

Article

Modelling the Non-Linear Energy Intensity Effect Based on a Quantile-on-Quantile Approach: The Case of Textiles Manufacturing in Asian Countries

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Abstract: The objective of the current examination is to identify the dynamic relationship between the textile industry and energy intensity. The study evaluates the asymmetric impact of textile manufacturing on energy intensity in leading Asian economies based on textile dominance. China, Indonesia, India, Pakistan, Bangladesh, Malaysia, South Korea, Thailand, Japan and Vietnam are dominant in textile manufacturing. In the present study we used yearly textiles and clothing data from top ten selected Asian textile manufacturing countries from 1990 to 2018. The results of quantile-on-quantile regression (QQ) confirmed that textiles and clothing (T&C) production have a positive and significant impact on energy intensity in all countries. The results further suggested that a low level of T&C production increases the level of energy intensity in all selected countries. On the other hand, the results of Granger causality in quantiles confirm a bidirectional causal relationship between T&C production and energy intensity in all selected countries except Thailand and Japan, where a uni-directional causal connection between textile and clothing manufacturing and energy intensity can also be found. This study recommends that governments and investors need to invest more in green and advanced technologies to reduce the energy intensity in Asian economies.

Keywords: non-linear model; energy intensity; Asian countries; quantile-on-quantile

1. Introduction

Industrialization has a positive impact on several economic indicators and is an important factor in the growth of many countries. Benefits of industrial development include job creation, augmented trade, increased economy of scale and technological progress [1]. Since the start of the First Industrial Revolution, the textile industry has been considered an important part of world economy. This industry has historical roots dating back to 3000 BC [2,3]. The prominence of the textile industry is notable for generating foreign exchange through trade expansion, particularly in emerging economies [3]. In many Asian countries, textile sector is considered as a backbone for creating employment opportunities for both men and women [3–6].

However, from an environmental perspective, industrial growth is notable for adversely influencing climate conditions [7–9]. Many investigations have highlighted the growing problems due to environmental degradation. In recent years, climate vulnerability has been recognized as an international issue, since it is responsible for carrying numerous harmful effects on a country's growth and the prospect of sustainability [10,11]. The extensive usage of energy and resources (water, minerals, etc.) in various industries has augmented the problems linked to environmental quality and poses a severe threat to environmental sustainability. The rapid degradation of climate conditions is linked to increased industrialization, augmented energy intensity (ENI) and the burning of fossil fuels [12]. In a similar context, many recent studies have raised environmental concerns about the growth of the textile industry [13–16]. In this regard, Yan et al. (2016) [17], while analyzing the environmental impacts, argued that energy utilization is the barricade for the notion of sustainability in the textile industry. Given concerns for the significant water usage in fabric dyeing, Nimkar (2018) [18] stated that the increased utilization of supercritical carbon dioxide has solved the issue of effluent expulsion into the environment. However, the process has increased the industrial reliance on power due to this process being energy-intensive. Similarly, Huang, et al. [2] also established that the textile manufacturing process of weaving, spinning and wetting is highly energy-intensive, and leads to an increasing environmental burden.

In line with the above, the purpose of the present investigation is to identify the dynamic relationship between the textile industry and energy utilization. We evaluate the asymmetric impact of textile manufacturing on energy intensity in leading Asian economies based on the dominance of their textile industries in a global context. The major textile manufacturing countries in Asia are China, Indonesia, India, Pakistan, Bangladesh, Malaysia, South Korea, Thailand, Japan and Vietnam. Empirical investigations in several studies in the current literature have adopted traditional statistical methods while examining crucial relationships [19–22]. In this regard, Sharif, Afshan and Qureshi (2019) [23] asserted that the use of conventional econometrics may lead to biasness and produce unreliable results, and that more-advanced methods are needed to examine the relationship between crucial variables to strengthen the reliability of outcomes.

Considering the above matters, the current study has adopted a novel quantile-on-quantile (Q-Q) approach developed by Sim and Zhao (2015) [24] to examine the critical association between textile manufacturing and energy intensity (a measure of the energy inefficiency of an economy) in the selected economies. Our adopted methodology recognizes the non-linear relationship between the variables of interest in numerous lower, middle and upper quantiles of both dependent and independent variable. Although the stage of economic development varies in selected nations, the novelty of the Q-Q approach lies in being able to examine the impact of low, medium and high levels of textile development on variant low, medium and high levels of energy intensities in a given economy using the bivariate method of association. In this way, the Q-Q methodology is able to capture the influence of the country-specific textile industry growth on varying energy trends in the Asian nations separately. Hence, the current study can offer fresh insights on a matter of international concern: the increasing energy dependence of national industries. Focusing on the textile and garment manufacturing sector across the Asian region, we achieve this objective using a detailed analysis of several quantiles that portray relationships at different stages of the growth of the variables.

The rest of the article is outlined as follows: Section two presents the existing studies on the textile-environment nexus, with a focus on carbon emissions and energy consumption. Section three briefly discusses the methodology. The empirical outcomes and their interpretations are explained in section four. At the end, section five provides the conclusion of the study, along with its policy implications.

2. Literature Review

Given the significance of sustainability in modern business, many studies have investigated the impact of business and industrial practices on environmental conditions [25–28]. In this context, many studies are focused on identifying energy efficiency solutions [29–31]. In this regard the role of energy intensity has

been investigated in several economic sectors, including transportation [32–34], manufacturing [35–37], development [38,39], information and communication [40,41], agriculture [42,43], etc. Considering the constant demand for textiles and clothing, as well as the significant impact of the textile industry on economic growth in many countries, empirical evaluation of the contribution of the textile industry to growth, and its growing environmental impact, have been identified in several studies [13,44], particularly for developing economies [14,45–47]. Among them, You, Cheng and Yan (2009) [48] examined the role of the textile industry and its environmental impact in China. The authors analyzed Chinese textile industry data from 1990 to 2006. Their study established that textile and clothing production is positively related to the country's economic growth; however, it has negatively influenced environmental conditions, thereby posing a threat to the sustainable development of the Chinese economy. Similarly, elaborating the ecological concerns in the textile sector industry of India, Chavan (2001) [49] found a negative impact of the textile industry due to the lack of environmental regulations, energy dependence and increased pollution, especially in textile wet processing operations. Martínez (2010) [50] also investigated the role of energy in the textile industries of Colombia and Germany between 1998 and 2005. This study found that the manufacturing of textiles is directly linked to energy utilization. The increase in production resulted in increased energy usage in both countries, putting higher pressure on the environment. The study further concluded that in order to bring about efficiency in energy usage, the textile industry in Germany relies on process transformation and the price of energy. Energy efficiency in the textile industry of Colombia is attained through alteration of manufacturing procedures, research and development investment, and technological advancements.

Moreover, Li et al. (2011) [51] investigated carbon dioxide utilization in the production of black garments. The study reported that material processing produces highest toxic emission i.e., fifty-six percent. The investigation also found that emission from waste-water and energy usage account for the second highest emissions, i.e., thirty-four percent of CO₂ discharge. These thus account for 90% of emissions. Similar results are reported in the examination of Wang and Xu (2011) [52] that stated that a significant portion of CO₂ discharge of China is from the textile manufacturing industry. Likewise, Yan et al., (2016) [17] analyzed carbon emissions in the textile industry of China. They found power usage (electricity and thermal power) to be significant reasons for the increased carbon discharge of the textile industry. Wang et al. (2015) [53] studied CO₂ discharges in the Chinese textile industry. The study reported that energy efficiency and economy of scales with technological improvements are improving emission levels in the textile sector, resulting in decreased emission levels.

Sitompul and Owen (2005) [54] examined the Indonesian textile industries that contribute significantly to CO₂ discharge and power consumption. For this study, the authors utilized data from 1980–2000. They found that economic growth is the highest contributing factor underlying increased CO₂ discharge, particularly from the textile sector of Indonesia, along with the chemical and paper industries. In Iran, Hasanbeigi et al. (2012) [55] inspected the environmental impact of the textile industry. The authors focused on five prominent sub-sectors of the textile industry. The results showed that power utilization is the leading cause of environmental damage in the spinning sub-sector of the textile industry. In the worsted fabric wet-processing, manufacturing, carpet production and weaving sub-sectors, the authors found thermal power to be the significant detrimental factor contributing to environmental degradation. Reddy and Ray (2010) [56] studied factors contributing to environmental degradation in the textile industry of India using data from 1992 to 2005. They found that 16% of power consumption in the Indian economy is attributable to the textile industry. Moreover, the authors stated that the textile industry contributes highest in terms of CO₂ discharge with emission levels increasing by 800% percent in the studied period.

Zabaniotou and Andreou (2010) [57] examined increasing GHG emissions in the textile industry of Greece. They reported that use of cotton fiber is a useful way to decrease emissions in the textile industry. In addition, the authors found that cotton ginning waste could be a solution to energy substitution and improve GHG emanation in the textile industry of Greece. Priambodo and Kumar (2001) [58] analyzed carbon discharge and energy efficiency in Indonesian industries. The authors

studied 73 small and medium industries (SMI). In terms of fuel usage, the study revealed that the textile industry plays a dominant part of national energy use. Likewise, the study also found that textile SMIs contribute the highest carbon emissions in the Indonesian economy.

In another study, Bevilacqua et al., (2010) [59] examined the contribution of South African textile industries to ecological deterioration. In doing so, the study focused on the supply-chain of textile industries in the country. Power usage was the prime cause of augmented CO₂ discharge in the textile related supply-chain. The study found that the increase in electricity consumption and thermal energy resulted in increased greenhouse gas emissions. Hong et al., (2010) [60] analyzed the association of the textile industry in Taiwan with ecological degradation. For this, the authors investigated the role of energy in 303 businesses in Taiwan. In particular, the study focused on the impact of energy saving in the studied businesses associated with the textile industry. The study reported that power saving has resulted in declining emission levels to 143,669 tons, highlighting the dominant role of energy usage in the textile enterprises of Taiwan.

Likewise, Ma and Lu (2015) [16] examined the factors contributing to environmental degradation in the textile industry of China. They reported that economic growth is a vital factor in increased CO₂ emissions in China. Similarly, the study found that energy intensity plays a vital part in reducing CO₂ discharge in the Chinese textile industry. Lin and Maubarak (2013) [61] concluded that energy use is the vital contributor to carbon discharge in the textile industry of China between 1986 and 2010. In recent literature, Huang et al., (2017) [2] also reported that coal consumption is the main reason for deteriorating environmental conditions associated with the Chinese textile industry. Similar to Ma and Lu (2015) [16], the authors found that energy intensity plays a significant role in the Chinese textile industry.

Ganesan et al. (2015) [15] examined the role of energy and carbon discharge in the Indian textile industry in more recent years. Unlike Reddy and Ray (2010) for observation in the 90's [56], the outcome of the study stated that energy usage in the Indian textile industry is reduced by almost six percent. A similar trend is exhibited in CO₂ discharge patterns and reduced by eight percent. Based on their findings, the authors suggested that the measures of environmental quality are improving in Indian textile industries in terms of energy intensity and carbon emissions. Lin and Ahmad (2017) [62] investigated the factors contributing to environmental degradation in Pakistan. The study employed data from 1990 to 2014. They found that an increase in population gives rise to environmental degradation in the country. Moreover, growth of the economy also played a dominant part in enhancing emissions, particularly in the textile industry. The authors further found mixed results in terms of energy use intensity, stating that the level of energy usage is dependent on factors such as energy price, process efficiency, etc. resulting in heterogeneous findings in decomposed series.

Focusing on power utilization, Palamutcu (2010) [63] analyzed the energy structure in the Turkish textile industry. The author emphasized the power consumption in the processing stage of cotton. The study reported increased utilization of energy for cotton processing in the Turkish textile industry. The study found that actual utilization of energy in processing is much larger than the anticipated power usage, and therefore should be controlled for having an adverse environmental impact. Similarly, Thai, Tokai and Nguyen (2011) [64] studied the notion of sustainability in the textile industry of Vietnam. The study focusses on an eco-labeling perspective in the apparel industry, while highlighting the presence of ecological threats during the production process of textile and clothing. Particularly, the study stated that wet processing is the largest pollution source, water- and energy-intensive process, contributing 76 percent to total water and 56 percent to total energy usage, and it stresses the need for environmental adaption in textile industry.

3. Methodology

This section explains the quantile-on-quantile (QQ) approach, which generally involves comparison amongst two probability distributions by plotting their quantiles against each other (Sim and Zhou, 2015) [24]. Recently researchers looked at the QQ method in a generic sense, and

believe it to be method developed from a combination of quantile regression and non-parametric estimation. Further, this section sheds light on the relationship between the variables of the study, i.e., textile and clothing manufacturing and energy intensity. The quantile regression methodology was widely acknowledged by the researchers after it was developed and shared in the seminal work of Koenker and Bassett (1978) [65]. This approach was seen as an advancement of the classical linear regression model. The unique feature that differentiates quantile regression analysis from ordinary least square (OLS) estimation is its ability to analyze the detailed impact of the independent variable on dependent variable, i.e., it examines the center as well as the tail part of the dependent variable distribution. In addition, the feature of local linear regression also differentiates quantile regression from OLS estimation as it details the local effect. The quantiles of an independent variable is use to examine the effect on the dependent variable. This study examines the impact of textile and clothing production on the energy use intensity of a country, and will be carried out by checking the quantile effect of textile production on quantile effect of energy intensity of the country. In this context the quantile regression model for the study is:

$$EIN_t = \gamma^\omega (T\&C_t) + \varepsilon_t^\omega \quad (1)$$

where, EIN_t stands for the energy intensity, i.e., adjusted energy intensity of a country for all the changes in the energy price of a country in a period denoted by t . In the same way, the variable $T\&C_t$ explains the growth rate of the textile production activities in a specific country in a period t . The term ω refers to the quantile of the conditional distribution of the energy intensity, which in this model is EIN_t . Further, the model also takes into consideration the error term, i.e., ε_t which in this specific model is zero (conditional ω th quantile). Further, the relevant information regarding the link between the textile production and energy intensity was not known; hence γ was also incorporated into the model as an unknown function.

In order to use nonparametric estimation techniques, several elements are of critical importance, such as bandwidth choice. The main reason for its criticality lies in its feature of identifying the neighborhood size around the target point, which ensures the smoothness of estimates. Apart from this, the justification for the choice of bandwidth is dependent on creating an equilibrium between bias and variance that are the results of large and small bandwidth. In this study, the experience of Sim and Zhou (2015) [24] was borrowed and that is why we used bandwidth parameter of 0.05.

4. Data Analysis and Interpretation

In this research, the authors have used the yearly data of textiles and clothing (T&C) (as the percentage of manufacturing value-added) and energy intensity level of primary energy (as the megajoule per GDP purchasing power parity (PPP)) as an intermediary for energy inefficiency of the top ten Asian textile manufacturing countries selected. Additionally, the present research used the yearly data from the period of 1990 to 2018. The information was changed into quarterly from yearly perception using a quadratic match approach. This methodology is refreshing when the data is changed from low period to high period since it adjusts the regular and end-to-end varieties in the data period. The quadratic match-sum method was applied in different past examinations [23,66]. All the data was gathered by the World Development Indicator (WDI) administered by the World Bank [67]. The final data was utilized in the form of normal logarithmic series to give vigorous and comparable results.

The discoveries of descriptive measurements are clarified in Table 1. The mean for energy intensity and T&C manufacturing is positive in all countries. The highest mean figure for energy intensity is for South Korea (7.421), followed by India (6.548) and Vietnam (6.151). On the other hand, the lowest value for energy intensity is China (3.172), followed by Bangladesh (3.544) and Indonesia (4.584). The middle values for energy intensity are Malaysia (5.295), Pakistan (5.187) and Thailand (5.186). The mean value of energy intensity for Japan is 4.869. Opposingly, the highest value for T&C manufacturing is in the case of Bangladesh (38.385%) followed by Pakistan (29.224%) and Vietnam (17.512%). The lowest values are Japan (2.850%), Malaysia (3.480%) and South Korea (7.173%). The medium average values are Indonesia (14.108%), China (11.118%), Thailand (10.892) and India (10.499%). Moreover, the outcomes of Jarque–Bera (JB) measurements are also used to check the normality of the factors for all nations. The results of JB tests demonstrated non-normal distribution for T&C and energy intensity in all nations indicating a solid presence of non-linearity in the every one of the nations, which propels us to apply distinctive quantile analyses, given the ability of the method to identify structural breaks whilst accounting for asymmetric and nonlinearity in the relationship amongst variables [68,69].

Table 1. Results of descriptive statistics.

Countries	Mean	Min.	Max.	Std. Dev.	JB Test	P-Value
Panel A: Energy Intensity						
China	3.172	0.426	4.462	0.321	14.821	0.000
India	6.548	4.731	8.548	1.224	20.882	0.000
Pakistan	5.187	4.422	5.626	0.361	30.617	0.000
Bangladesh	3.544	3.129	3.901	0.225	13.270	0.000
Malaysia	5.295	4.682	5.773	0.304	18.051	0.000
Indonesia	4.584	3.525	5.306	0.513	18.244	0.000
Thailand	5.186	4.485	5.648	0.354	34.666	0.000
Vietnam	6.151	5.619	7.548	0.486	13.845	0.001
Korea	7.421	6.548	8.348	0.569	22.872	0.000
Japan	4.869	3.742	5.325	0.445	6.247	0.044
Panel B: Textile and Clothing Manufacturing						
China	11.183	9.975	14.793	1.393	14.969	0.000
India	10.499	7.193	15.474	2.434	23.029	0.000
Pakistan	29.244	26.129	33.329	2.786	37.453	0.000
Bangladesh	38.385	19.798	51.043	9.556	91.320	0.000
Malaysia	3.480	1.552	6.485	1.637	26.247	0.000
Indonesia	14.108	9.786	21.339	3.549	24.445	0.000
Thailand	10.892	6.448	29.664	5.349	36.566	0.000
Vietnam	17.512	9.812	21.828	3.935	16.732	0.000
Korea	7.173	3.463	13.816	3.499	26.423	0.000
Japan	2.850	1.585	4.744	1.144	28.310	0.000
Source: authors' estimates						

Moreover, the authors of the present study have investigated the association between energy intensity and textile and attire manufacturing in all selected top Asian nations. The discoveries of the correlations estimation are reported in Table 2. The coefficient of association for all countries is significant at the 1% level, indicating a positive connection between T&C manufacturing and energy intensity in all selected countries. The highest coefficient is found in Bangladesh (0.981) trailed by

Pakistan (0.958) and China (0.945). The lowest estimation of correlation is found by in South Korea (0.875), Japan (0.853) and Malaysia (0.856). The middle value of the coefficient of correlation is found in the case of Indonesia (0.924), India (0.917), Vietnam (0.893) and Thailand (0.883). Moreover, the t-stats and significance values affirm the importance of the connection between energy intensity and T&C manufacturing. The discoveries of a relationship affirms a positive association between both variables in every single Asian nation, which suggests that T&C manufacturing is one of the wellsprings of energy consumption in Asian nations.

Table 2. Results of correlation between (textiles and clothing) T&C and augmented energy intensity (ENI).

Country	Correlation	t-Statistics	P-Value
China	0.945	8.382	0.000
India	0.917	6.968	0.000
Pakistan	0.958	10.481	0.000
Bangladesh	0.981	8.358	0.000
Malaysia	0.856	15.359	0.000
Indonesia	0.924	19.544	0.000
Thailand	0.883	22.894	0.000
Vietnam	0.893	7.437	0.000
Korea	0.785	15.464	0.000
Japan	0.853	7.829	0.000

Source: authors' estimation

In the further stage, we used a unit root test focused on various quantiles to confirm the stationary features of T&C manufacturing and energy intensity in all countries. The findings of the quantile unit root tests are reported in Table 3. It comprises a persistence parameter $\alpha(\tau)$ value and t-statistics of both variables in all nations. This table, in addition, reveals the parameter across various eleven quantiles from {0.05, 0.10, ... 0.95}. The discoveries of quantile unit root estimations showed that both variables are indicating non-stationary behavior at the level. This finding confirms that T&C manufacturing and energy intensity have a unique order of integration in all countries.

The present investigation employed quantile cointegration to research the long-run non-linear relationship among T&C and energy intensity in different countries. The findings of quantile cointegration are displayed in Table 4. This table shows the α and δ , which are two unique estimations near to the level of significance at 1%, 5%, and 10%, respectively. The results of quantile cointegration assert an essential non-linear long-run relationship among T&C manufacturing and energy intensity in all countries. Finally, the authors utilized QQ regression to explore the impact of energy intensity of T&C production on all top selected Asian textile and clothing producing nations.

The findings of QQ regression are pictured in Figure 1. The authors have reported the graphical portrayal for all ten selected Asian nations using the x-axis for T&C manufacturing, y-axis for energy intensity, and the z-axis as the cross-tabulation coefficient of the T&C producing and energy intensity for all selected Asian nations. Figure 1 clarifies the impact of energy intensity of T&C production on all ten selected Asian economies at various quantile appropriations.

Table 3. Quintile Unit Root Test.

Quantile	China				India			
	T&C		ENI		T&C		ENI	
	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats
0.05	0.873	0.05	0.847	-0.112	0.804	-1.36	0.862	-0.254
0.1	0.873	0.152	0.854	-0.145	0.881	0.331	0.863	-0.309
0.2	0.87	-1.171	0.844	-2.426	0.864	-0.879	0.864	-2.124
0.3	0.872	-0.39	0.849	-2.346	0.859	-1.671	0.866	-2.252
0.4	0.871	-1.083	0.859	-1.754	0.86	-1.486	0.87	-1.343
0.5	0.871	-2.315	0.86	-2.465	0.859	-1.374	0.87	-0.989
0.6	0.871	-1.276	0.858	-2.165	0.857	-1.399	0.87	-0.916
0.7	0.871	-1.918	0.849	-2.087	0.854	-1.67	0.869	-0.932
0.8	0.87	-1.764	0.824	-1.229	0.837	-1.728	0.873	0.353
0.9	0.871	-0.1	0.806	-0.704	0.854	-0.414	0.876	0.134
0.95	0.864	-0.601	0.753	-0.922	0.856	-0.244	0.872	-0.008
Quantile	Pakistan				Bangladesh			
	T&C		ENI		T&C		ENI	
	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats
0.05	0.847	-0.509	0.866	-0.099	0.855	-0.322	0.853	-0.218
0.1	0.854	-1.768	0.873	0.027	0.859	-1.412	0.858	-0.718
0.2	0.853	-2.236	0.867	-0.632	0.862	-1.796	0.867	-0.439
0.3	0.854	-2.054	0.87	-0.414	0.864	-1.61	0.864	-1.137
0.4	0.855	-1.927	0.87	-1.051	0.867	-1.616	0.863	-1.718
0.5	0.855	-2.071	0.87	-2.262	0.868	-1.673	0.862	-2.076
0.6	0.856	-0.99	0.87	-1.114	0.863	-1.745	0.862	-1.722
0.7	0.857	-1.314	0.868	-0.832	0.862	-1.707	0.862	-1.646
0.8	0.857	-1.456	0.867	-0.627	0.863	-1.706	0.862	-1.011
0.9	0.849	-1.721	0.853	-0.674	0.859	-0.7	0.869	-0.12
0.95	0.845	-0.583	0.848	-0.383	0.855	-0.481	0.829	-0.347
Quantile	Malaysia				Indonesia			
	T&C		ENI		T&C		ENI	
	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats
0.05	0.849	-1.524	0.873	0.588	0.896	0.052	0.869	-0.115
0.1	0.86	-2.133	0.873	0.788	0.896	0.156	0.876	-0.149
0.2	0.857	-1.726	0.872	1.39	0.893	-1.202	0.866	-2.49
0.3	0.867	-1.878	0.87	1.407	0.895	-0.4	0.872	-2.408
0.4	0.868	-1.544	0.871	0.737	0.894	-1.111	0.882	-1.801
0.5	0.867	-1.75	0.871	-0.617	0.894	-2.376	0.883	-2.53
0.6	0.868	-1.806	0.869	-1.362	0.894	-1.309	0.881	-2.222
0.7	0.867	-1.918	0.865	-0.894	0.894	-1.969	0.872	-2.143
0.8	0.858	-2.035	0.86	-0.4	0.893	-1.811	0.846	-1.261
0.9	0.857	-0.85	0.774	-1.724	0.894	-0.103	0.827	-0.723
0.95	0.858	-0.588	0.662	-1.707	0.887	-0.617	0.773	-0.947

Table 3. Cont.

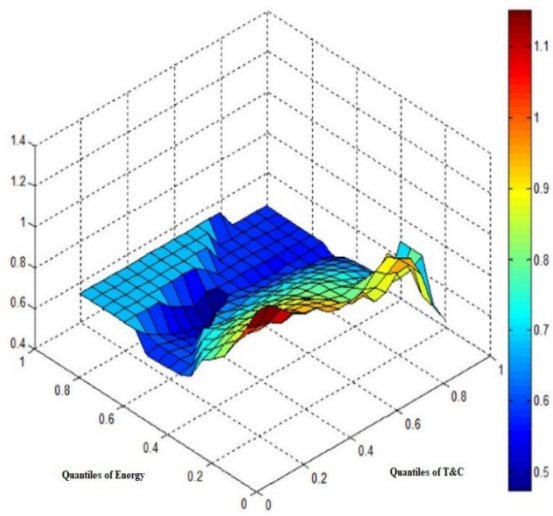
Quantile	Thailand				Vietnam			
	T&C		ENI		T&C		ENI	
	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats
0.05	0.825	-1.396	0.885	-0.261	0.87	-0.522	0.889	-0.102
0.1	0.905	0.34	0.886	-0.317	0.877	-1.814	0.896	0.027
0.2	0.887	-0.902	0.887	-2.18	0.875	-2.295	0.89	-0.648
0.3	0.882	-1.715	0.889	-2.312	0.876	-2.108	0.893	-0.424
0.4	0.882	-1.525	0.893	-1.378	0.877	-1.978	0.893	-1.079
0.5	0.882	-1.41	0.893	-1.016	0.878	-2.126	0.893	-2.321
0.6	0.88	-1.436	0.893	-0.94	0.878	-1.016	0.893	-1.143
0.7	0.876	-1.714	0.892	-0.956	0.879	-1.349	0.891	-0.854
0.8	0.859	-1.773	0.897	0.362	0.88	-1.494	0.89	-0.643
0.9	0.876	-0.425	0.899	0.138	0.871	-1.767	0.875	-0.692
0.95	0.879	-0.251	0.895	-0.009	0.868	-0.598	0.871	-0.393
Quantile	South Korea				Japan			
	T&C		ENI		T&C		ENI	
	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats	$\alpha(\tau)$	t-stats
0.05	0.877	-0.331	0.876	-0.224	0.871	-1.565	0.896	0.604
0.1	0.882	-1.45	0.881	-0.737	0.882	-2.19	0.896	0.809
0.2	0.884	-1.844	0.89	-0.451	0.88	-1.772	0.895	1.427
0.3	0.887	-1.653	0.887	-1.167	0.89	-1.928	0.894	1.444
0.4	0.89	-1.658	0.886	-1.763	0.89	-1.584	0.894	0.756
0.5	0.891	-1.717	0.885	-2.131	0.89	-1.796	0.894	-0.633
0.6	0.886	-1.791	0.885	-1.768	0.891	-1.854	0.892	-1.398
0.7	0.885	-1.752	0.885	-1.69	0.89	-1.969	0.888	-0.918
0.8	0.886	-1.751	0.885	-1.038	0.881	-2.089	0.883	-0.41
0.9	0.881	-0.719	0.892	-0.123	0.88	-0.872	0.795	-1.769
0.95	0.878	-0.494	0.85	-0.356	0.881	-0.603	0.68	-1.752

Source: Authors' Estimation

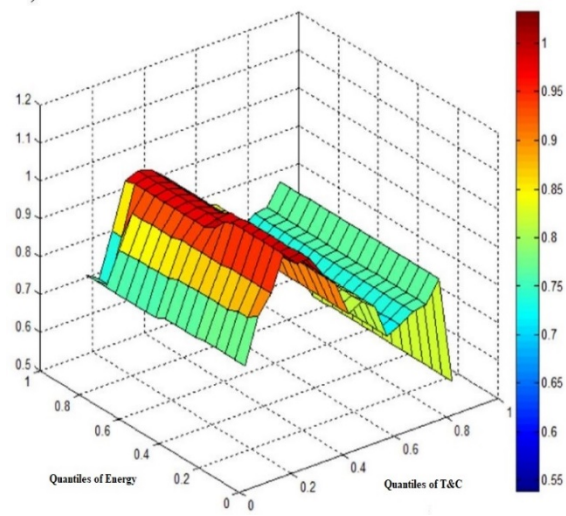
Table 4. Quintile Cointegration Test.

China						Indonesia					
Model	Coefficient	Supremum norm value	Critical Value at 1%	Critical Value at 5%	Critical Value at 10%	Model	Coefficient	Supremum norm value	Critical Value at 1%	Critical Value at 5%	Critical Value at 10%
ENI _t vs. T&C _t	α	2321.246	1118.771	835.246	293.126	ENI _t vs. T&C _t	A	1110.689	535.319	399.655	140.257
	δ	465.286	244.154	136.81	119.346		Δ	222.634	116.825	65.462	57.106
India						Thailand					
Model	Coefficient	Supremum norm value	Critical Value at 1%	Critical Value at 5%	Critical Value at 10%	Model	Coefficient	Supremum norm value	Critical Value at 1%	Critical Value at 5%	Critical Value at 10%
ENI _t vs. T&C _t	α	3137.966	959.516	524.846	257.649	ENI _t vs. T&C _t	A	1501.48	459.117	251.132	123.282
	δ	854.036	319.921	190.71	137.41		Δ	408.646	153.078	91.252	65.749
Pakistan						Vietnam					
Model	Coefficient	Supremum norm value	Critical Value at 1%	Critical Value at 5%	Critical Value at 10%	Model	Coefficient	Supremum norm value	Critical Value at 1%	Critical Value at 5%	Critical Value at 10%
ENI _t vs. T&C _t	α	1907.117	1253.856	765.913	514.174	ENI _t vs. T&C _t	A	912.533	599.955	366.48	246.026
	δ	1118.8	646.329	379.385	165.604		Δ	535.333	309.261	181.531	79.24
Bangladesh						South Korea					
Model	Coefficient	Supremum norm value	Critical Value at 1%	Critical Value at 5%	Critical Value at 10%	Model	Coefficient	Supremum norm value	Critical Value at 1%	Critical Value at 5%	Critical Value at 10%
ENI _t vs. T&C _t	α	4304.168	1254.004	844.698	466.681	ENI _t vs. T&C _t	α	2059.494	600.026	404.178	223.301
	δ	2436.524	970.314	563.462	293.199		δ	1165.848	464.284	269.61	140.292
Malaysia						Japan					
Model	Coefficient	Supremum norm value	Critical Value at 1%	Critical Value at 5%	Critical Value at 10%	Model	Coefficient	Supremum norm value	Critical Value at 1%	Critical Value at 5%	Critical Value at 10%
ENI _t vs. T&C _t	α	2937.394	1501.96	1071.565	822.234	ENI _t vs. T&C _t	α	1405.509	718.67	512.731	393.429
	δ	1240.125	862.113	421.565	257.702		δ	593.385	412.511	201.714	123.307

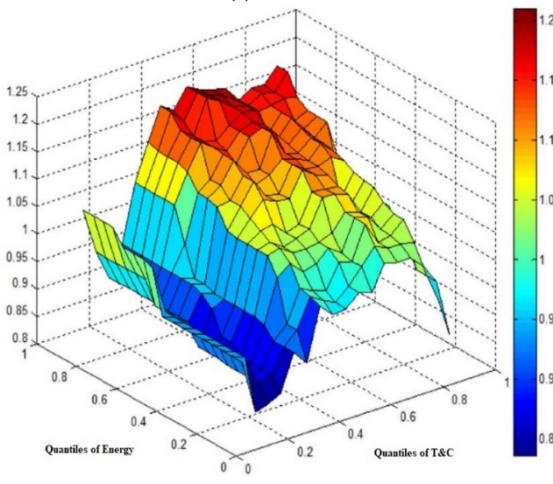
Note: This table presents the results of the quantile cointegration test of Xiao (2009) for the logarithm of the Textile & Clothing (T&C) and per capita of carbon dioxide emission (CO₂). Abbreviations ENI, energy intensity; T&C, textiles and clothing sector.



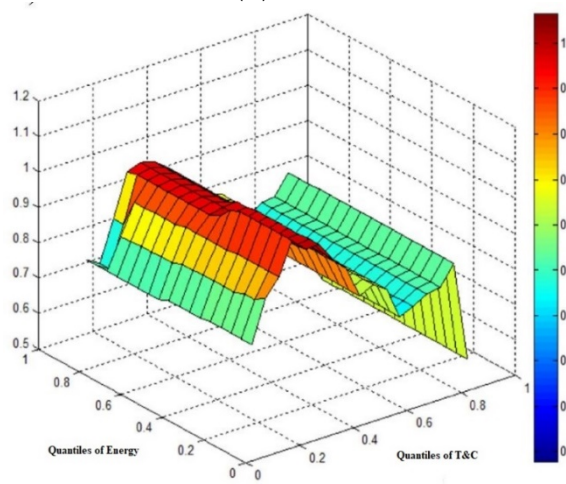
(i) China



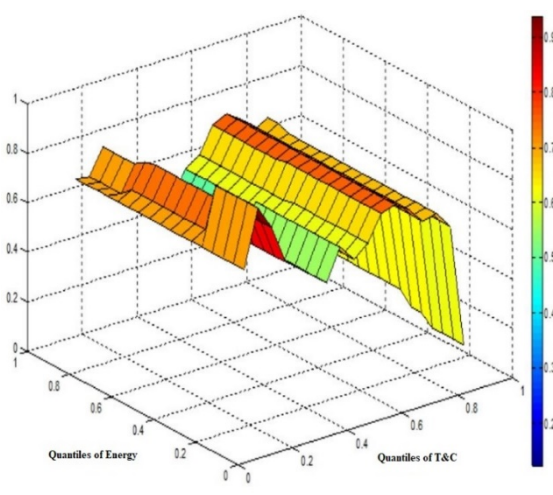
(ii) India



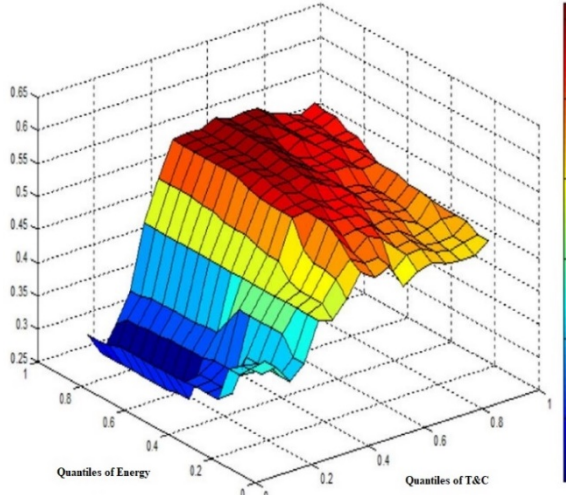
(iii) Pakistan



(iv) Bangladesh



(v) Malaysia



(vi) Indonesia

Figure 1. Cont.

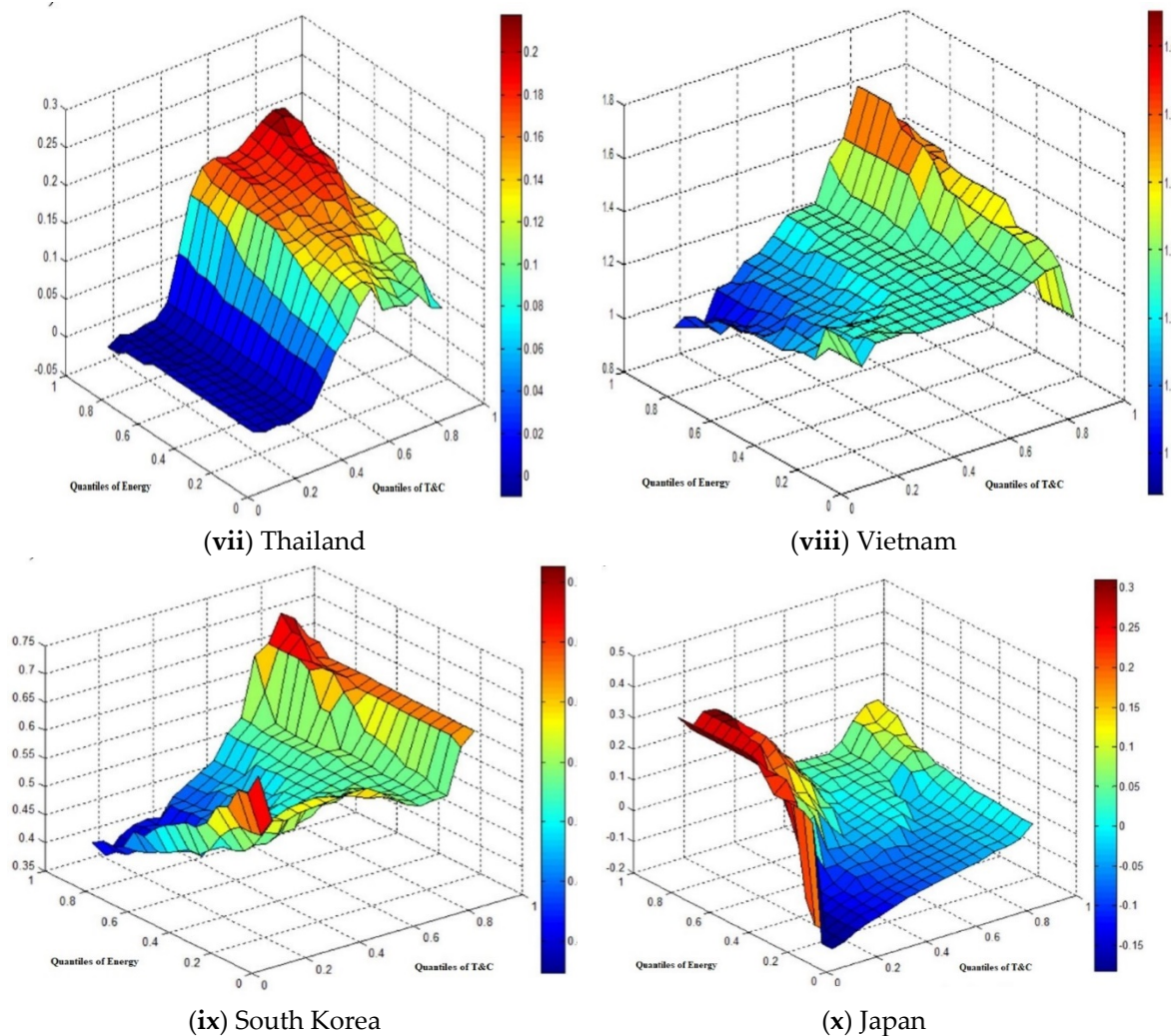


Figure 1. Results of quantile-on-quantile regression.

In China, the results confirm that the effect of T&C production on energy intensity is significant and substantial to the overall grouping of quantiles. Furthermore, the impact of T&C production on energy intensity is perceptible in the low quantiles of both variables (i.e., 0.05–0.40), suggesting that T&C manufacturing actually has a positive effect on energy intensity at all quantile distributions; however, the effect is stronger in the low tails of both variables. Overall, the results of QQ suggest that the effect of energy intensity on T&C manufacturing is positive and significant. However, as the manufacturing of T&C increases, the level of energy intensity decreases and becomes weaker. In this situation, the Chinese government and local investors need to implement some green technology to reduce the energy consumption, which ultimately decreases energy inefficiency in the Chinese economy.

The effect of T&C production on energy intensity is very similar in the cases of Malaysia and India. The results suggested that the impact of T&C production on energy intensity is significant as the maximum number of various quantiles. The highest effect of T&C manufacturing on energy intensity is reported at lower-middle quantiles of T&C (0.25–0.50) and also across all quantiles of energy intensity (0.05–0.95). Technically speaking, the results of QQ regression suggest that the effect of T&C production on energy intensity is significant and positive at lower-middle quantiles of T&C production; however, the effect becomes weaker at a high level of T&C production. In the case of South Korea, Vietnam and Bangladesh, the results confirm that the effect of T&C production on energy intensity is significant and noteworthy across all combination of quantiles. Furthermore, the impact of T&C production on energy intensity is noticeable in the high quantiles of T&C production (i.e., 0.85–0.95) and all quantiles

of energy intensity (i.e., 0.05–0.95), suggesting that T&C manufacturing has a positive effect on energy intensity at all quantile distributions. However, the effect is stronger in the high tails (maximum) of T&C production. In general, the results of QQ confirm that the effect of T&C manufacturing on energy intensity is positive and significant. However, as the manufacturing of T&C decreases, the level of energy intensity decreases too. This finding suggested that these Asian countries' energy levels are very much dependent on textile and clothing manufacturing. Therefore, the governments of these countries need to shift the textile industry towards renewable energy consumption to reduce energy inefficiency. Interestingly in the case of Pakistan, Indonesia and Thailand, the graphs of QQ confirm that the influence of T&C production on energy intensity is important and remarkable in all mixtures of quantiles. Additionally, the influence of T&C production on energy intensity is visible in the high quantiles of T&C production (i.e., 0.80–0.95) and high quantiles of energy intensity (i.e., 0.75–0.95), implying that T&C manufacturing essentially has a positive effect on energy intensity at all quantile distributions. However, the effect is more robust in the high tails (maximum) of T&C production and energy intensity. In summary, the results of QQ confirm that the effect of T&C manufacturing on energy intensity is positive and significant. However, as the manufacturing of T&C increases, the level of energy intensity increases too. In the case of Japan, the outcomes confirm that the impact of T&C production on energy intensity is significant and considerable across entire sets of quantiles.

Furthermore, the effect of T&C production on energy intensity is observable in the low quantiles of T&C production (i.e., 0.05–0.10) and all quantiles of energy intensity (0.05–0.95), suggesting that T&C manufacturing actually have a positive effect on energy intensity at low quantiles. However, the effect is stronger in the low tails of T&C production. On the other hand, while seeing the effect of T&C production at high quantiles (0.50–0.95), it can be found that it gives a negative impact on energy intensity. We suggest that the increase in T&C production helps to reduce the energy intensity in the Japanese economy. This finding suggests that the direction of the government and policymakers is in the right path, and it reduces the level of energy inefficiency with the help of textile and clothing production.

In the final step, the present study aims to investigate the causal relationship between T&C production and energy intensity. In doing so, the authors applied Granger causality in quantiles to examine the cause-and-effect connection between both variables. The results of Granger causality in quantiles are reported in Table 5 that shows the p-values of both directional causal relationships. The results confirm bi-directional causal connection between textile and clothing manufacturing and energy intensity in all selected countries, except Thailand and Japan. The results show a uni-directional causal connection between textile and clothing production and energy intensity in the cases of Japan and Thailand, where causality is running from textile and clothing production to energy intensity and does not reverse.

Table 5. Granger Causality in Quintile Test Results.

China												
Causality	[0.05–0.95]	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.95
$\Delta T \& C_t$ to ΔENI_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ΔENI_t to $\Delta T \& C_t$	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 ΔENI_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ΔENI_t to $\Delta T \& C_t$	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 ΔENI_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ΔENI_t to $\Delta T \& C_t$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Bangladesh												
$\Delta T \& C_t$ to ΔENI_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ΔENI_t to $\Delta T \& C_t$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Malaysia												
$\Delta T \& C_t$ to ΔENI_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ΔENI_t to $\Delta T \& C_t$	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 ΔENI_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ΔENI_t to $\Delta T \& C_t$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thailand												
$\Delta T \& C_t$ to ΔENI_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ΔENI_t to $\Delta T \& C_t$	0.195	0.493	0.543	0.584	0.603	0.689	0.712	0.642	0.543	0.49	0.327	0.215

Table 5. Cont.

Vietnam												
$\Delta T\&C_t$ to ΔENI_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ΔENI_t to $\Delta T\&C_t$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
South Korea												
$\Delta T\&C_t$ to ΔENI_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ΔENI_t to $\Delta T\&C_t$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Japan												
$\Delta T\&C_t$ to ΔENI_t	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
ΔENI_t to $\Delta T\&C_t$	0.482	0.148	0.264	0.331	0.548	0.427	0.368	0.301	0.287	0.216	0.189	0.167
Source: Authors' Estimation												

5. Conclusions

The current study has evaluated the asymmetric impact of textile manufacturing on energy intensity of ten leading Asian economies based on textile dominance. The selected countries are China, Indonesia, India, Pakistan, Bangladesh, Malaysia, South Korea, Thailand, Japan and Vietnam. The results of quantile-on-quantile analysis confirms that T&C production has a positive and significant impact on energy intensity in all selected countries. The results further suggest that a low level of T&C production increases the level of energy intensity in all selected countries. Conversely, at high quantiles (high level of T&C production), the effect is also positive in all countries except Japan. On the other hand, the results of Granger causality in quantiles confirm a bidirectional causal relationship between T&C production and energy intensity in all selected countries except Thailand and Japan, where a uni-directional causal connection between textile and clothing manufacturing and energy intensity can be found. This study recommends that governments and investors invest more in green and advanced technologies to reduce the energy intensity in Asian economies.

6. Discussion and Future Recommendation

The prominence of the textile industry is notable for generating foreign exchange through trade expansion, particularly in emerging economies. In many Asian countries, the textile sector is considered to be the backbone of the economy, creating employment opportunities for both men and women. However, from an environmental perspective, industrial growth is notable for carrying adverse influence, especially in regard to climate change. In recent years, climate vulnerability has been recognized as an international issue, since it is responsible for carrying numerous harmful effects on many countries' growth and sustainability. The rapid degradation of climate conditions has been found to link with increased industrialization, increased energy intensity and burning of fossil fuels [70–72]. In line with this statement, our objective was to identify the dynamic relationship between the textile industry and energy utilization across several levels of growth. In doing so, the utilized methodology has been selected to recognize the link between T&C and ENI in numerous quantiles representing the low, medium and high levels of the studied variables. The outcomes reveal that the effect of T&C manufacturing on energy intensity is positive and significant in all selected Asian countries. Moreover, the effect is high and is the same in India, Bangladesh and Malaysia (low T&C production positively affects energy intensity). On the other hand, the effect of high T&C production is significant and positive on energy intensity in the case of Indonesia, Thailand, Vietnam and Pakistan and South Korea. Finally, the present research can be extended in the future by adding multivariate modelling such as non-linear-Auto-Regressive Distributed Lag (ARDL) or quantile-ARDL. Future research could also introduce other essential factors, such as CO₂ emissions, economic growth and renewable energy consumption.

Author Contributions: The following was the contribution of each author of this study. M.H. has worked on the original idea. M.H. has performed the detailed conceptualization and investigation of this research. H.I.H. has finalized the methodology. H.I.H. has conducted data analysis of this research. S.K. has performed the write up of this project including the writing of original draft. S.K. has performed the data collection and data analysis. L.W.M. has written the final draft and done the review, proof reading and editing for final submission. P.S. has coordinated the methodology and data analysis stage of this research project. All authors have read and agreed to the published version of the manuscript.

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