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Asymmetric impact of textile and clothing manufacturing on carbon-dioxide emissions: Evidence from top Asian economies

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A B S T R A C T

The aim of the current investigation is to analyze the impact of textile and clothing (T&C) manufacturing on carbon dioxide emission (CO_2) in top Asian economies. In doing so, the study has utilized the quarterly data of percentage of manufacturing covered by T&C sector and CO_2 per capita from the period of 1990−2018. The empirical investigation is carried out by applying the innovative Quantile-on-Quantile (QQ) regression and Granger causality in quantile methods. The findings of the study have identified the significant asymmetric behavior in the quantiles of T&C industry on the quantiles of CO_2 emission in the considered economies. Precisely, the outcomes have documented the significant positive contribution of T&C manufacturing on CO_2 emission in China, India, Pakistan, and Indonesia. On the other hand, the effect of T&C on CO_2 emission is negative in the case of Vietnam. As for causal relationships, the study also confirmed the presence of bi-directional causality between T&C and CO_2 emission in all countries except Indonesia, where the relationship is uni-directional. The study recommended regulators to introduce some incentives and subsidies for the new investors in T&C industry with higher emphasis on green manufacturing.

1. Introduction

The climate condition in the current times is facing deterioration. The major reason for this declining environmental condition is the greenhouse gas (GHG) emissions. These GHG emissions often reach the atmosphere as a result of numerous industrial activities. The increased scales of manufacturing and advancements in automation in industries have amplified the levels of GHG in the environment. In the current era of globalization, the role of industrialization is likely to expand further, resulting in a higher concentration of GHG into the environment [1]. The discharge of contaminated particles not only make atmosphere physically unbalanced and detrimental but also disrupt biological condition for causing pollution through chemical constituents and energy particles [2]. Such substances in the atmosphere initiate climate change and also harm biological life. Unfortunately, the major part of these harmful constituents originated and reached atmosphere through industrialization leading to toxic gases, aerosols, vapours and smoke [2]. At present, almost all industries are causing environmental pollution. Among them, textile sector is prominent to cause higher environmental degradation with increased adverse environmental impacts [3].

In several Asian economies, the magnitude of the textile sector and its dominance in the economic structure and trade are extensively large, leading to enhance its influence on climate change. In precise terms, fabrics are considered unlikely to create atmospheric pollution; however, the process involved in its manufacturing and finishing resulted in augmented GHG emissions. In this regard, Akhtar et al. [1] stated that textile sector alone contributes 1 ton of

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carbon from a total of 19.8 tons of carbon emission in the atmosphere. Textile industries cause both direct and indirect effects on environmental degradation. The burning of fossil-fuel involved in the manufacturing process of textiles generate direct GHG in the atmosphere. Indirectly, textile sector augments toxic emission from higher utilization of electricity incurred in entire supply chain of textiles.

The dyeing process of fabric until early 1800 was eco-friendly that relies on natural dyes of textile products. However, the creation of mauvine in 1856, leading to the introduction of synthetic dyes has changed the dynamics of textile sector. At present, textile sector is generating and utilizing 1.3 million tons of dyeing and pigmentation in a year, where the majority of these are toxic [4]. Moreover, up to 25% of dyes in the process of dying is wasted, and up to 20% is released as aqueous effluent. These discharges comprising effluent are injurious due to their chemical nature and toxicity [4]. Moreover, the activities involved in wet procedures also generate toxic emissions. The major fossil was burning in textile results from the higher usage of fossil-based energies consumed in heating boilers in order to generate steam accessible for drying the clothing [5]. In addition, the adoption of electrical-motors, lighting and air compressors enhanced the utilization of energy in textile sector [6].

Hence, it would not be wrong to conclude that textile sector is an energy intensive industry [7]. A greater part of energy mix in the textile sector is inefficient and mostly fossil-based [8] resulted into emitting carbon dioxide emission that constituted a major part of greenhouse gases and thus considered the prime reason of global warming. According to Heo, Seong and Park [9]; carbon dioxide constituted more than 60% of the present levels of greenhouse gases, thereby enhances its significance in causing environmental degradation. Thus, based on the substantial contribution of CO_2 emissions in the disruption of environment, many recent studies in the existing literature emphasized on investigating the factors that influence the changes in CO_2 discharge in numerous industries, for instance, Zhang et al. [10] in coal-chemical industry, Wang et al. [11] in power sector, Shyam and Shridhar [12] in Marine industry, Ma and Cai [13] in tertiary industry and Rasool et al. [14] in transportation sector.

As for textile industry, many studies have raised concerns for having higher levels of energy usage that resulted into emitting higher CO_2 and therefore prominent in causing environmental degradation [15]. Even after, the prevailing literature failed to identify the conclusive role of textile industry in causing environmental damage since there exist very few investigations that empirically analyzed the exclusive impact of manufacturing or production of textile on CO_2 emission. Therefore, in response, the current study is motivated to examine the role of T&C manufacturing of the top five textile exporting Asian economies in influencing CO_2 discharge. Given the importance of competitiveness in Asian markets for having homogeneous labor conditions and industrial structure, the minor change in prevailing environmental policies can alter countries' global competitiveness and export revenues as majority of the Asian economies largely rely on textile industries but also considered vulnerable to deteriorating climate change. Precisely, the objective of the current investigation is to empirically analyze the effect of T&C manufacturing on the environmental degradation of five developing Asian economies. These include the economies China, Indonesia, India, Vietnam, and Pakistan. To the best of our knowledge, the current investigation is first of its kind that examined the impact of T&C on CO_2 emission. Moreover, many studies elaborated that developing countries are more potential to cause environmental destruction due to their prime focus on self-survival and output growth [16,17]. Hence, the current study is also novel for evaluating textile-environment link in the developing economies of Asia that are more textile dependent. In this regard, the countries are selected based on their significant contribution of textile sector in exports & growth and high intensity of climate change resulted in enhanced floods, water shortage, heat waves, tsunami, droughts etc. Moreover, against the simple panel estimation, the present study is superior for examining the textile-CO_2 link by focusing on the time-series relationship in all five economies separately. In this way, the outcomes would be able to offer the exclusive depiction of the studied relationship that can support policy making with respect to each country. Moreover, the results can also provide insights regarding the economies that are more vulnerable to environmental degradation arising from the growth of T&C manufacturing.

Furthermore, to ensure the validity of the derived findings, the emphasis of many studies has evolved vastly on the advanced econometrics in performing empirical investigation (for instance Ref. [18], in adopting Quantile ARDL method [19]; in applying Q-Q regression and [20] in utilizing Adaptive neuro-fuzzy inference approach) to combat the biasness and unreliability associated with the application of conventional and outdated methodologies. Conforming to the evolved methodological awareness, the present analysis seeks to examine the nonlinear impact of textile manufacturing and clothing of the selected economies on the carbon-di-oxide emission by applying the innovative quantile method introduced by Sim and Zhou [21]. Particularly, the current analysis applied the advanced method of Quantile-on-Quantile Regression Approach to testing how the quantile of textile produce reacts with the quantiles of CO_2 discharge. The understanding derived from such a novel method would be able to identify the asymmetric patterns in textile-environment nexus. In this way, the anticipated results could recognize the changing nonlinear behavior across the quantile distribution in estimating where textile industry can threaten or hurt environmental stability. Moreover, the findings could provide policies suggestion to government in identifying the threats that can result from the expansion of textile industries. This could enable policymakers to enforce eco-friendly industrial practices to curtail the use of fossil-based energy in textile sector and find solutions in environmentally friendly green energy sources.

The responsiveness gathered from the current investigation would be able to recognize the asymmetric relationship between the textile industry and environmental degradation in top Asian economies. In other words, the expected findings would be able to capture the market conditions where the textile sector can boost or weaken environmental degradation. The results can offer several policy implications to government in detecting the true potentials of textile sector in country's growth process and also beneficial for the environmental concerns. The rest of the study is outlined as follows. In the next section, the overview of existing literature would be made to formulate the expected relationship between the variables of interest. In section three, a brief discussion of the adopted methodologies is provided. In section four, the findings of the study are reported and interpreted. Lastly, section five concluded the study and offered recommendations and policy implications.

2. Literature review

The fundamentals of sustainable development lie in finding environment-friendly explanations of economic growth. In this regard, the renowned environment Kuznets theory stated that the growth and advancements in a country's economy carry adverse impact on ecological condition, however, when reaching the benchmark, the increase in income improve environmental quality [22]. With the passage of time, many studies seek to investigate the role of industries in influencing environmental condition, such as agriculture [23], transportation [24], manufacturing [25], tourism [26] etc.

In this regard, several examinations inspected the role of the textile sector and its growing carbon footprint and energy dependence. In similar context, many studies in the prevailing literature aimed to investigate the role of carbon dioxide in textile sector. In this regard, several clothing enterprises measured carbon intensity of their clothing. For instance, Li, Wu, and Jiang [27] analyzed the carbon footprint of cotton clothing in black color. The outcome of the examination found that processing raw material consumed highest emission, i.e. 56%. Moreover, the analysis also established that CO_2 emission discharged from waste-water and energy utilization attributed 34% of carbon footprint. In another study, Wang and Xu [28] also analyzed the contribution and causes of carbon-dioxide emission in Chinese textile industry. The study reported that extension of textile sector is the core cause of augmented greenhouse gas emissions in China.

Focusing on the reasons for increased carbon intensity in Chinese textile industry, Zhao [29] examined CO_2 footprint of the textile industry and established that energy utilization in electricity and thermal energy is the vital contributor of enhanced carbon emission in textile and manufacturing sector. Moreover, Wang et al. [30] also measured the carbon emission in textile sector of China. The findings of the investigation documented that carbon footprint in textile sector of the country is reflecting downward trend. Also, Zabaniotou and Andreou [31] investigated the role of greenhouse gases in textile industry of Greece. The study concluded that cotton fibre comprises of forty percent carbon, therefore, considered as the alternate cause of emissions. Moreover, the study also established that the waste from ginning of cotton should be utilized as the substitute energy for decreasing toxic emissions in Greek textile sector.

For Indonesian industries, Priambodo and Kumar [32] analyzed the small and medium industries' (SMI) contribution in influencing CO_2 emission and energy utilization in the country. In doing so, the study analyzed the data of seventy-three SMI. The results of the study established that food and beverage SMI contributed highest in energy consumption. Moreover, the study found that textile industry incurred highest fuel utilization and carbon discharge in Indonesian economy. In another study, Sitompul and Owen [33] also studied the industrial contribution to carbon emissions and energy usage in Indonesia from 1980 to 2000. The outcomes of the study elaborated that gross domestic product (GDP) played a vital role in enhancing carbon emission in the textile, paper and chemical industry of the country.

Emphasizing on Iran's textile industry, Hasanbeigi, Hasanabadi, and Abdorrazaghi [34] analyzed the environmental degradation aspect in five textile sectors. These include wet-processing, spinning, worsted-fabric manufacturing, weaving along with carpet manufacturing. The outcomes of the study summarized that electricity consumption is a vital detrimental factor in spinning sector. On the other hand, thermal energy is the vital cause of increased energy intensity in worsted-fabric manufacturing, weaving, wet-processing and carpet manufacturing. The study concluded that efforts should be required to made in the highlighted sectors to reduce their energy dependence and their subsequent negative impact on environmental degradation for up-surging the level of carbon emissions.

Furthermore, Reddy and Ray [35] examined the manufacturing sectors of Indian industries that contributed to CO_2 emission and energy utilization in the economy between 1992 and 2005. The results of the study reported that the textiles industry enhanced power utilization by 16.4%. The study also stated that textile sector incurred highest emission in the economy and has increased the emission eightfold in the studied period. In addition, Ganesan et al. [6] also inspected the energy conservation potential and emission reduction in textile sector of India. The findings of the investigation documented that 5.9% of the energy utilization is declined in textile sector of the country. The study also found that emission of carbon is also seen to be declined by 833 ton indicating improvement in sustainability of Indian textile industry.

For the Pakistani textile sector, Lin and Ahmad [36] examined the factors that enhance power-related CO_2 emissions in textile industry between 1990 and 2014. The study documented that population is a vital reason for increased carbon emission in the country. Moreover, the results found that economic growth also plays a crucial role in enhancing environmental degradation in Pakistan's textile industry. On the other hand, the results concluded that energy intensity and fuel substitution indicated heterogeneous results in different decomposed series and reflected inconclusive findings. Also, Bevilacqua, Ciarapica, and Giacchetta [37] inspected the factors affecting environmental degradation in textile supply-chain. In doing so, the study examined the textile organizations of South Africa. The findings elaborated that energy utilization is the vital cause of enhanced carbon footprint in textile industry. Specifically, the results suggested that electricity and thermal power are vital contributors to GHG that led to enhance environmental degradation. The study also found the significant role of transportation in spreading pollution and disrupting environment.

In another study, Hong et al. [38] examined the link between environmental quality and Taiwan's textile industry. In doing so, the study analyzed power conservation outcomes of 303 organizations. The author found that energy-saving measures in the industry are helpful in curtailing carbon emission of textile sector up to 143,669 tons and therefore has potentials to improve environmental quality in Taiwan. Similarly, for Sweden's textile industry, Zamani et al. [39] also analyzed recycling measures in textile sector and their potential influence on environmental degradation. The results established that incineration contained detrimental impact on environment and added extensively to atmospheric deterioration. On the other hand, the study suggested that material reprocessing displayed exceptional results and contributed to saving eight tonnes of CO_2 discharge and 164 GJ of energy through textile waste.

Focusing on the factors that give rise to environmental degradation in China, Ma and Lu [40] analyzed the driving factors of carbon emission in the Chinese textile sector. The outcomes of the study reported that rise in GDP is the major contributor to carbon discharge in the country. Moreover, the study also found energy utilization to be a significant factor in extended environmental degradation in China. Similar results were reported in the study of Lin and Moubarak [41] while examining carbon intensity in Chinese textile sector from 1986 to 2010. In a recent examination, Huang et al. [15] inspected the driving forces of enhanced carbon emissions in Chinese textile industry. The study documented that coal utilization is the vital cause of increased carbon emission in the country. Also, the authors stated that electricity usage is also a crucial indicator of deteriorating environmental conditions in Chinese textile industry.

Hence, in the light of above discussion, it is cleared that the role of textile industry in causing environmental degradation is prominent. However, the focus of the majority studies is attributed to recognize the energy-textile link, without giving exclusive significance to the role of T&C manufacturing in causing environmental degradation in the form of carbon discharge. Moreover, the majority of the prevailing studies have focused on simple methodologies in examining environmental impact of textile sector. The use of simple methodology is greatly criticized in the modern literature for causing biasness in the findings and reporting unreliable results.

Also, the focus of majority of the existing study is limited to single economy. To fill the above mentioned gaps of the literature, the current study will add to the prevailing studies by examining the precise impact of T&C manufacturing in influencing the levels of carbon emission in the economies of India, Pakistan, China, Indonesia and Vietnam separately. Moreover, against the conventional methods that are commonly utilized in the current literature, the empirical examination is the current study has adopted the novel method of Quantile-on-Quantile regression introduced in 2015 by Sim and Zhou, that can reveal the significant relationship among the variables by not regressing the mean (similar to Ordinary Least Square and ARDL methods) but the median of the variables, leading to provide the link between the variables on several quantile across the time-series against the traditional single averaged outcome. Hence, in this way, the expected findings can elaborate the impact of the textile manufacturing on several low to high levels of CO_2. And also, the influence of CO_2 on several levels of T&C manufacturing resulting in providing superior understandings of the textile-CO_2 relationship.

3. Methodology

In the present research, we apply the unique Quantiles-on-quantiles (QQ) regression methodology suggested by Sim and Zhou [21]. In the current scenario, the examination checks the effect that which of quantiles of Textile and Clothing (T&C) significantly influenced the quantiles of carbon dioxide emission (CO_2). The nonlinear distribution of the T&C and CO_2 in an important to confirm the selection of the QQ method as an important method for displaying the affiliation between the variables. In addition, Ordinary Least Square Regression (OLS) centers around the presumptions that are once in a while experienced by information bearing such nuance nature. Additionally, another problem is that the OLS may be complicated in its single conditional mean-coefficient explanation when using data having multi-modular dispersals, the quantiles regression, is proper and reasonable to allow one to find different elements of the relationship among indicator and dependent variable [21].

Moreover, traditional quantiles regression, nonetheless, gauges the provisional mean impacts of indicator variable (IV) on different quantiles of the model variable (DV). The QQ strategy is an expansion of quantile regression presented by Sim and Zhou [21] to deal with the few lacks intrinsic in the basic quantile regression. Also, it consolidates the basic quantiles estimation and non-parametric estimation. It includes detail assessment of the impacts of the IV on different quantiles of the DV, estimation of the impacts of each quantile of the IV on the DV utilizing OLS which empowers the stratification of the IV as quantile distribution; and consolidating the two to allow the estimation the differential impacts of quantiles of IV on the quantiles of the DV. Subsequently, the issue of interdependency is explained. Figure-1 below explain the efficacy of QQ compared with QR.

The present research receives the one model approach as sent in Sim and Zhou [21]; which is additionally founded on the arrangement of conditions suggested by Ma and Koenker (2006). Having recently demonstrated the τ-quantile of the CO_2 as the function of its lagged qualities, the study currently presents the τ-quantile of $T\&C_t$ as a component of CO_{2t} explained by $T\&C_t$ in the below-mentioned model:

$$CO_{2_t} = \beta^{\tau}\,(T\&C_t) + \mu_t^{\tau} \quad (1)$$

As the present study has one predictor, i.e., T&C, so there should be a single equation. Here for the seeing, also, having no past data of the connection between CO_2-T&C, the factor stacking $\beta^{\tau}(.)$ is hence ambiguous. μ_t^{τ} is the residual term with zero τ-quartile. Taking the main request Taylor extension of $\beta^{\tau}(.)$, around ${CO_2}^{\tau}$, the authors changed equation (2) into linear as below:

$$\beta^{\varphi}\,(T\&C_t)\; \approx \beta^{\varphi}(T\&C^{\tau}) + \beta^{\varphi'}(T\&C^{\tau})(T\&C_t - T\&C^{\tau}) \quad (2)$$

The dual indexing of $\beta^{\varphi}(T\&C^{\tau})$ and $\beta^{\varphi'}(T\&C^{\tau})$ in φ and τ denotes that both $\beta^{\varphi}(T\&C^{\tau})$ and $\beta^{\varphi'}(T\&C^{\tau})$ are functions of both φ and τ. The previous equation can be represented as:

$$\beta^{\varphi}\,(T\&C_t)\; \approx \beta_0(\varphi,\ \tau) + \beta_1(\varphi,\ \tau)(T\&C_t - T\&C^{\tau}) \quad (3)$$

and then substitute this equation (3) into the initial QQ equation will give us:

$$CO_{2_t} \underbrace{\beta_0(\varphi,\ \tau) + \beta_1(\varphi,\ \tau)(T\&C_t - T\&C^{\tau})}_{*} + \mu_t^{\tau} \quad (4)$$

Finally, the persistence of data transmission is critical while applying non-parametric estimation systems. The bandwidth shows the degree of the region around the goal, and in this manner, the bandwidth attests a higher practical for inclination in assessment technique while a shorter bandwidth can take coefficients with higher assortments. As such, focusing on Sim and Zhou [21]; bandwidth measures $h = 0.05$ was used in the present assessment. Also, the QQ theory is responsible for the structural break, nonlinearity and regime moving in the dataset [42]. The strategy is ideal for the related economic issues since it explains the relationship between predictor and criterion (considering low, medium and high). Consequently, this methodology is accustomed to examining the association among T&C and CO_2 across various quantiles to have a superior understanding.

In the current research, the annual information of T&C (as % of manufacturing value-added) and carbon dioxide emission (as metric ton per capita) as a proxy for environmental degradation is adopted for top Asian textile and cloth exporting nations.[1] Also, the present research opted the annual information from the time of 1990–2018. As per the suggestion of Sim & Zhou [21]; the QQ approach is appropriate for the long time series data. In doing so, the present research follows the procedure of Arain et al. [43]; Sharif et al. [19] and Shahbaz et al. [42] to transform the data from yearly to quarterly observation by utilizing quadratic match approach. This approach is appreciated when the information is transformed from low period to high period since it modifies the seasonal and starts to sum-up the variations in the sample size. All the information is collected by the World Development Indicator (WDI) supervised by World Bank. In the end, the final information is used in the natural logarithmic series to give robust and actual outcomes.

The findings of descriptive statistics are explained in Table 1. The mean value for both variables is positive in all top Asian countries. The maximum average figures for T&C are in the case of Pakistan (29.244%) followed by Vietnam (17.071.244%). On the other hand, the minimum mean T&C figure is in the case of India (10.109%) and China (10.969%). However, Indonesia has the middle T&C figures which are 13.873%. Contrary, the maximum average figures for per capita of CO_2 emission are in the case of China (4.724) followed by Indonesia (1.578). The minimum average figure of per capita of CO_2 emission is in the case of Pakistan (0.800) and Vietnam (1.068). In addition, the middle mean figures of per capita of CO_2 emission is in the case of India (1.180). Furthermore, the results of JB statistics are

[1] China, India, Pakistan, Indonesia and Vietnam.

Table 1
Results of descriptive statistics.

Countries	Mean	Min	Max	St. Dev	JB-Test	P-Value
Panel A: Textile and Clothing						
China	10.969	9.975	13.704	1.202	24.972	0.000
India	10.109	6.816	15.474	2.342	22.437	0.000
Pakistan	29.244	15.619	44.809	8.624	16.441	0.000
Indonesia	13.873	9.786	21.339	3.569	33.065	0.000
Vietnam	17.071	9.812	21.828	3.794	41.459	0.000
Panel A: Per Capita of Carbon Dioxide Emission						
China	4.724	2.229	7.557	2.124	23.416	0.000
India	1.180	0.738	1.728	0.333	32.921	0.000
Pakistan	0.800	0.616	0.947	0.093	21.872	0.000
Indonesia	1.578	0.974	2.564	0.425	51.792	0.000
Vietnam	1.068	0.303	1.820	0.539	42.739	0.000

Source: Author Estimation

also used to check the normality of the variables for all countries. The findings of JB test are shown non-normal distribution for T&C and CO_2 emission in all countries representing a strong presence of non-linearity in the all the countries. Hence, consistent with the earlier studies of Mishra, Sinha, Sharif and Suki [44] and Sharif, Shahbaz and Hille [45] the values of JB allowed the current study to apply different quantile estimates as it permits to answer asymmetry, structural break, nonlinearity in the model.

In addition, the study analyzed the connection between per capita of carbon dioxide emission and Textile & clothing in all top Asian countries. The findings of correlation estimation result are reported in Table 2. The coefficient of connection for all nations is significant at 1% level, showing a positive relationship between T&C manufacturing and CO_2 in all top Asian countries. The most extreme coefficient is found in China (0.983) trailed by Pakistan (0.927) and India (0.901). The lowest estimation of relationships is found in the case of Indonesia (0.857) and Vietnam (0.893). The t-statistics and p-value confirm the significance of the relationship between textile & clothing and CO_2 emission. Hence, the findings of correlation confirm a positive connection between textile manufacturing and carbon dioxide emission in all Asian countries, which suggests that textile manufacturing is correlated with environmental degradation in Asian countries.

In the accompanying phase, the present research used a unit root test on different quantiles to check the stationary properties in all top Asian countries. The discoveries of quantile unit tests are represented in table-3. This table contains a determination parameter $\alpha(\tau)$ worth and t-stats of the studied in all countries. The table moreover reported the parameter over eleven quantiles from {0.05, 0.10,… 0.95}. Consistent with the study of Mishra et al. [44]; the findings of quantile unit root test attest variables are non-stationary at the level data. This shows T&C and CO_2 emission have an alternate order of integration in all Asian textile manufacturing countries. Moreover, the study used quantile cointegration to investigate the long run nonlinear association among T&C and CO_2 emission in every one of the countries. The results of quantile cointegration are represented in table-4. This table declared the α and δ estimations indicated the critical value

Table 2
Results of correlation.

Countries	Correlation	t-Statistics	P-value
China	0.983	15.322	0.000
India	0.901	23.922	0.000
Pakistan	0.927	19.482	0.000
Indonesia	0.857	18.585	0.000
Vietnam	0.893	22.549	0.000

Source: Authors Estimation

Table 3
Results of Quantile Unit Root test.

Quantiles	China				India				Pakistan				Indonesia				Vietnam			
	CO_2		T&C		CO_2		T&C		CO2		T&C		CO_2		T&C		CO_2		T&C	
	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$
0.05	0.915	0.047	0.798	−0.105	0.757	−1.281	0.812	−0.240	0.798	−0.479	0.815	−0.093	0.805	−0.303	0.803	−0.205	0.799	−1.436	0.822	0.554
0.10	0.915	0.143	0.804	−0.136	0.830	0.312	0.813	−0.291	0.804	−1.665	0.823	0.025	0.809	−1.330	0.808	−0.677	0.810	−2.009	0.822	0.742
0.20	0.912	−1.103	0.795	−2.285	0.814	−0.828	0.814	−2.000	0.803	−2.106	0.817	−0.595	0.811	−1.692	0.817	−0.413	0.808	−1.626	0.821	1.309
0.30	0.913	−0.367	0.800	−2.210	0.809	−1.574	0.816	−2.121	0.804	−1.934	0.819	−0.389	0.814	−1.516	0.814	−1.071	0.816	−1.769	0.820	1.325
0.40	0.913	−1.020	0.809	−1.652	0.810	−1.399	0.819	−1.265	0.805	−1.815	0.819	−0.990	0.817	−1.522	0.813	−1.618	0.817	−1.454	0.821	0.694
0.50	0.913	−2.180	0.810	−2.321	0.809	−1.294	0.819	−0.932	0.805	−1.950	0.819	−2.130	0.817	−1.575	0.812	−1.955	0.817	−1.648	0.820	−0.581
0.60	0.912	−1.201	0.808	−2.039	0.807	−1.318	0.820	−0.863	0.806	−0.932	0.819	−1.049	0.813	−1.644	0.812	−1.622	0.817	−1.701	0.818	−1.282
0.70	0.912	−1.806	0.800	−1.966	0.804	−1.572	0.819	−0.877	0.807	−1.238	0.817	−0.784	0.812	−1.607	0.812	−1.550	0.817	−1.807	0.815	−0.842
0.80	0.912	−1.661	0.776	−1.157	0.788	−1.627	0.823	0.332	0.808	−1.371	0.817	−0.590	0.813	−1.606	0.812	−0.952	0.808	−1.916	0.810	−0.376
0.90	0.913	−0.095	0.759	−0.663	0.804	−0.390	0.825	0.126	0.800	−1.621	0.803	−0.635	0.809	−0.660	0.818	−0.113	0.807	−0.800	0.729	−1.623
0.95	0.906	−0.566	0.710	−0.869	0.806	−0.230	0.821	−0.008	0.796	−0.549	0.799	−0.360	0.805	−0.453	0.780	−0.327	0.808	−0.554	0.624	−1.608

Source: Author Estimation

Table 4
Results of quantile cointegration test.

Model	Coefficient	Supremum norm value	Critical Value at 1%	Critical Value at 5%	Critical Value at 10%
China					
CO_{2t} vs. $T\&C_t$	A	4396.439	2118.951	1581.956	555.180
	Δ	881.252	462.372	259.119	226.041
India					
CO_{2t} vs. $T\&C_t$	A	5943.308	1817.323	994.058	487.987
	Δ	1617.545	605.929	361.205	260.255
Pakistan					
CO_{2t} vs. $T\&C_t$	A	3612.080	2374.803	1450.639	973.845
	Δ	2119.007	1224.148	718.555	313.654
Indonesia					
CO_{2t} vs. $T\&C_t$	A	8152.095	2375.084	1599.858	883.894
	Δ	4614.777	1837.775	1067.198	555.319
Vietnam					
CO_{2t} vs. $T\&C_t$	A	5563.425	2844.711	2029.544	1557.310
	Δ	2348.796	1632.842	798.445	488.088

Note: This table presents the results of the quantile cointegration test of Xiao (2009) for the logarithm of the Textile & Clothing (T&C) and per capita of carbon dioxide emission (CO_2).

Table 5
Granger causality in quantile test results.

	0.05–0.95	0.05	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	0.95
China												
$\Delta T\&C_t$ to ΔCO_{2t}	8.668***	4.658***	3.694***	6.785***	5.791***	3.521***	5.721***	5.092***	6.327***	3.571***	2.851***	2.783***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
ΔCO_{2t} to $\Delta T\&C_t$	15.583***	10.448***	11.386***	11.573***	12.021***	13.593***	12.352***	11.892***	10.421***	9.482***	9.119***	7.482***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
India												
$\Delta T\&C_t$ to ΔCO_{2t}	3.594***	2.995***	2.962***	2.986***	3.046***	3.157***	3.684***	3.019***	2.964***	2.820***	2.735***	2.704***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
ΔCO_{2t} to $\Delta T\&C_t$	12.482***	8.411***	8.846***	9.035***	9.119***	9.386***	9.948***	9.318***	8.863***	8.382***	7.481***	6.492***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Pakistan												
$\Delta T\&C_t$ to ΔCO_{2t}	8.582***	7.003***	6.472***	6.311***	6.035***	5.853***	5.210***	4.972***	4.327***	3.968***	3.643***	3.227***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
ΔCO_{2t} to $\Delta T\&C_t$	7.386***	8.402***	8.698***	9.039***	9.413***	10.503***	8.692***	8.216***	7.582***	7.103***	6.932***	6.035***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Indonesia												
$\Delta T\&C_t$ to ΔCO_{2t}	5.962***	4.953***	4.864***	4.064***	4.895***	5.069***	5.192***	5.330***	4.683***	4.019***	3.884***	3.268***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
ΔCO_{2t} to $\Delta T\&C_t$	0.401	0.693	0.482	0.325	0.296	0.252	0.336	0.413	0.712	0.757	0.857	1.085
	[0.374]	[0.284]	[0.342]	[0.485]	[0.593]	[0.683]	[0.492]	[0.385]	[0.275]	[0.216]	[0.196]	[0.146]
Vietnam												
$\Delta T\&C_t$ to ΔCO_{2t}	11.493***	6.702***	7.039***	7.195***	7.495***	7.993***	8.049***	7.592***	7.039***	6.472***	6.013***	5.693***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
ΔCO_{2t} to $\Delta T\&C_t$	9.604***	6.793***	6.478***	5.963***	5.127***	5.003***	4.582***	4.002***	3.958***	3.257***	3.058***	2.925***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

Notes: This table presents the estimated coefficients of the Granger causality test by quantiles. The first line indicates the different quantiles. ***, ** and * indicate significance at 1%, 5% and 10% levels, respectively. P-values associated to the F-test values are reported between brackets.
Source: Authors Estimation

at 1%, 5%, and 10% independently. Similar to Sharif et al. [45]; the results of quantile cointegration showed the presence of a basic nonlinear long-run association among the studied variables.

Next, the authors applied QQ regression to investigate the influence of T&C manufacturing on CO_2 emission in all top textile and clothing manufacturing countries. The results of QQ regression are presented in Figure-1-5. In this figure, the graphical representation for all top five Asian countries clarifying the x-axis as T&C, y-axis as per capita of CO_2 emission, and z-axis as the cross-tabulated coefficient of the T&C and CO_2 for all countries is displayed. In other words, the figure-1-5 explains the long-run asymmetric effect of T&C manufacturing on CO_2 emission in all top Asian economies at different quantiles distributions (see Fig. 6).

The findings of QQ regression confirm that the impact of T&C on CO_2 emission on account of China. Similar to Wang and Xu [28]; the results endorse that the effect of T&C on CO_2 emission is significant and important across all quantiles. Furthermore, the impact of T&C on CO_2 is perceptible in the high quantiles of T&C (i.e. 0.80–0.95)

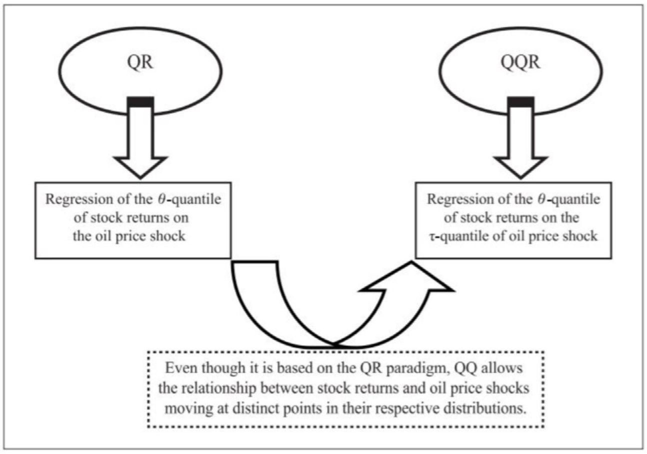

Fig. 1. Efficacy of the QQ approach.

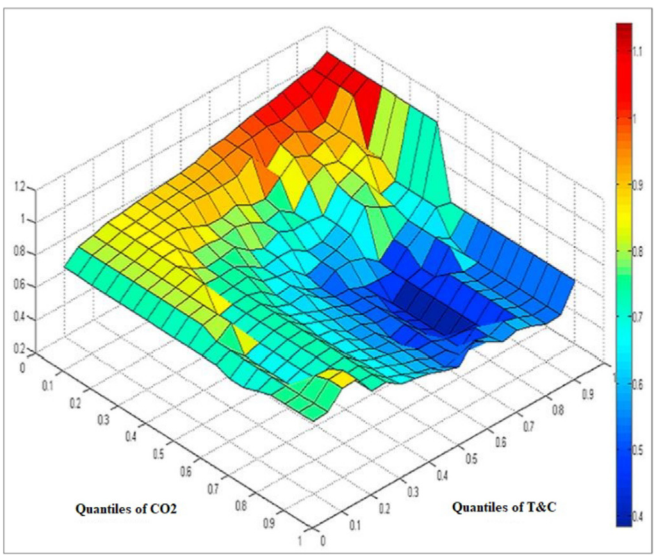

Fig. 2. Quantile-on-Quantile estimations outcome in the case of China.

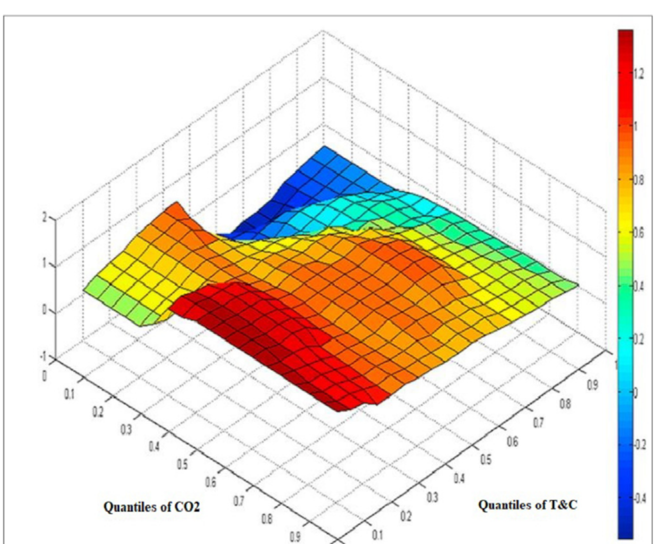

Fig. 3. Quantile-on-Quantile estimations outcome in the case of India.

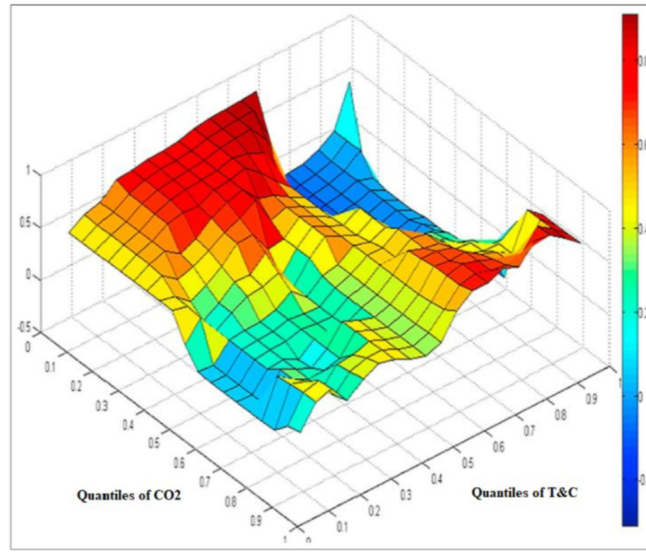

Fig. 4. Quantile-on-Quantile estimations outcome in the case of Pakistan.

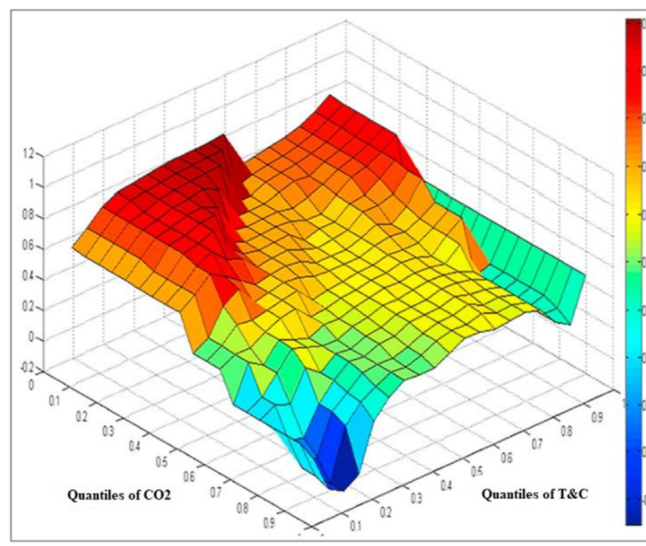

Fig. 5. Quantile-on-Quantile estimations outcome in the case of Indonesia.

and low quantiles of CO_2 emission (i.e. 0.05–0.35), proposing that most extreme amount of T&C manufacturing increase the level of environmental degradation in the Chinese economy. Overall, the results of QQ suggest that the effect of T&C manufacturing on CO_2 emission is positive and significant. However, contrasting with the conclusion of Wang et al. [30] stating that emission in textile sector is improving, the result of the present study highlighted that as the levels of manufacturing of T&C increases, the level of CO_2 emission is also increased. Therefore, the Chinese government and local investors need to adopt the technologically oriented types of machinery and investment to reduce the level of environmental degradation from T&C manufacturing.

The outcomes of QQ approach that the effect of T&C on CO_2 emission is very interesting in the case of India. Consistent with the findings of Reddy and Ray [35]; the findings confirm that the effect of T&C on CO_2 emission is overall positive and significant in all groupings of quantiles. Moreover, the influence of T&C on CO_2 is more noticeable in the low quantiles of T&C (i.e. 0.05–0.45) and lower-middle to high quantiles of CO_2 emission (i.e. 0.35–0.95).

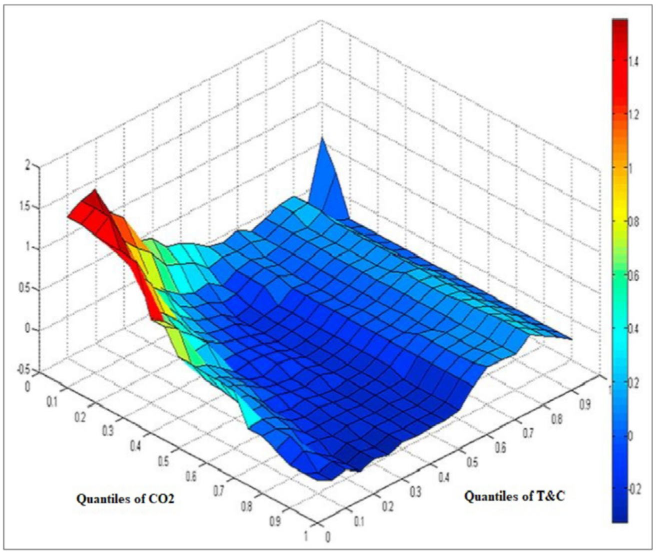

Fig. 6. Quantile-on-Quantile estimations outcome in the case of Vietnam.

This highlighted that high emission levels are resulted into lower levels of T&C manufacturing in India. Generally, the findings of QQ recommended that the impact of T&C manufacturing on CO_2 emission is positive and significant in almost all quantiles of combination, but the relationship is more pronounced in the lower levels of T&C manufacturing. The finding corresponded to the earlier study of Ganesan et al. [6] that stated that emission levels of textile manufacturing has shown the decreasing trend. On the other hand, the effect of T&C manufacturing on environmental degradation is also significant but negative at the high quantiles of T&C manufacturing (i.e. 0.75–0.95) and low level of CO_2 emission (0.05–0.35). This suggested that T&C manufacturing help to reduce CO_2 emission only when the level of environmental degradation is at low level. Therefore, the policymakers need to introduce some more environmentally friendly technology in textile and clothing manufacturing, which helps more to reduce carbon dioxide emission even in the worse environmental degradation.

In the case of Pakistan, the findings check that the effect of T&C on CO_2 emission is overall strong positive and significant in all groupings of quantiles. Furthermore, the impact of T&C on CO_2 is more noteworthy in the middle quantiles of T&C (i.e. 0.30–0.65), suggesting that maximum impact of T&C manufacturing on the carbon dioxide in Pakistan. Technical speaking, the findings of QQ confirm that the effect of T&C manufacturing on CO_2 emission is strongly positive and significant in almost all quantiles of grouping. Moreover, consistent with the study of Akhtar et al. [1] stating that the carbon footprint of textile sector is increasing as the level of manufacturing is enhancing, the results also confirmed that the manufacturing of T&C at high level exerts high impact and increases environmental degradation in Pakistan. Opposingly, the impact of T&C manufacturing on CO_2 emission is also significant and positive at the high quantiles of T&C manufacturing (i.e. 0.75–0.95) and high level of CO_2 emission (0.85–0.95). This proposed that T&C manufacturing increases the level of CO_2 emission also when the level of environmental degradation is higher. In this regard, the government of Pakistan and policymakers need to introduce some green and advanced manufacturing strategies that can help to and maintain the environmental degradation level in Pakistan.

In the case of Indonesia, the results corresponded to the findings of Priambodo and Kumar [32] and confirm that the impact of T&C on CO_2 emission is strong positive. Moreover, the effect of T&C on CO_2 is more notable in almost all quantiles of T&C (i.e., 0.05–0.95) and low quantiles of CO_2 emission (i.e. 0.05–0.40), suggesting that most impact of T&C manufacturing on the carbon dioxide in Indonesia. In general, the outcomes confirm that the effect of T&C manufacturing on CO_2 emission is positive and substantial in all quantiles of mixture. However, as the manufacturing of T&C is at any level (i.e. low, middle, and high), it exerts high impact and increases the CO_2 emission. Contrary, the influence of T&C manufacturing on CO_2 emission is also significant but negative at the low quantiles of T&C manufacturing (i.e. 0.05–0.25) and high level of CO_2 emission (0.80–0.95). This confirmed that T&C manufacturing decreases the level of CO_2 emission also only when the level of environmental degradation is higher. From the policy point of view, the findings suggested that policymakers need to adopt environmentally friendly manufacturing policies to reduce environmental degradation in Indonesia.

The outcomes of the QQ approach that the effect of T&C on CO_2 emission is very interesting in the case of Vietnam. The findings confirm that the effect of T&C on CO_2 emission is overall negative and significant in all groupings of quantiles. Moreover, the influence of T&C on CO_2 is more noticeable in the low quantiles of T&C (i.e. 0.05–0.25) and lower quantiles of CO_2 emission (i.e. 0.05–0.30), proposing that highest effect of T&C manufacturing on the environmental degradation in Vietnam. In simple words, the findings of QQ recommended that the impact of T&C manufacturing on CO_2 emission is negative and significant in almost all quantiles of combination. But, as the manufacturing of T&C is low, exerts positive impact and increases the environmental degradation in Vietnam. On the other hand, the effect of T&C manufacturing on environmental degradation is also significant but negative at the high quantiles of T&C manufacturing (i.e. 0.75–0.95) and high level of CO_2 emission (0.80–0.95). This suggested that the T&C manufacturing help to reduce CO_2 emission when the level of environmental degradation is at middle to high level. The findings are novel as there exists no study that analyzed the impact of T&C on CO_2 discharge in Vietnam. Hence, in the light of the derived finding, the present study, consistent with Phuong [46] stressed that the government of Vietnam needs to focus more on expanding and greening textile sector so as to increase the positive effect of T&C manufacturing on environmental quality.

Next, the study applied Granger-causality in quantiles, which was proposed by Troster (2018). The results of Granger-causality in quantiles are reported in table-5 that indicated the causal effect of T&C manufacturing on CO_2 emission in all top Textile manufacturing countries. The findings confirmed a bidirectional causality between T&C manufacturing and carbon dioxide emission all countries which means the causality is running in both directions from T&C manufacturing to CO_2 emission and from CO_2 emission to T&C manufacturing. However, in the case of Indonesia, the study has different findings. The outcomes confirmed a unidirectional causal relationship between T&C manufacturing and CO_2 emission where the causality is running from T&C manufacturing to CO_2 emission while the reverse is not found significant.

4. Conclusion

The climate condition in the current times is facing deterioration. The major reason for this declining environmental condition is the greenhouse gas (GHG) emissions. These GHG emissions often reach the atmosphere as a result of numerous industrial activities. The increased scales of manufacturing and advancements in automation in industries have amplified the levels of GHG in the environment. In the current era of globalization, the role of industrialization is likely to expand further, resulting in a higher concentration of GHG into the environment. The discharge of contaminated particles not only make atmosphere physically unbalanced and detrimental but also disrupt biological condition for causing pollution through chemical constituents and energy. Such substances in the atmosphere initiate climate change and also harm biological life. Moreover, in several Asian economies, the magnitude of textile sector and its dominance in the economic structure and trade are extensively large leading to enhance its influence on climate change. In precise terms, Fabrics are considered unlikely to create atmospheric pollution; however, the process involved in its manufacturing and finishing resulted in augmented GHG emissions. In this regard, It is stated that textile sector contributes 1 ton of carbon from entire 19.8 tons of carbon emission in the atmosphere. Textile industries cause both direct and indirect effects on environmental degradation. The burning of fossil-fuel involved in the manufacturing process of textiles generate direct GHG in the atmosphere. Indirectly, textile sector augments toxic emission from higher utilization of electricity incurred in entire supply chain of textiles.

Hence, based on the above-mentioned impact of textile sector on the atmosphere, the current investigation is motivated to empirically analyze the effect of textile and manufacturing on the environmental degradation of five Asian economies. These include the countries of China, Indonesia, India, Vietnam, and Pakistan. Given the importance of competitiveness in Asian markets for having homogeneous labor conditions and industrial structure, the minor change in prevailing environmental policies can alter countries' global competitiveness and export revenues as majority of the selected economies largely rely on textile industries but also considered vulnerable to deteriorating climate change. The study used quarterly data from the period of 1990–2018. Initially, the authors applied descriptive statistics, and the results confirmed a nonlinear possibility in both variables for all countries. Furthermore, the results of quantile unit root test confirmed that both variables are showing nonstationary features at level series. In the next step, the findings of quantile cointegration confirm the presence of a nonlinear long-run relationships between textile and clothing manufacturing and carbon dioxide emission in all top Asian economies. In addition, the findings of QQ regression explained that the effect of T&C manufacturing is positive on CO_2 emission in China, India, Pakistan, and Indonesia. However, the effect of T&C manufacturing on CO_2 emission is negative in the case of Vietnam. In the final phase, the current study applied Granger-causality in quantiles, which confirm a bidirectional causal relationship between T&C manufacturing and CO_2 emission in all countries except for Indonesia where causality is running from T&C to CO_2 emission.

The current study recommends the regulators to introduce some environmentally friendly policies to encourage greening textile sector. Also, there is a need of promote green technology in the processing of T&C sector in Asian region. Moreover, as suggested by Lin and Moubarak [47]; the present study suggests the government and policy makers to enhance the investment in textile sector with a special focus on research and development to encourage innovation in eco-friendly cutting-edge technologies related to manufacturing and distribution of textile sector. Furthermore, there is a need to introduce carbon tariffs to discourage energy-related GHG emission so as to curtail the adversities of carbon footprint [48]. In addition, the collaboration among numerous stakeholders should be encouraged to enhance the ecological awareness of employees, managers, distributors and traders involved in the textile processing to amplify the benefits of textile sector on country's growth as well as on environmental sustainability.

Lastly, the current study is limited to recognize the general impact of T&C manufacturing on environmental degradation which is useful to provide the broaden impact of textile industry on CO_2 discharge, however the future studies can be recommended to augment the textile-environment nexus with detailed examination of textile process, such as spinning, weaving, dyeing, wetting, printing etc. Also, the future research can focus on other deteriorating influence of textile sector such as waste spread and water consumption to identify the overall environmental impact of textile industry.

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