: untangling the evidence about foreign direct investment and the environment. *Foreign direct Investment and the Environment*, 13(8), 47-74. <https://nautilus.org/napsnet/napsnet-special-reports/havens-halos-and-spaghetti-untangling-the-evidence-about-the-relationship-between-foreign-investment-and-the-environment/>
- Zomorodi, A., & Zhou, X. (2017). Impact of FDI on environmental quality of China. *International Journal of Business, Economics and Management*, 4(1), 1-15. <https://archive.conscientiabeam.com/index.php/62/article/view/1171/1643>