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Asymmetric nexus between commercial policies and consumption-based carbon emissions: new evidence from Pakistan

Muhammad Zubair Chishti[1,2,3*], Hafiz Syed Muhammad Azeem[4] and Muhammad Kamran Khan[5*]

*Correspondence:
chishtimz9@gmail.com;
mzchishti@eco.qau.edu.pk;
kamrankhanaup@gmail.com

[1] School of Business, Zhengzhou University, Zhengzhou, Henan, China
[2] School of Economics, Quaid I Azam University, Islamabad, Pakistan
[3] Department of Economic, University of Chakwal, Chakwal, Punjab, Pakistan
[4] Ministry of Finance, Government of Pakistan, Islamabad, Pakistan
[5] Management studies department, Bahria Business School, Bahria University, Islamabad, Pakistan

Abstract

The current study extends the previous literature by exploring the effects of a newly discovered driver, i.e., import taxes (as a proxy for commercial policies), on the consumption-based carbon emissions (CCO2e) for 1990Q1-2017Q4. For empirical analysis, several tests and methods, including Augmented Dickey–Fuller unit root test, Zivot–Andrews unit root test, asymmetric cointegration bound testing approach, non-linear ARDL, Wald-test, Granger causality test and wavelet quantile correlation (WQC) method are utilized. Furthermore, NARDL technique estimates reveal that contractionary commercial policy enhances the environmental quality by disrupting the detrimental effects of CCO2e. However, expansionary commercial policy escalates the environmental pollution by boosting the carbon emissions. Also, the exports and the renewable energy improve the ecological quality; however, GDP deteriorates the atmospheric quality by increasing the CCO2e. Besides, WQC method and the trivariate Granger causality test are deployed to confirm the robustness of the results. Based on the findings, some crucial policies are also recommended for sustainable and green development in Pakistan.

Keywords: Commercial policies, Consumption-based carbon emissions, Asymmetric ARDL, Wavelet quantile correlation (WQC), Pakistan

Introduction

Recently, it is noted that the current pace of global economic growth is around 3–4%. Consequently, the global climate is enduring a higher risk of degradation based on carbon emissions (CO2e) stemming from fossil fuels' immoderate use (Chishti et al., 2021a, b, c, d). Since the 1960s, CO2e has quadrupled, and recently it is reported as 81% of the greenhouse gas emissions. Further, the last 10 years (viz., 2010–2019) were the warmest decade, and 2017 was the warmest year, reported by the World Meteorological Organization (2019). Accordingly, the global atmosphere suffers from several potent threats such as over-extending seasons, fluctuations in the world precipitation trends, and decline in polar ice caps (Ullah et al. 2020a, b; Chishti et al. 2020a, b). Hence, to divulge the carbon emissions' drivers has become the predominant research interest for scholars.

Over the last few decades, a drastic change is observed in international trade due to an upsurge in economic activities among the developed and underdeveloped nations. For example, international trade's growth rate was recorded by 62% from 2005 to 2015. According to the World Bank report, global trade contribution to the global GDP reached 58% in 2017 while it was 30% in 1960. Even though the global economies have enjoyed numerous economic opportunities on account of high ratio of international trade; however, it has caused irrevocable atmospheric destruction, viz., CO2e (Hasanov et al. 2018). Thus, the debate on the nexus between international trade (IT) and CO2e turned into serious environmentalists' concern.

In this regard, several studies explore the association between IT and CO2e. However, most scholars employ territory-based CO2e instead of considering the consumption-based CO2e that adjusts IT's effects (Kirikkaleli and Oyebanji 2022; He et al. 2021a, b). Furthermore, it is evident that consumption-based CO2e (CCO2e) can capture the carbon emissions stem from IT, as compared to the territory-based CO2e (PCO2e); hence, the use of CCO2e instead of PCO2e can be a more robust proxy for environmental pollution (Liddle 2018; Knight and Schor 2014; Kirikkaleli et al. 2022; Abbasi et al. 2022). Also, most of the prior studies use IT as an aggregate variable, instead of using the separate effects of exports and imports. Moreover, some recent studies investigate the separate impacts of exports and imports and reveal that imports tend to increase, and exports tend to decrease the detrimental effects of CCO2e (He et al. 2021a, b).

The developing economies are crippled by the trade deficit issue on account of a large number of imports. Hence, the authorities often use commercial policies to protect domestic industries, generate revenues, save the environment, and reduce the trade deficit. When the authorities decide to increase the import taxes to generate revenue and protect domestic industries. It leads to an increase in the prices of imports for domestic consumers. Accordingly, consumers' purchasing power tends to fall, and importers decrease the imports of intermediate and final goods. As a result, the ratio of CCO2e diminishes due to lower domestic consumption.

On the other hand, the reduction in import taxes by authorities disrupts consumer goods' high prices. It enhances the purchasing power, and consumers increase the demand for cheap imports. Consequently, this process escalates the domestic consumption level due to an upsurge in imports; it leads to soaring the CCO2e. Since the commercial policies directly link with imports and exports, which directly associate with CCO2e (Khan et al. 2020a, b), it is worth examining the effects of commercial policies on CCO2e for developing economies, specifically Pakistan.

The study's prime focus is to divulge the dynamic effects of commercial policies (import taxes) on CCO2e for a developing South Asian country "Pakistan." The South Asian economies highly depend on imports to fulfil the domestic consumers' demand. Similarly, Pakistan also depends on an enormous number of imports, as Fig. 1 demonstrates the overall scenario of imports and exports of South Asian economies. Therefore, Pakistan has to endure a huge trade deficit as in 2017, the total imports and exports were $57,440 million and 21,878 million, respectively. Figure 2 depicts the sector-wise total imports of Pakistan. The excessive imports lead to an increase in CO2e, as reported by erstwhile literature (Khan et al. 2020a, b). Like other economies, Pakistan is also responsible for producing CO2e, and it was recorded 0.65% of the

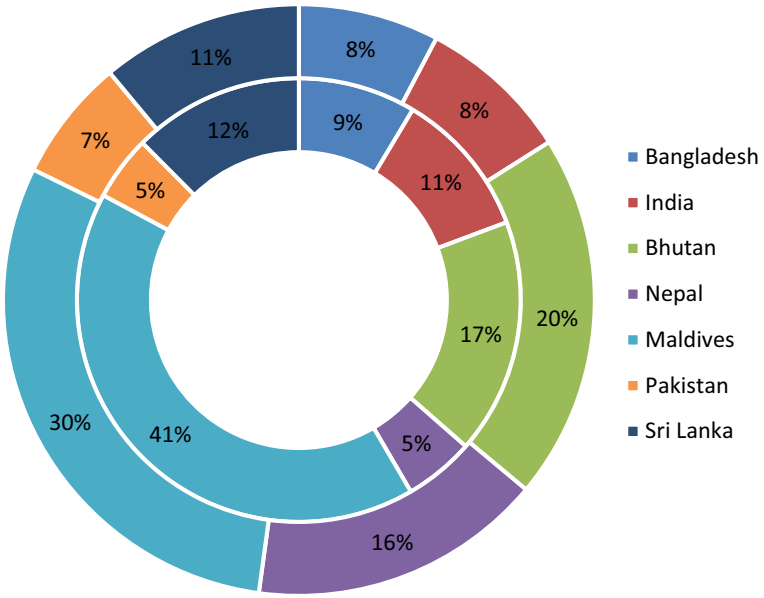

Fig. 1 The exports and imports of South Asian economies in 2017 (% of GDP). Source: World Bank (2020)

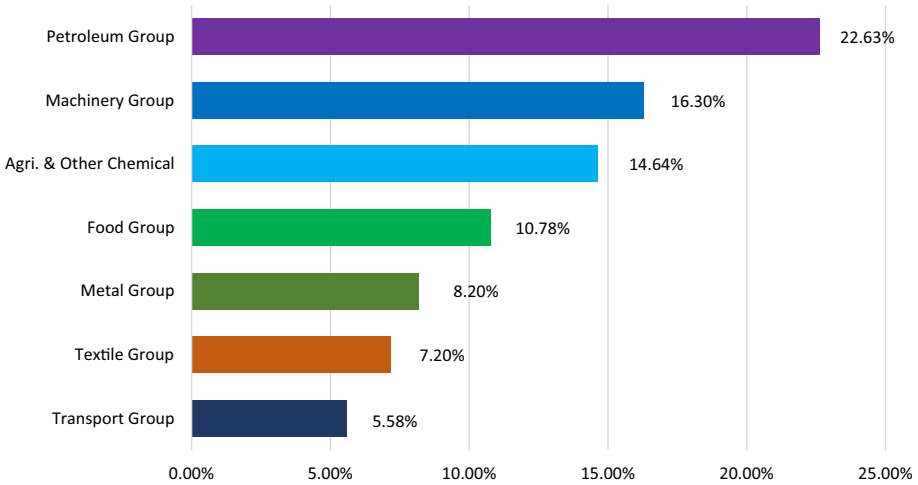

Fig. 2 Sector-wise imports of Pakistan in 2017. Source: State Bank of Pakistan (2020)

world's CO2e in 2017. Further, Fig. 3 represents the overall scenario of carbon emissions, and Fig. 4 depicts the contribution of different sectors to CO2e in Pakistan.

Pakistan imports many intermediate and final consumer goods that directly link with CCO2e. Also, Pakistan's monetary authorities keep practicing to alter the import taxes. The variation in import taxes leads to create the oscillations in the imports and domestic consumption. Further, it is evident that domestic consumption is highly sensitive to carbon emissions (Chishti et al. 2021a, b, c, d; Khan et al. 2020a, b), while the domestic consumption is highly sensitive to import taxes. Hence, these nexuses induce to analyze the impact of commercial policies on the carbon emissions. This aspect may be critical and important in order to obtain the objective of SGD-13

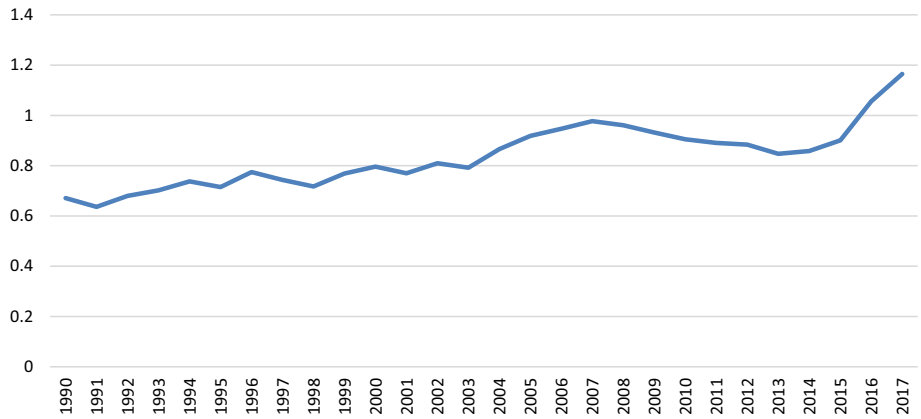

Fig. 3 Consumption-based CO2e in Pakistan

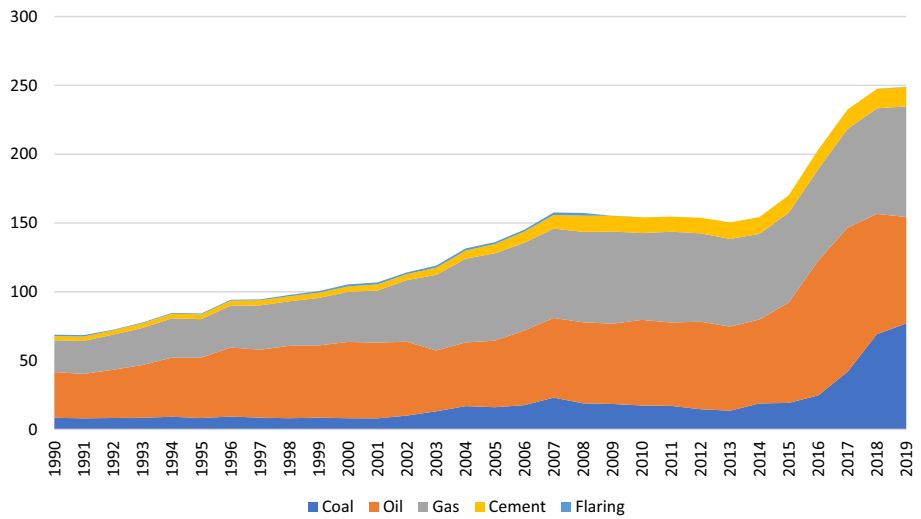

Fig. 4 The contribution of various sources to production-based CO2e in Pakistan

(climate action) for policy makers. Besides, less attention is paid to explore the likely effects of commercial policy on the carbon emissions since to the best of our knowledge, there is only single study by Qingquan et al. that investigate the impacts of commercial policy on the environment in which the study deploys exports taxes as a proxy for commercial policy. In this context, the recent study articulates the following research question:

Research question: Do the commercial policies affect the consumption-based carbon emissions in Pakistan?

Thereby, it is notable for exploring the dynamic effects of commercial policy on CCO2e. Considering the critical role of commercial policy in determining the carbon emissions, the current study extends the previous literature in several ways and presents its contribution as follows. Firstly, this is the first study, to the best of our knowledge, that develop the theoretical nexus between import taxes (as a proxy for commercial policy) and CCO2e, expecting some new and interesting results. Secondly, our study,

for the first time, assesses the link of expansionary and contractionary commercial policies (ECP & CCP) with carbon emissions for Pakistan. Thirdly, unlike the previous studies, the current study utilizes the consumption-based CO2e as proxy for environmental quality. Since the production-based CO2e (PCO2e) does not adjust the emissions stem from international trade, hence, the results based on the PCO2e can be suspected for biasness (Khan et al., 2020a, b; Liddle 2018). Therefore, our study tackles the plausible biasness by introducing CCO2e as proxy for environmental quality. Fourthly, Wavelet Quantile Correlation (WQC) method and trivariate Granger causality is also applied to verify the selected series' causal relationship. Lastly, this is the first study that explores the effects of CCP and ECP on CCO2e for Pakistan.

Literature review

This segment of the article classifies the pertinent literature review into the following bunches. The first bunch underlines the nexus between income and CO2e, while the second bunch summarize the relationship between REC and carbon emissions. In the last bunch, international trade's link with the environment is elaborated.

Income and CO_2 emissions

The famous EKC hypothesis is based on the nexus between per-capita income and carbon emissions. The ECK notion argues that CO2e rises along with an increase in income at an early stage. After achieving a specific threshold, the rise in income causes to decrease the CO2e (Chishti et al., 2021a, b, c, d; Ullah et al., 2020a, b; Grossman and Krueger 1991). The hypothesis is rigorously investigated for different economies. However, the scholars report contradictory findings. For instance, several studies for OECD (Bilgili et al. 2016), India (Sinha and Shahbaz 2018), for high-income countries (Jaunky 2011), for MENA countries (Awad and Abugamos 2017), for NAFTA and BRIC countries (Rehman et al. 2019), for Saudi Arabia (Mahmood et al. 2020), for developed countries (Disli et al. 2016) and China (Hang and Yuan-Sheng 2011) have inspected the EKC hypothesis and validated the presence of the hypothesis.

However, many other studies for Canada (Lantz and Feng 2006); Azerbaijan (MikaYilov et al. 2018); emerging economies (Saidi and Mbarek 2016); ASEAN countries (Chandran and Tang 2013) and Malaysia (Azlina et al. 2014) failed to validate the EKC hypothesis and argued that the previous countries did not obtain the specific threshold that confirms the occurrence of EKC hypothesis. In the light of the literature review discussed above, it can be inferred that the inconclusive findings regarding the presence of EKC hypothesis requires more research. Further, the available literature pays less attention to testifying the ECK notion while employing the CCO2e, i.e., a more robust proxy for environmental pollution as compared to PCO2e. Hence, the current study tends to seeks the existence of EKC hypothesis while using the CCO2e as a dependent series.

Renewable energy consumption (REC) and CO_2 emissions

It is a matter of the fact that fossil fuels are the backbone for any economy's growth (Rehman et al. 2021; Ullah et al. 2020a, b; Usman et al. 2020). At the same time, the use of non-renewable resources is alarming for the global atmosphere. Approximately 81% of the total energy is generated by fossil fuels that is a huge portion of the total energy

(Chishti et al., 2021a, b, c, d) and the use of conventional energy is rising day by day. Whereas the effects of fossil fuels are concerned, the scholars [such as Ahmad and Khattak (2020), Bhuiyan et al. (2018), Ahmad et al. (2019), Mirza and Kanwal (2017), Zaman and Abd-el Moemen (2017) for South Africa, Selected Asian economies, China, SAARC, Pakistan, and global economies, respectively] are of view that conventional energy deteriorates the environment.

Since fossil fuels are also a major source of carbon emissions, therefore, to replace fossil fuels energy has become the imperative concern of environmentalists. In this context, the authorities have commenced the efforts for green and sustainable development at global level. For example, the Paris Agreement and COP26 conference were held on December 2015 and November 2020, respectively. Consequently, renewable energy has become, approximately, 21% of global energy as recorded in 2020 (Chishti and Sinha 2022).

Many studies are available which explores the nexus between renewable energy (REC) consumption and CO_2 emission. Virtually, all scholars believe that the use of renewable energy mitigates the detrimental effects of environmental pollution. Since REC is based on the pure and clean technologies that fulfil the requirements of energy for production process, hence, the use of REC helps attaining the sustainable development along with creating the beneficial effects on environmental quality. In this context, several studies are available that explore the dynamic effects of REC on the environment. For instance, Chishti et al. (2021a, b, c, d) confirm that renewable energy impedes atmospheric pollution in BRICS economies. Ding et al. (2021) assert that the REC enhances environmental quality by disrupting the CO2e in G7 countries in a similar vein. Likewise, Khan et al. (2020a, b) deduce that the ratio of CO2e tends to fall on account of using the REC in Pakistan. Besides, Chishti et al. (2020a, b) for South Asian economies, Akram et al. for Pakistan, Ullah et al. (2020a, b) for top 10 polluted countries, Waheed et al., (2018) for Pakistan, Cheng et al. (2019) BRICS, Hasnisah et al. (2019) for 13 Asian economies, and Bilgili et al. (2016) for OECD economies conclude that the employment of REC significantly reduces the CO2e. However, Bulut (2017) argues that the use of renewable and non-renewable energy deteriorates the environmental quality in Turkey's case. To recapitulate, most environmentalists suggest that REC plays an essential role in improving ecological quality. In a nutshell, REC is the major determinant of the carbon emissions that shrinks the harmful effects of CO2e.

Trade and CO2e

International trade (IT) significantly contributes to the global carbon emissions (Hasanov et al. 2018). The erstwhile studies argue that IT boosts the transfer of goods from one nation to another nation and increases energy use. Likewise, it causes to transfer the heavily polluted firms across the nations. Ultimately, these trends increase the use of energy that results in CO2e. Further, the scholars bifurcate the IT into exports and imports to check their separate carbon emissions effects (Qingquan et al. 2020). Although several studies explore IT's effects on CO2e, however, less attention is paid to check the impact of IT on CCO2e. For instance, Hasanov et al. (2018) argue that imports cause to trigger the CCO2e since the imports increase the consumption level. Further, the study confirms that PCO2e rises along with an increase in exports. Likewise, Khan et al. (2020a, b) demonstrate that exports negatively affect CCO2e and imports have a positive link with CCO2e in G7 economies.

Based on the above discussion, our study claims that some studies endeavor to examine the effects of exports and imports on CCO2e. Further, the imports and the exports are highly sensitive to commercial policies such as imports and exports taxes. Since the trade is the significant driver of carbon emission, hence, it is rational to assume that commercial policy may affect the environment via trade. In this context, there is only one study by Qingquan et al. (2021), to the best of our knowledge, investigates the impact of export taxes as a proxy for commercial policy on CCO2e. Since the previous literature body does not pay attention on the import taxes (as a proxy for commercial policy) and carbon emissions nexus, our study anticipates the import taxes as a considerable driver of environmental quality. To fill this gap, the current study extends the prior literature by studying the asymmetric effects of imports taxes on CCO2e, for the first time. To this end, we split the imports taxes (commercial policy) into positive shocks (contractionary commercial policy) and negative shocks (expansionary commercial policy) and explore their effects on CCO2e (a more robust proxy for environmental quality as compared to PCO2e). Similarly, our study also the explores the effects of remittances, REC, and GDP on CCO2e unlike the majority of the previous study that deploy PCO2e as a proxy for the environmental quality. Thus, it is worth exploring the effects expansionary and contractionary commercial policies with the consort of REC, FFC, remittances and national income on CCO2e for Pakistan.

Theoretical underpinning

In this section, the theory-based association between selected independent series and dependent series is elaborated. Since the prime focus of the study is divulge the dynamic impacts of commercial polices on CCO2e, thus, Fig. 5 expresses the theoretical effects of expansionary and contractionary commercial policies on consumption-based CO2e. In general, the government deploys import taxes as a commercial policy tool to maintain trade balance, generate revenues, and protect domestic newly developed firms. Over time, the authorities increase and decrease the import taxes. When govt increases the taxes on imports, this situation is called contractionary commercial policy. In this situation, the number of imports tends to fall. However, the demand for the final and intermediate consumer goods remains the same, and the demand-side becomes greater than the supply-side. This process makes the consumer goods expensive; accordingly, consumers' purchasing power shrinks. Consequently, the local consumers decrease the consumption level, resulting in a decline in consumption-based CO2e because now fewer imports are domestically consumed.

On the other side, when the authorities plan to reduce import taxes, it is called expansionary commercial policy. In this situation, many intermediate and final consumer goods are imported. Accordingly supply side becomes greater than the demand side, and the price level tends to fall. Due to increased purchasing power, consumers enhance the demand for goods. Hence, a higher level of consumption leads to a higher level of CCO2e because now more imported goods are domestically consumed that are produced in abroad.

Similarly, exports also play a remarkable role in determining the CCO2e. The reason being, Khan et al. and Ding et al. argue that due to exports, fewer goods remain for domestic consumption, and the recipient economy consumes more. Therefore,

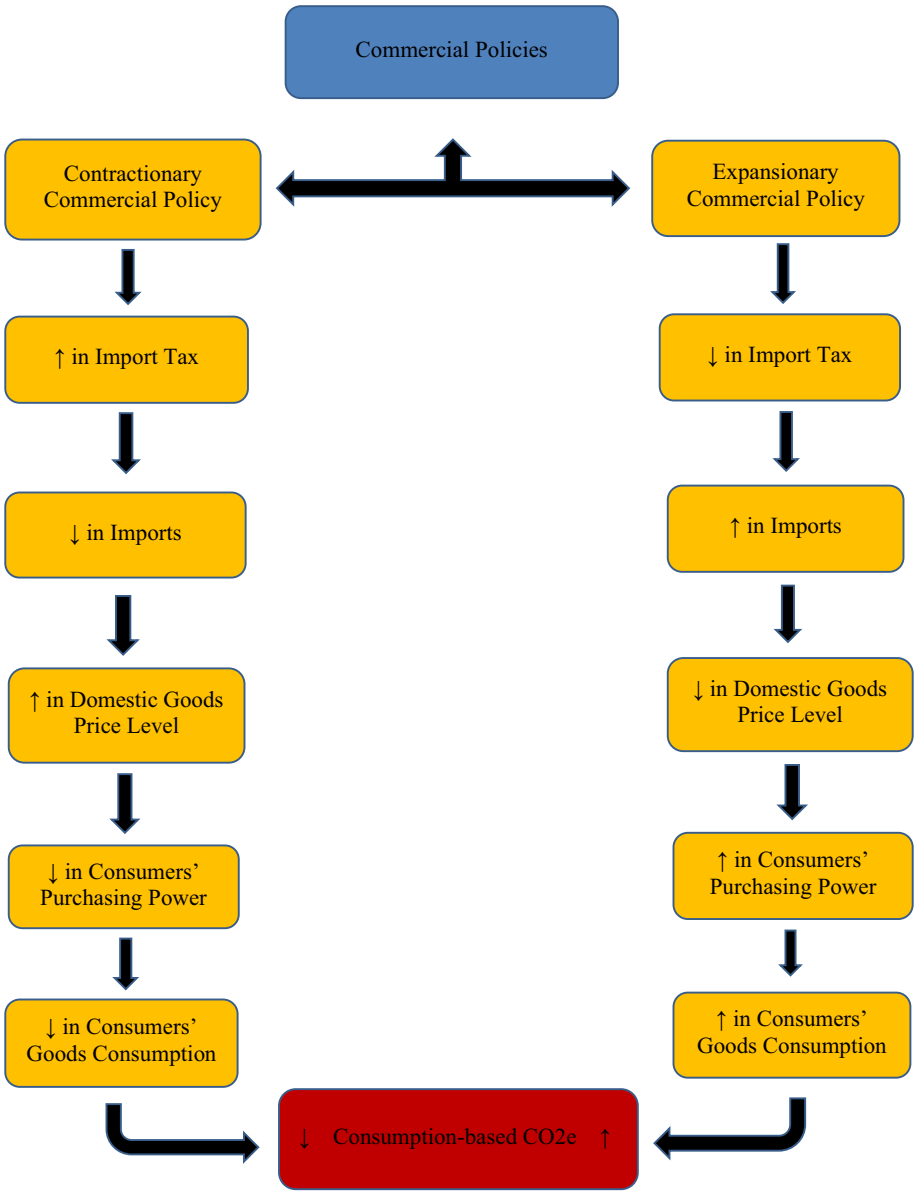

Fig. 5 Theoretical nexus between commercial policies and CCO2e

exports exhibit an adverse impact on CCO2e in exporting-economies. In a similar vein, it is widely accepted that renewable energy assists in improving the green environment by disrupting carbon emissions (Chishti et al. 2021a, b, c, d; Chishti et al. 2020a, b; Ullah et al. 2020a, b). Besides, majority of the scholars believe that economic growth is another considerable variable that intensifies the ratio of carbon emissions (Chishti et al. 2021a, b, c, d; Hasanov et al. 2018).

Modeling and econometric methods

Based on theoretical discussion in previous section, we specify the following model:

$$CCO2e_t = b_0 + b_1 IMT_t + b_2 EXP_t + b_3 REC_t + b_4 GDP_t + \varepsilon_t \quad (1)$$

where b_0 to b_7 are the long-run coefficients. Further, IMT_t, EXP_t, REC_t, and GDP_t are import taxes, exports, renewable energy consumption, and gross domestic product, respectively. Further, we use general to specific approach to testify the significance and justification of the modeled variables (Chishti et al. 2021a, b, c, d; Chishti et al. 2020a, b). Since the main focus of the study is to explore asymmetric effects of import taxes with the consort of other modeled variables on the environment, we firstly erect the ARDL model, and then it would be converted into asymmetric ARDL model. The reconstruction of the model can be expressed as:

$$\begin{aligned}\Delta CCO2e_t = {} & \alpha_0 + \sum_{k=1}^{p} \beta_k \Delta CCO2e_{t-k} + \sum_{k=1}^{p} \gamma_k \Delta IMT_{t-k} \\ & + \sum_{k=1}^{p} \delta_k \Delta EXP_{t-k} + \sum_{k=1}^{p} \vartheta_k \Delta REC_{t-k} + \sum_{k=0}^{p} \rho_k \Delta GDP_{t-k} \\ & + b_1 CCO2e_{t-1} + b_2 IMT_t + b_3 EXP_t + b_4 REC_t \\ & + b_5 GDP_t + \varepsilon_t\end{aligned} \tag{2}$$

The model presented in Eq. 2 is known as ARDL model developed by Pesaran et al. (2001). Further, the sign of Δ attached with the variables denotes the short-run estimates, while b_1 to b_8 are the long-run coefficients. There are several advantages to employ ARDL approach that demonstrate its superiority over traditional cointegration methods. For instance, it can compute the coefficients of the variables that are stationary at I(0) or I(1) or the mixture of both. Also, it computes the consistent results even for the small sample size. Further, it is a single step approach. However, if the modeled variable is I(2), the findings of ARDL become inconsistent (Chishti et al. 2021a, b, c, d; Chishti et al. 2020a, b).

During the last decade, it is observed that the majority of the economic variables possess the potential hidden cointegration, which the linear ARDL approach cannot tackle. Shin et al. extended the ARDL technique and developed its extension called Non-linear ARDL method to resolve this issue. This extended technique is capable of divulging the hidden cointegration across the series. Also, it is more efficient and more powerful in exploring the effects of regressors than the former (Chishti 2021; Chishti et al. 2021a, b, c, d). Further, the main objective of the paper is to explore the effects of expansionary and contractionary commercial policy on CCO2e. To this end, the import taxes (commercial policy) are decoupled into positive and negative shocks. To do so, we follow the following process:

$$IMT^{+}{}_t = \sum_{n=1}^{t} \Delta IMT^{+}{}_t = \sum_{n=1}^{t} \max(\Delta IMT^{+}{}_t, 0) \tag{3}$$

$$IMT^{-}{}_t = \sum_{n=1}^{t} \Delta IMT^{-}{}_t = \sum_{n=1}^{t} \min(\Delta IMT^{-}{}_t, 0) \tag{4}$$

where $IMT^{+}{}_t$ = contractionary commercial policy (CCP): a situation in which authorities increase the import taxes and $IMT^{-}{}_t$ = expansionary commercial policy (ECP): a situation in which authorities opt to decline the import taxes. Putting Eqs. 3 and 4 in Eq. 2, we get the following model:

$$\begin{aligned}\Delta CCO2e_t = \alpha_0 &+ \sum_{k=1}^{p} \beta_k \Delta CCO2e_{t-k} + \sum_{k=1}^{p} \gamma_k \Delta IMT^{+}_{t-k} \\ &+ \sum_{k=1}^{p} \tau_k \Delta IMT^{-}_{t-k} + \sum_{k=1}^{p} \delta_k \Delta EXP_{t-k} + \sum_{k=1}^{p} \vartheta_k \Delta REC_{t-k} \\ &+ \sum_{k=0}^{p} \rho_k \Delta GDP_{t-k} + b_1 CCO2e_{t-1} + b_2 \Delta IMT^{+}_{t-k} \\ &+ b_3 \Delta IMT^{-}_{t-k} + b_4 EXP_t + b_5 REC_t + b_6 GDP_t + \varepsilon_t\end{aligned} \tag{5}$$

Equation 5 is termed as Non-linear ARDL (NARDL) model. The advantages and the disadvantages of NARDL are as of ARDL, as it is the extension of the latter. Besides, we follow the Akaike Information Criterion for selecting the optimal lags. The remarkable benefit of this approach is that the optimal lag selection impedes the exigencies of endogeneity and serial correlation (Chishti et al. 2021a, b, c, d; Chishti et al. 2020a, b). In addition, the Wald test for both short- and long-run symmetries is deployed which verifies the accuracy of asymmetric model. Furthermore, the NARDL technique compute the asymmetric multiplier effects of CCP and ECP on CCO2e that can be obtained as:

$$m_h^{+} = \sum_{j=0}^{h} \frac{\partial CCO2e_{t+j}}{\partial CCP_j^{+}},\ m_h^{-} = \sum_{j=0}^{h} \frac{\partial CCO2e_{t+j}}{\partial ECP_j^{-}} \quad \text{for h} = 1, 2, 3 \ldots$$

where $m_h^{+} \to L_{mi^{+}}$ as $h \to \infty$, and $m_h^{-} \to L_{mi^{-}}$.

The multiplier effects help in observing how a unit shock in IMT (CP) brings an adjustment in CCO2e from initial to new long-run equilibrium. Besides, the unit root (ADF) test is utilized to check the selected series' stationarity. The current study uses the quarterly data, which may have the potential structural break effect, which cannot be tackled by traditional unit root tests such as the ADF test. Hence, we deploy the Zivot–Andrews unit root test that presents consistent results in the presence of structural break. Also, the long-run association is confirmed by applying the bound testing approach. Besides, for robustness check, the study employs the novel wavelet quantile correlation (WQC) technique introduced by Kumar and Padakandla (2022) since this method is robust and straightforward in capturing the nexus between two time series in different quantiles. Hence, this method is reliable to assure the authenticity of calculated results (Kumar and Padakandla, 2022). Besides, the main equation of WQC method can expressed as follows:

$$WQC_\tau(d_j[X], d_j[Y] = \frac{qcov_t(d_j[X], d_j[Y]}{\sqrt{var\left(\theta_\tau\left(d_j[Y] - Q_{\tau, d_j[Y]}\right)\right) var(d_j[X])}} \tag{6}$$

In above equation, X, and Y represent the independent and dependent series, respectively. Also, we split our time period into three scales (short run, medium run, and long-run) in order to capture the more informative behavior across the dependent and independent series. Additionally, trivariate Granger causality test is deployed to inspect the causal nexus across the modeled series which presents reliable results even in the case of several variables (Odhiambo, 2009).

Data

The study's primary focus is to investigate the symmetric and asymmetric effects of commercial policies with the consort of some other variables on CCO2e for 1990Q1-2017Q4. To this end, the data for GDP, exports, and renewable energy are retrieved from the World Bank's site. Further, import taxes data as a proxy for the commercial policy is taken from the site of the State Bank of Pakistan. Since the import taxes has the significant correlation with the imports; therefore, the study includes only the import taxes (as a proxy for commercial policy) in the model without including the imports to avoid the issue of high multicollinearity. The rationale behind to use the import taxes as a proxy for commercial policy can be explained as follows. Firstly, import taxes are most important kind of commercial policy and are widely used as separate representative of commercial policy (Salvatore, 2014). Secondly, although there are also some other restrictions and regulations represent the commercial policy, the data for such series is not accessible except for the import taxes. Thirdly, there are also many scholars [For example, Muhammad et al. (2018), and Chae et al. (2019)] which deploy import taxes as a proxy for commercial policy. Hence, following the rationale discussed above and considering the data availability issue, we employ the import taxes as a proxy for commercial policy. Besides, the data of consumption-based CO2e are obtained from Global Carbon Atlas. As per the assertion of Qingquan et al. (2020), Shahbaz et al. (2018a, 2018b), and Sbia et al. (2014), all the series are transformed into quarterly data from annual frequency to estimate the robust findings; hence, the total number of observations are 112. Since the transformation of modeled series into quarterly data from annual frequency has increased the number of observations, it assists in resolving the issue of degree of freedom; hence, we can generate the reliable results. All the series are in logarithmic form except the series in percentage. Table 1 presents the definitions and the sources of the modeled series.

Results and discussion

Proceeding to the result's interpretation, Table 2 demonstrates the significant difference between the minimum and maximum values. It shows the remarkable oscillations in the modeled series' trends, specifically in the series of exports, imports taxes (commercial policy), and renewable energy consumption (REC). Further, REC has the highest mean (49.70) and, similarly, also has the largest standard deviation (3.82) among the modeled series. It is necessary to check the stationarity of the series before estimation since econometric techniques' results become useless in the case of I (2) variable (Weimin et al. 2021; Chishti et al. 2020a, b). Thus, the ADF unit root test is deployed, as Table 3 reports. The results indicate that there is not a single series which is I (2). However, the ADF test cannot differentiate between the unit root and structural break. Hence, the outcome of the ADF test may be misleading in the presence of likely structural break. Therefore, we employ the Zivot–Andrews test that differentiates between the unit root and structural break. The results in Table 4 show that all series are stationary at first difference. Hence, we can confidently proceed with the estimation of coefficients. To compute the results, the general to specific method is utilized in order to selected the suitable and appropriate NARDL specification for robust findings. To do so, the study follows Shin et al., Ibrahim (2015), and Mohammadian (2015) which also follow the general to

Table 1 Variable's description and sources

Variables	Symbol	Unit	Data source
Consumption-based carbon dioxide emissions	CCO2e	CO2e in tCO_2 per person	Global Carbon Atlas
Import taxes	IMT	% of the taxes	State Bank of Pakistan (2020)
Exports	EXP	% of GDP	World Bank (2020)
Renewable energy	REC	% of the final energy consumption	World Bank (2020)
GDP per capita	GDP	GDP per capita (constant 2010 US $)	World Bank (2020)

Table 2 Descriptive statistics

	CCO2e	EXP	GDP	IMT	REC
Mean	2.112355	13.97762	11.13840	4.961765	49.70359
Median	2.112579	14.09424	11.13315	5.061443	48.50172
Maximum	2.362456	17.36369	11.38939	6.922459	58.29161
Minimum	1.852735	8.048916	10.89377	1.882781	44.12005
Std. Dev	0.146548	2.290776	0.140921	0.611663	3.829744

Table 3 ADF test

	Level T-Stat	Difference T-Stat
CCO2e	− 0.8532	− 4.7824*
IMT	− 0.3211	− 5.1840*
EXP	− 0.6723	− 4.8300*
REC	− 1.1023	− 4.0001*
GDP	− 0.9037	− 3.9929*

* indicates a level of significance at 1%

Table 4 Zivot Andrews unit root test

	At level		At 1st difference	
	T-Stat	Break year	T-Stat	Break year
CCO2e	− 2.80	2002Q4	− 8.99***	2008Q2
CP	− 3.01	2005Q2	− 9.44***	2008Q3
EXP	− 3.40	1998Q4	− 10.00***	2005Q1
REC	− 3.18	2008Q2	− 9.97***	2002Q2
GDP	− 2.96	2002Q1	− 9.78***	1998Q3

***Signifies the significance level at 1%

specific approach. Also, Akaike Information Criterion (AIC) is deployed to choose the optimal lag selection (Chishti et al. 2021a, b, c, d).

Next, the cointegration test results assert that the F-stat of both symmetric and asymmetric models are 6.17 and 13.67, respectively, as reported in Panel C of Tables 8 and Table 5. Since the aforementioned values are greater than the tabulated values of the upper-bound (at 5% significance level), these findings confirm the presence of a long-run

Table 5 NARDL estimates

Variable	Coefficient
Panel A: Short-run estimates	
CCP	0.110** (1.99)
CCP (− 1)	0.092*** (2.78)
CCP (− 2)	0.034** (2.18)
ECP	0.026 (1.63)
ECP (− 1)	0.181*** (4.16)
EXP	− 0.014 (1.01)
EXP (− 1)	− 0.09*** (3.00)
REC	− 0.20** (2.32)
GDP	0.874*** (5.43)
GDP (− 1)	0.514* (1.74)
CointEq (− 1)	− 0.596*** (6.63)
Panel B: Long Run estimates	
CCP	− 0.074* (1.90)
ECP	0.192*** (2.94)
EXP	− 0.056** (2.15)
REC	− 0.238*** (4.13)
GDP	0.825*** (5.32)
C	− 6.842*** (6.10)
Panel C: Diagnostic tests	
WALD test: CP (Short-run)	5.44***
CP (Long-run)	7.86***
F-Stat	15.21***
R^2	0.9842
Adj R^2	0.9696
DW Stat	2.08
J-B Normality	0.83
X^2 LM	0.99
X^2 RESET	1.23
CUSUM	Stable
CUSUMQ	Stable

***, **, and * indicate the significance level at 1%, 5%, and 10%, respectively

association across the modeled series. After meeting all the necessary conditions, we move towards interpreting the NARDL estimates.

Since the primary aim of the current study is to divulge the dynamic impacts of CCP and ECP on the CCO2e, we deploy NARDL model and findings are reported in 6. However, we also compute the results of linear ARDL technique which are documented in Table 8 given in Appendix 1. Before computing the short- and long-run effects of modeled series, we confirm the short and long run symmetries by applying Wald test as the outcome is documented in Panel C, Table 5. The findings demonstrates that Wald test's values are 5.44 (for short-run) and 7.86 (for long-run), indicating the existence of symmetries in commercial policy at 1% significance level. Simply, the significance of Wald test's values confirms the justification of ECP & CCP and their robustness. Hence, the Wald test's outcome promises the presence of short and long-run asymmetries in import taxes (commercial policies). Thus, it is rational to explore the asymmetric effects of commercial policies on CCO2e.

To do so, we split the imports taxes' series into positive and negative shocks. Further, the negative shocks in import taxes show "the expansionary commercial policy" (ECP), and the positive shocks indicate "the contractionary commercial policy" (CCP).

Focusing on the asymmetric short-run estimates, as Table 5 (Panel A) reports, the findings determine that ECP possesses the significant positive association with CCO2e such that a 1% increase in ECP leads to escalate the CCO2e by 0.20%. It shows that ECP significantly degrades the environmental quality by increasing the detrimental effects of CCO2e. On the contrary, a 1% rise in CCP tends to contract the ratio of CCO2e by 0.07%, indicating that CCP plays a considerable role in enhancing the green environment by impeding the CCO2e. Like CCP, EXP and REC also demonstrate the significant adverse effects on CCO2e, implying that a 1% upsurge in EXP and REC leads to dwindle the level of CCO2e by 0.09% and 0.20%, correspondingly. However, the results suggest that GDP exhibits the direct link with CCO2e such that a 1% rise in carbon emissions is observed due to increase in GDP by 0.87%. Overall, the short-run coefficients affirm the significant role of ECP and CCP in determining the CCO2e.

Do the short-run coefficients remain consistent in the long-run? Before computing the long-run coefficients, we apply asymmetric bound testing approach to confirm the long-run association among the modeled series as the findings is reported in Panel C, Table 5. Since the F-statistics' value is 15.21 (significant at 1%), it corroborates the presence of cointegration among the selected series, indicating that the long-run estimates are meaningful. Hence, we confidently compute the long-run coefficients. The long-run estimates in Panel B demonstrate that the CCP has a significantly adverse impact on CCO2e, implying that a 1% rise in import taxes results in a 0.07% decline in the ratio of CCO2e. It seems that the increasing ratio of import taxes makes imports expensive for domestic consumers. Accordingly, it decreases consumers' purchasing power, and demand for such goods declines. This process discourages the imports of intermediate and final consumer goods. The decrease in imports reduces the size of domestically consumed goods, resulting in shrinking the CCO2e. Contrarily, ECP exhibits a significantly positive link with carbon emissions, indicating that the deleterious effects of CCO2e expand by 0.19% because of a fall in import taxes by 1%. Since a downfall in import taxes increases consumers' purchasing power for intermediate and final foreign goods by lowering the prices of imports. Accordingly, more imports are demanded that enhance the ratio of imports. More imports lead to more domestic consumption. Since it is evident that the domestic consumption has positive link with CCO2e (Khan et al. 2020a, b), this process results in boosting the level of CCO2e. These are unique findings of the current study, specifically in Pakistan's context. Since the positive and negative shocks in commercial policy (ECP $ CCP) significantly affects the CCO2e, it indicates the robustness and significance of ECP and CCP.

Further, the results determine the negative association between exports and CCO2e, indicating that a 1% increase in exports tends to disrupt the ratio of carbon emissions by 0.05%. These findings are in line with the study by Ding et al. (2020) for Australia and Khan et al. (2020a, b) for G7 economies. The rationale behind this negative nexus is that exports lead to decrease the amount of goods for domestic consumption in the exporting-economy and more goods are consumed in the host economy. Accordingly, less domestic consumption of good results in less carbon emissions. Likewise, REC is also a factor that significantly reduces the CCO2e by 0.23%, implying that environmental pollution's adverse effects tend to fall when 1% more renewable resources are used. The same results were also reported by Khan

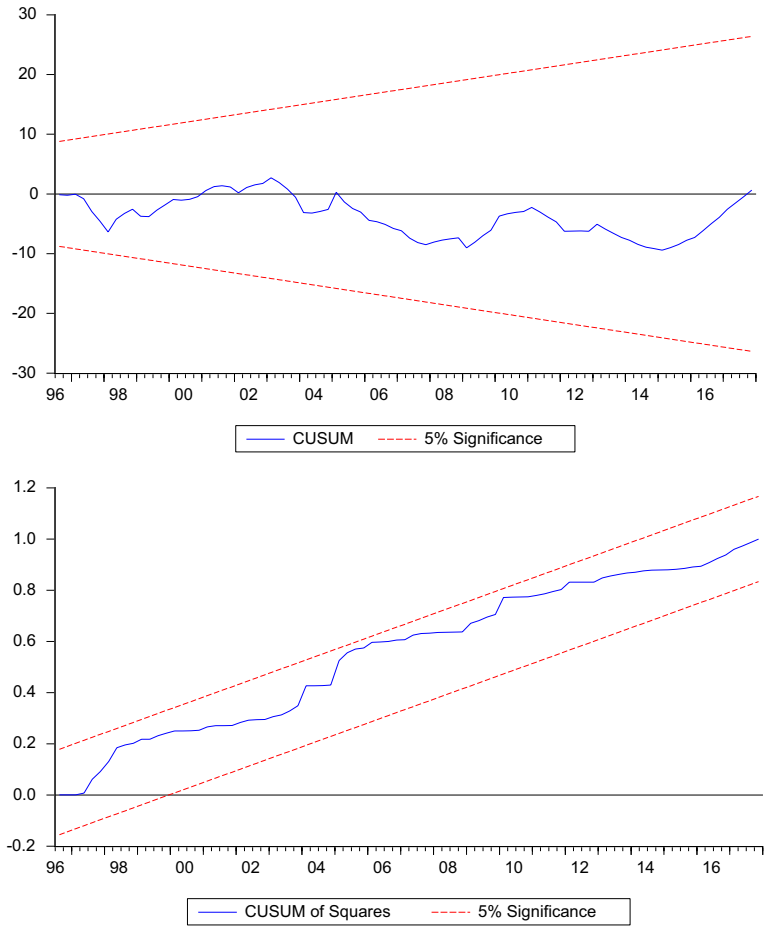

Fig. 6 CUSUM AND CUSUMQ tests of NARDL approach

et al. and David and Venkatachalam. Since the renewable energy consists of the clean and eco-friendly technology that fulfil the energy requirement for production process along with disrupting the carbon emission.

Additionally, the coefficient of GDP asserts a significantly positive association with CCO2e. The results suggest that, on average, 1% rise in GDP is accountable for boosting the carbon emissions by 0.82%. Further, the value of ECM is −0.59 that is significant at 1% level. The significant ECM value indicates a 59% convergence rate from short-run disequilibrium to long-run equilibrium.

After the results' interpretation, several post-estimation tests are also performed to confirm the analysis' robustness for forecasting and decision making, as the details are given in Panel C of Table 5. The results indicate that both models' findings are free from the issue of autocorrelation and heteroscedasticity since the DW stats and LM stats are 2.08 and 0.99, respectively. Further, CUSUM and CUSUMQ tests (see: Figs. 9 (in Appendix 2) and 6) are deployed to assess that the models' coefficients are stable or not. Since the blue line is within upper and lower-bound, we can infer that the models' coefficients are stable. Hence, our estimated model is robust and appropriate for decision making.

Also, the outcome of Jarque–Bera and Ramsey RESET tests assert that the residuals are normally distributed and the specification of the model is accurate and reliable,

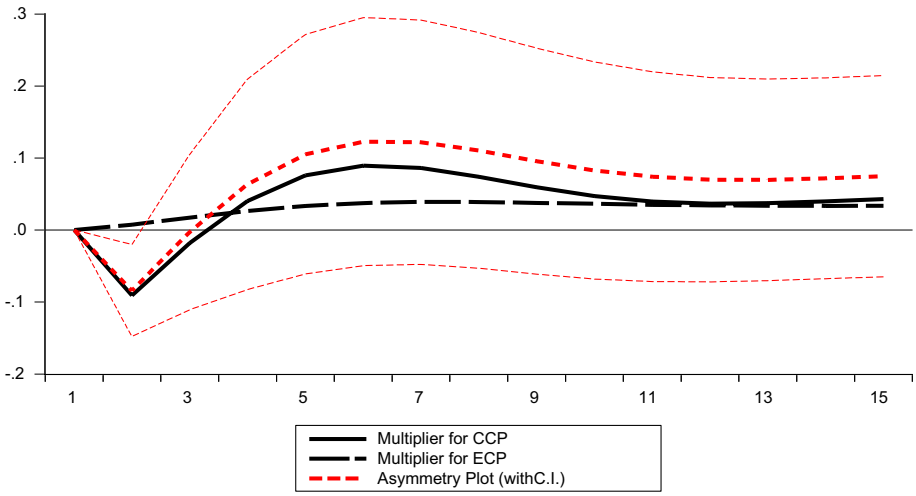

Fig. 7 Multiplier effects of commercial policies on CCO2e

correspondingly. Besides, the dynamic multipliers for NARDL approach are also presented in Fig. 7. The multipliers plot exhibits how positive and negative shocks tend to adjust the initial long-run equilibrium to new long-run equilibrium. In Fig. 7, the positive and negative curves demonstrate asymmetric adjustment of CCO2e to positive and negative shocks (CCP & ECP) of commercial policy, correspondingly, at a given forecasting horizon. It can be analyzed that asymmetries in CCO2e significantly follow the positive shock of commercial policy (CCP), indicating that CCP has the paramount effects on CCO2e as compared to the ECP in the long-run. In the other words, the overall impression of the multipliers' plot is that there is a positive asymmetry in the long-run. Besides, the multipliers plot also demonstrates the robustness of positive and negative shocks in commercial policy since the positive and negative shocks tend to adjust the initial long-run equilibrium to new long-run equilibrium.

Robustness check

To affirm the robustness of the results, we deploy the novel WQC method. Further, 1Q1–4Q4, 6Q1–12Q4, 14Q1–28Q4 indicate the short, medium, and long-runs, correspondingly. The outcome of WQC method supports the NARDL method findings as Fig. 8 reports. For example, ECP exhibits the positive link with CCO2e across the all-time periods during each quantile. On the other hand, CCP indicates a significant negative association with CCO2e during each quantile, supporting the NARDL outcome. In a similar vein, EXP and REC demonstrate the negative link while GDP signify an adverse association with CCO2e, backing the coefficients estimation of NARDL method. Hence, it can be inferred that outcome WQC supports the findings of NARDL; thus, the results are authentic and reliable.

Secondly, we also apply trivariate Granger causality to verify the modeled series' causal nexus. Firstly, the short-run causality's results are discussed as Table 6 reports. The findings suggest the one-way causal nexus that run from CCP, ECP, EXP, and REC to CCO2e. It implies that both commercial policies (CCP & ECP) significantly cause consumption-based emissions, validating the findings of NARDL approach. Again, this is another unique outcome of the current study that assert the one-way casual nexus between CCP, ECP

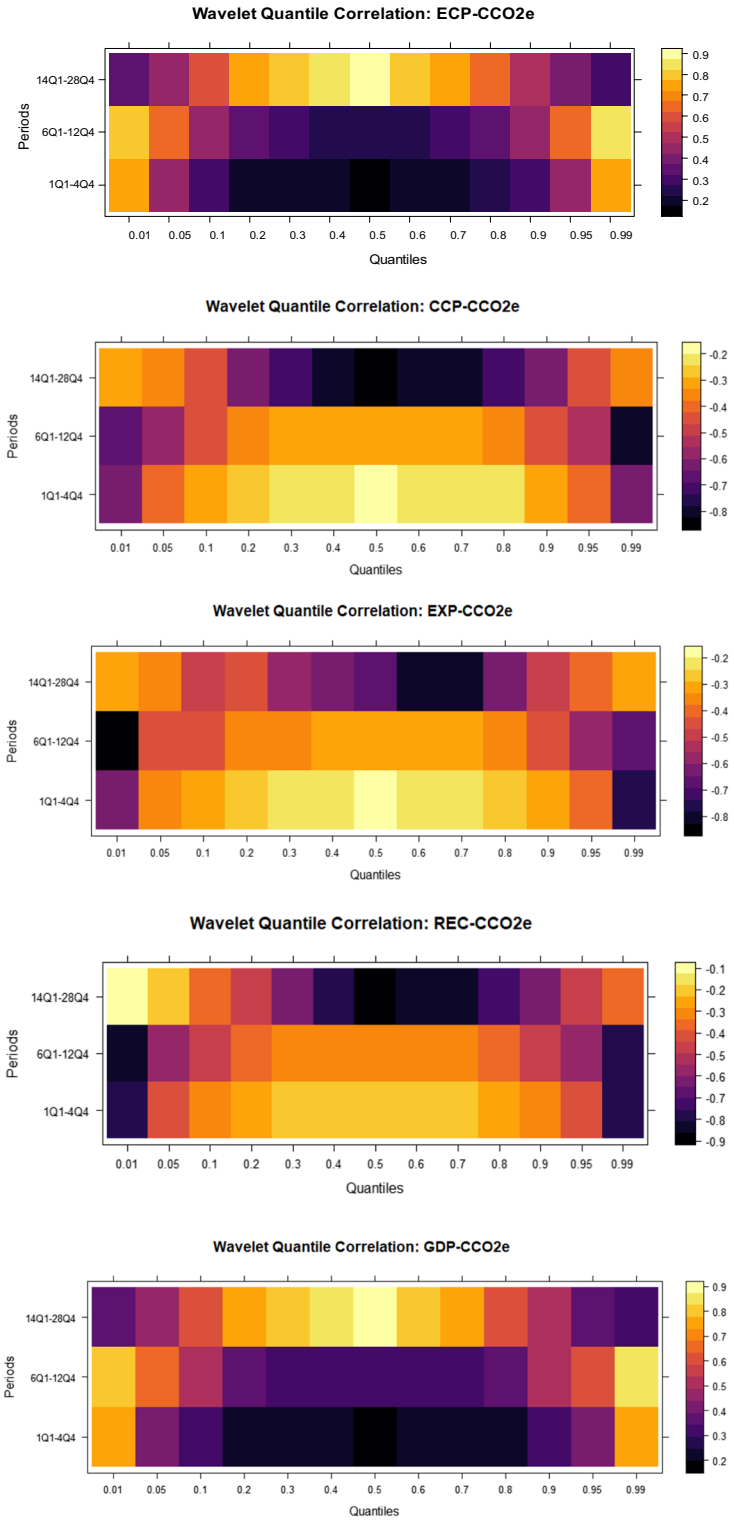

Fig. 8 WQC between CCO2e and modeled series

Table 6 Short-run causality

Null hypothesis	F-statistics	Direction of the causality
CCP does not Granger cause CCO2	12.003***	CCP → CCO2
CC02 does not Granger cause CCP	1.837	
ECP does not Granger cause CCO2	9.331***	ECP → CCO2
CCO2 does not Granger cause ECP	0.858	
EXP does not Granger cause CCO2	7.175**	EXP → CCO2
CCO2 does not Granger cause EXP	1.833	
REC does not Granger cause CCO2	8.889***	REC → CCO2
CCO2 does not Granger cause REC	2.048	
GDP does not Granger cause CCO2	13.003***	GDP ↔ CO2
CCO2 does not Granger cause GDP	5.084*	

***, ** and * signify the significance level at 1%, 5%, and 10%, respectively

Table 7 Long-run and strong causality

Dependent variable	Independent variables						
	Long-run	Strong					
	ECM	ΔCCO2 and ECM	ΔECP and ECM	ΔCCP and ECM	ΔEXP and ECM	ΔREC and ECM	ΔGDP and ECM
Δ*CCO2*	7.54***	–	7.14***	4.50**	6.34***	4.15**	8.65***
Δ*ECP*	5.14**	0.845	–	–	–	–	–
Δ*CCP*	6.95***	1.734	–	–	–	–	–
Δ*EXP*	4.75**	2.045	–	–	–	–	–
Δ*REC*	8.44***	8.843***	–	–	–	–	–
Δ*GDP*	9.32***	3.84*	–	–	–	–	–

***, ** and * signify the significance level at 1%, 5%, and 10%, respectively

and CCO2e. Likewise, EXP, and REC also significantly cause the CCO2e, supporting the results of the studies by Ding et al. (2021) and Ahmed & Khattak. Similarly, we find that there is no evidence on the casual link between GDP, and CCO2e, against the outcome of the study by Khan et al. (2020a, b).

Similarly, the outcome of long-run and strong causality test also supports the short-run causality results as Table 7 indicates. For example, we find the unidirectional causal nexus between ECP and CCO2e which runs from ECP to CCO2e, and similarly, in the case of CCP. Also, the other modeled series also show the casual link with CCO2e. On the basis of the above results, it can be inferred that any policy to target CCP, ECP, EXP REC, and GDP tends to causes the changes in CCO2e. Conversely, any policy to impede the carbon emissions does not affect CCP, ECP, EXP, REC, and GDP.

Conclusion

The current study extends the previous literature and introduces "imports taxes" (a proxy for commercial policy) as new driver of carbon emissions. To this end, our study splits the commercial policy into expansionary and contractionary commercial policies (ECP & CCP) and divulge their effects on consumption-based CO2e with the consort of exports (EXP), renewable energy consumption (REC), and GDP for 1990Q1-2017Q4.

The application of ADF and Andrew-Zivot unit root tests assert that all series are 1(0) and 1(1), not a single variable is 1(2). Further, the bound testing approach confirms the symmetric and asymmetric long-run association across the modeled variables. Also, Wald-test suggests the asymmetries in commercial policies for both periods. The NARDL estimates reveal the following outcome. Firstly, the findings determine that CCP significantly contributes in ameliorating the green environment by disrupting the ratio of CCO2e in both periods. On the other hand, ECP demonstrates a positive link with CCO2e and deteriorates the environment. It means that CCP and ECP are the significant determinants of CCO2e and these are prime and unique findings of the current study.

Also, the results suggest that REC, and EXP significantly reduce the detrimental effects of CCO2e. However, GDP is accountable for boosting carbon emissions in both periods. In addition, WQC technique significantly supports the outcome of NARDL technique by confirming the association among the modeled series during each quantile. Besides, the trivariate Granger causality test asserts the casual nexus among expansionary and contractionary commercial policies and CCO2e which run from ECP and CCP to the carbon emissions. In the similar vein, EXP, REC, and GDP also granger-cause the CCO2e. It means that any policy adopted by govt to target CCP, ECP, EXP, REC, and GDP tends to affect the CCO2e.

Core policy framework

Based on the findings of current study, the following policies are recommended. Firstly, the findings suggest the significant sensitivity of ECP and CCP to CCO2e. Since Pakistan economy highly depends on the imports such as the imports (with the amount of $37,357 million) were almost twice of the exports (with the amount of $18,700 million), authorities, in response, should not rush in imposing a high ratio of import taxes to curtail the imports. This practice may generate adverse effects on free trade agreements and GDP growth. However, the tool of CCP can be used for the green environment by promoting awareness regarding the deleterious effects of imports and introducing the incentives to the green imports. Secondly, REC significantly enhances the environmental quality by curbing the carbon emissions unlike the FFC. The Pakistani authorities should start practicing the green subsidy program for the producers who deploy the green technologies for the production. Also, a special tax discount renewable resources may play a remarkable role in discouraging the employment of fossil fuels.

Thirdly, the results determine that exports tend to decrease the ratio of CCO2e from exporting economy as the goods are consumed in other economy. It means that the environmental pollution is transferred to the importing economy via exports. In this context, we suggest that world economies should adopt the policy of green goods' production. To do so, World Trade Organization (WTO) can play a significant role in promoting the green trade through implying the *"Green Trade Policy"*. Consequently, *"Green Trade Policy"* can induce the global economies to import and export the green products; it may lead to achieve the green environment at global level. Fourthly, the findings suggest a significant positive association between remittances and carbon emissions. The policy-makers should adopt the step of *"Green Climate Public Awareness"* to induce the consumers to demand the green and environmentally-friendly products. Aa a result, the foreign remittances may play a pivotal role in the promoting the green environment. Lastly, the authorities of Pakistan should spare a specific amount of

the budget to invest on the green technologies at the macro level. Consequently, this step can help in achieving the threshold that confirms the validity of the EKC hypothesis.

Limitations of the study

Like other empirical studies, the current study also possesses some limitations that may help in opening the new sights in future research. Firstly, the current study explores the effects of ECP and CCP for Pakistan, the same model can be testified for other economies and regions, specifically for the economies which have the high ratios of import taxes. Secondly, our study focuses only on the import taxes as commercial policy to check its effects on the environment, the scholars are encouraged to use all other trade restrictions and regulations along with import taxes as a commercial policy in future for more informative results. Lastly, the current model can be enriched by including some other economic indicators such as exchange rate, aggregate domestic consumption per-capita, institutional quality, regulatory quality, corruption, economic complexity index, global value chain, macroeconomic uncertainty, financial inclusion, and innovation in environmental-related technologies.

Appendix 1

See Table 8.

Table 8 ARDL estimates

Variable	Coefficient
Panel A: Short-run estimates	
IMT	−0.105**
IMT (−1)	−0.081*
EXP	−0.004
EXP (−1)	−0.084**
REC	−0.105***
GDP	0.904**
Coint Eq (−1)	−0.403***
Panel B: long-run estimates	
IMT	−0.074*
EXP	−0.052***
REC	−0.053*
GDP	0.831***
C	−9.321***
Panel C: diagnostic tests	
F-Stat	5.47***
R^2	0.9600
Adj R^2	0.9223
DW Stat	2.22
J-B Normality	1.46
X^2 LM	1.54
X^2 RESET	0.56
CUSUM	Stable
CUSUMQ	Unstable

***, **, and * indicate the significance level at 1%, 5%, and 10%, respectively

Appendix 2

See Fig. 9.

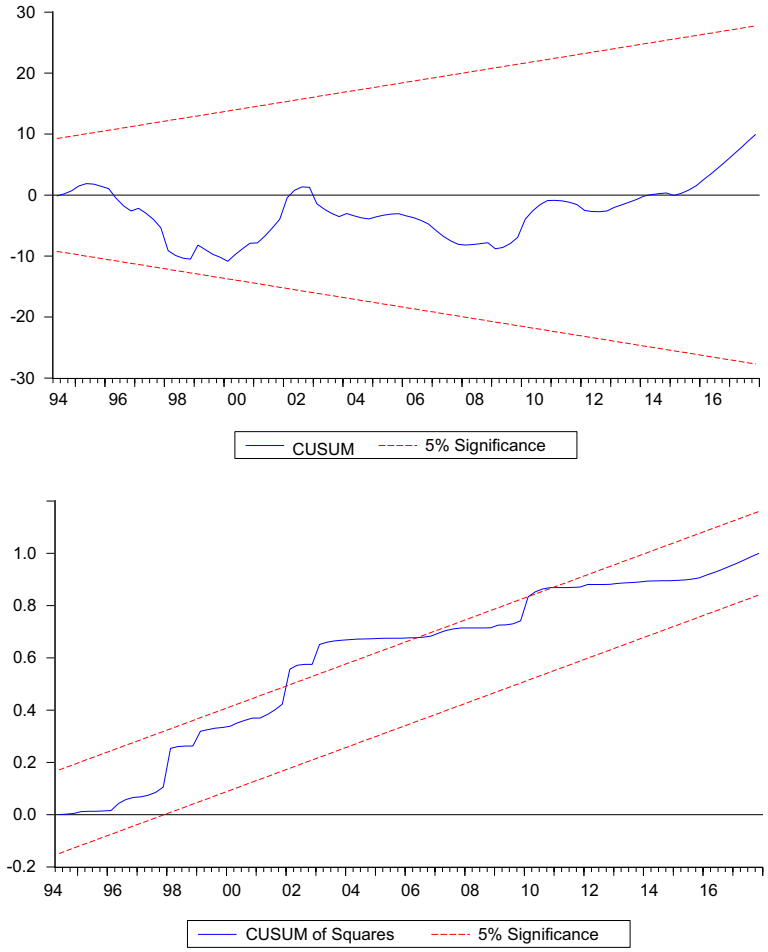

Fig. 9 CUSUM and CUSUMQ tests of ARDL approach

Abbreviations

CCO2e	Consumption-based carbon emissions
WQC	Wavelet quantile correlation
ARDL	Autoregressive distributed lag
IMT	Import taxes
EXP	Exports
REC	Renewable energy consumption
GDP	Gross domestic product
ECP	Expansionary commercial policy
CCP	Contractionary commercial policy

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Author contributions
MZC presented the main idea, did the estimation analysis, and completed the write-up of Introduction, results discussion and conclusion. HSMA helped in completing the literature review. MKK did the supervision and proof-reading of the article. All authors read and approved the final manuscript.

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Declarations

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