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# The asymmetric effect of film and drama industry, energy efficiency and economic growth on green innovation: Empirical evidence from quantile estimation

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## ABSTRACT

The popularity of green innovation has dramatically increased in the recent times because of the potential benefits attached with it. Therefore, in order to make the technology more affordable, green innovation is the key to enhancing the affordability factor. On the other hand, in order to safeguard the environment, the role of media is one of fundamental importance. In contrast, energy consumption is often regarded as a key indicator of economic prosperity, mostly at the cost of the environment. Hence, the present study attempts to explore the asymmetric effect of the film and drama industry, energy efficiency, and economic growth on green innovation, with the help of the latest quantile autoregressive distributed lag (QARDL) method for the period 2000Q1 to 2019Q4. The results have reported a positive and significant association of the Film and Drama Industry, Energy Efficiency, and economic growth on the quantiles of Green Innovation. Based on the findings, it is recommended that there is a dire need to develop content that promotes the green innovation, whereas, more investments are to be sought after, so as to enhance the level of energy efficiency.

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## 1. Introduction

Because of global warming, the climatic conditions across the world have also started showing signs of unpredictability (Umar, Ji, Mirza, & Naqvi, 2021). This is ultimately creating trouble for humankind in fulfilling their essential needs, such as accessing clean water, using the land for farming, food, and other utilities (Danish & Wang, 2019; Su et al., 2020; Umar, Ji, Kirikkaleli, & Xu, 2020). According to environmental scientists, negligence in handling the environment is extremely detrimental to the survival of mankind and other species. It alters other natural processes such as rainfall, frequency of storms and droughts, etc., and could also be far more dangerous and

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destructive in terms of their scale and magnitude (Guo et al., 2021; Su, Umar, et al., 2021). Even though the researchers agree to the terms of alleviating pollution as the potential solution to curb this grave situation (Danish & Wang, 2019), at the same time, there are also certain other measures and operations by which global warming could be controlled. These include the optimisation of resources (Najmi & Khan, 2017), improving the consumption of energy (Su, Yuan, et al., 2021; Umar, Su, Rizvi, & Loboň, 2021), reducing the factors of uncertainties (Ahmed et al., 2019), encouraging green investments (Ji et al., 2021; Naqvi et al., 2021; Shen et al., 2021) and most importantly boosting innovations (Ahmed et al., 2020).

The popularity of Green Innovation (GIN) has dramatically increased in the recent times, primarily because of its potential benefits (Najmi et al., 2020; Wang et al., 2021). For instance, in addition to improving the quality of the utilisation of resources, and enhancing the level of productivity, Green Innovation (GIN) further assists in decreasing the level of environmental pollution. At the same time, it also improves the level of affordability of environmentally friendly technologies (Popp, 2012). Despite the consensus among the countries in terms of their progression towards sustainable growth, certain hindrances are likely to interrupt the adoption of green and clean technologies, both internationally and locally (Biresselioglu et al., 2018; Su, Khan, et al., 2021). In conventional terms, environmentally friendly technology is assumed to be comparatively dearer, especially for developing countries. However, such technologies possess sustainable benefits that extend in the future as well (Ahmed & Najmi, 2018; Yu et al., 2022). Moreover, a company will be more willing to invest in such technologies, especially if they meet the objective of reducing misappropriateness and inefficiency, by improving the company's productivity (Guo et al., 2022; Ielasi et al., 2018; Kaiser & Welters, 2019).

In order for the mitigation of global warming, and the promotion of a culture to have acceptance towards GIN, so that pollution alleviation and environment preservation are ensured, in addition to the organisational and institutional initiatives and actions (Ahmed et al., 2020), individuals should play their role in the said purpose, respectively (Najmi et al., 2021). However, for that to happen, there is a need to create awareness regarding the consequences that would ensue if these individuals do not play their role (Khan et al., 2019), and incorporate environmental protection in the moral norms of the culture and society (Najmi et al., 2021; Rizvi et al., 2020). Whereas, for that to happen, the role of media is that of fundamental importance (Khan et al., 2019).

There are two aspects by which the media, or precisely the Film and Drama industry (F&D) can play their part in this drive for pollution alleviation, environment preservation, and most importantly, for the mitigation of global warming. Firstly, by creating and developing relevant content, producing investigative reports, short films, and awareness campaigns, the general public can convey the need for environmental protection (Chen & Valdmanis, 2019). The second aspect could be the role of this industry, as the consumer of the resources and energy in which every scene has a different demand, and every idea has a different production set up. Thus, this industry itself is a likely source which pitches in the increase in pollution and environmental deterioration (Lopera-Mármol & Jiménez-Morales, 2021). It should be noted that because of being non-environmentally friendly, this industry has always been criticised for its negligence (Brereton, 2013).

Sustainability accountability has been recognised, regarded, and has gained tremendous recent attention. Also, academic researchers are continuously evaluating the level of compliance made by the different industrial sectors, respectively (Lopera-Mármol & Jiménez-Morales, 2021). It has also been reported that the industry encountered several kinds of institutional pressures (Ahmed et al., 2019), including those pertaining to the government, competitors, and other stakeholders, which forces them to adopt sustainable practices for operational and sustainable excellence (Ahmed et al., 2020). However, the media industry, in general, and the F&D in particular, despite their capability of shaping and drawing the societal narrative, have been reported major contributors in carbon-emitting, pollution releasing, and socially unequal operations and endeavours (Brereton, 2013; Forster et al., 2020; Starosielski & Walker, 2016) (2–4). Based on the report's findings in 2006, the sector involved in the video and audio area is reported to have generated more than 1 million tons of carbon on a yearly basis (Vandenberg, 2006).

There are several kinds of unsustainable practices incurred by the F&D, but somehow are getting unnoticed. This includes abusing the natural resources for their content development, excessive production of clothes, overconsumption of energy, and excessive incurring the non-recyclable decoration in the set and location designs are some examples (Lopera-Mármol & Jiménez-Morales, 2021). In addition to this, big films involving big names are also reported to destroy, devastate and destruct the ecology. For instance, as reported by (Fitzpatrick et al., 2019), during the process of shooting the film 'Pirates of the Caribbean: Dead Men Tell No Tales' in Queensland (Australia), the chemical waste was more notorious and toxic will dumped without processing which contaminates the water; in picture 'Mad Max: Fury Road' several natural sights were damaged across the coastline of African Atlantic coast. However, on the other side, there are also certain examples from this sector in which sustainable measures were taken to reduce the footprints and optimise the resources. For instance, according to for shooting the season 10 of the famous crime series 'X-Files,' around USD 35,000 of the production expenses were saved by recycling the steel and aluminium used in the development of sets, the emissions of carbon were saved by around 33 tons, along with the avoiding of 45,740 plastic bottles (Salami et al., 2019). Among the other examples, the title of the films includes 'Fifty Shades Freed' which is the recipient of the 'EMA Green Seal Award' in 2016, 'Downtown Abbey,' and 'Yesterday,' which also received the 'EMA Green Seal Award' in 2019. Hence, the practices introduced on sets and the message given through the content, the F&D could be a potential candidate in promoting GIN.

Despite the fact that F&D is regularly being criticized for its negligence towards sustainability (Lopera-Mármol & Jiménez-Morales, 2021), however, since this industry is the most efficient and relevant industry for building the knowledge, understandings, and overall shaping of the narrative of society, therefore its importance for highlighting the sustainability and environmental preservation cannot be ignored (Chen & Valdmanis, 2019; Mirza et al., 2020). Precisely (Lopera-Mármol & Jiménez-Morales, 2021) has proposed a complete framework based on the greener practices through which the green shooting can be promoted and encouraged. In developing the framework, the authors have urged to bring innovative ideas for mitigating the non-sustainable operations. In addition to this, (Chen & Valdmanis, 2019) evaluate the media's performance in covering waste and environment-related issues. The authors reported that there is very little

coverage on the issues related to waste in the Chinese media, whereas general information related to science is comparatively given less space in the print media.

On the other hand, energy consumption is often regarded as an indicator of economic prosperity at the cost of the environment (Chang et al., 2018). The link of energy in excessing the carbon emissions has been highlighted by numerous researchers (Odhiambo, 2009; Tang et al., 2018; Yildirim et al., 2012). Therefore, the potential solution to curb the destruction is to improve energy productivity (Filippini & Zhang, 2016). Though there is a need to have investments in improving and advancing the quality of the technology for the purpose of energy efficiency (EEF), and its relationship with GIN is also reported (Ferrati et al., 2021; Lobato et al., 2021; Wurlod & Noailly, 2018). Despite Green Innovation is regarded as one of the potential solutions to curb global warming and climate worsening and is known to have a significant association with energy efficiency (Acemoglu et al., 2012; Sun et al., 2019). The majority of the research has explored the relationships considering GIN as a predictor and EEF as a criterion (Lin & Moubarak, 2014; Popp, 2005; Wurlod & Noailly, 2018). In addition, (Song & Yu, 2018) reported that GIN progression could lead to improved EEF. However, the study by (Sun et al., 2019) highlighted the role of technology in which the patents data was used for 71 countries from the year 1990 to 2014. The data set belongs to both developing and developed countries and reported a positive association between the two variables. In contrast, the researchers have also identified the least energy-efficient countries based on their findings Ghana, Bahrain, Jamaica, and Iceland, whereas Australia, Germany, and the USA were reported to be more energy-efficient countries. However, the relationship of EEF as the determinant of GIN is minimally explored.

Hence, the present study is an attempt to contribute to the literature in various ways. Firstly, by exploring the asymmetric effect of F&D, EEF, and economic growth (GDP) on GIN with the help of the latest 'Quantile Autoregressive Distributed Lag' (QARDL) proposed by Cho et al. (2015), which is capable of explaining the relationships by computing coefficients effects of the predictors on the quantiles of the criterion variables. Secondly, the selection of unique predictor variables, including F&D and EEF as the determinants to GIN, is also the potential contribution that highlights their role in improving ecological excellence. Lastly, by evaluating the relevancy of the Environment Kuznets Curve (EKC) in the current study, which is assessed precisely in the context of GIN.

The remaining research has been outlined as the next section summarises the related literature review, followed by the discussion on the methodology, computations of results, and outcome. In contrast, in the last, the study is concluded and recommendations are proposed.

## 2. Data and methodology

### 2.1. Data

The current study is based on the evaluation of asymmetric effects of three predictor variables which are film and Drama industry (F&D), energy efficiency (EEF), and economic growth (GDP) on the criterion variable, which is green innovation (GIN). All of the data of these variables were extracted from the database of Data Stream. Moreover, the time frame of the dataset of all of the studied variables was based on

the quarterly observation from the year 2000 to 2019. Moreover, since the current study is also evaluating the relevancy of the Environment Kuznets Curve (EKC), the square of GDP was also considered in the subsequent analysis at relevant stages. Lastly, in order to address the difference in the measurement units of the variables, their natural log has been taken respectively, so that they become homogenous in terms of its handling and the subsequent statistical and theoretical interpretations.

## 2.2. Methodology

### 2.2.1. Quantile autoregressive distributed lag (qardl)

As already discussed, ‘Quantile Autoregressive Distributed Lag’ (QARDL) is an innovative and latest tool that is accordingly utilised in the current study for a better and in-depth understanding of studied relationships between predictors and criterion variables. QARDL was proposed by (Cho et al., 2015). It can regress the predictors which in the present study are Film and Drama Industry (F&D), energy efficiency (EEF), and Economic Growth (GDP); on the quantiles of the criterion variable, which in the current study is Green Innovation (GIN). Moreover, the integration and its respective assessment for all of the studied relationships in accordance with the principles of time-varying is made with the help of the Wald Test. This test has the capability to assess the firmness and stability of the path coefficients when their integration is made across the quantiles of the criterion (Umar, Ji, Kirikkaleli, Shahbaz, et al., 2020). The typical representation of conventional ARDL in a mathematical form that explains the studied relationships among the predictors and criterion variable are depicted in equation 1.

$$GIN_t = \alpha + \sum_{i=1}^p \theta_i GIN_{t-1} + \sum_{i=0}^{q_1} \omega_i FDI_{t-1} + \sum_{i=0}^{q_2} \lambda_i EEF_{t-1} + \sum_{i=0}^{q_3} \theta_i GDP_{t-1} + \varepsilon_t \quad (1)$$

Referring to Equation 1, the error term has been reflected by  $\varepsilon_t$  and it has been further described as  $ESRI_t - E\left[\frac{ESRI_t}{F_{t-1}}\right]$ . Moreover, the term  $F_{t-1}$  reflects the smallest  $\sigma$ -field which is computed and generated from  $\{F\&D_t, EEF_t, GDP_t, GIN_{t-1}, FDI_{t-1}, EEF_{t-1}, GDP_{t-1}, \dots\}$ . Furthermore, the lag of the optimised order of the equation is selected by utilising the ‘Schwarz Information Criterion’ that are  $p, q_1, q_2, \text{ and } q_3$ . In addition to this, the lags were taken of the predictor variables, which are reflected as  $F\&D_t, EEF_t, \text{ and } GDP_t$ . And the lags were taken of the criterion variable, which is reflected as  $GIN_t$ . Therefore, the conventional ARDL, which is reflected as equation 1, is accordingly extended and reconstituted in order to adjust the simple kind of QARDL by (Cho et al., 2015) is shown below:

$$Q_{GIN_t} = \alpha(\tau) + \sum_{i=1}^p \theta_i(\tau) GIN_{t-1} + \sum_{i=0}^{q_1} \omega_i(\tau) F\&D_{t-1} + \sum_{i=0}^{q_2} \lambda_i(\tau) EEF_{t-1} + \sum_{i=0}^{q_3} \theta_i(\tau) GDP_{t-1} + \varepsilon_t(\tau) \quad (2)$$

In equation 2, there is an expansion of the error term, which is  $\varepsilon_t(\tau) = GIN_{t-1} - Q_{GIN_t}(\frac{\tau}{F_{t-1}})$ . Moreover, the  $\tau^{\text{th}}$  quantile of  $GIN_t$  is further described as  $Q_{GIN_t}(\frac{\tau}{F_{t-1}})$  Which is a constraint to the information set as already discussed (Kim, 2003). The restructuring of equation 2 in order to analyze the QARDL is shown as equation 3.

$$\begin{aligned}
 Q_{GIN} = & \alpha(\tau) + \sum_{i=1}^{q_1-1} \delta_{F\&D_i}(\tau)\Delta F\&D_{t-1} + \gamma_{F\&D}(\tau)F\&D_t + \sum_{i=1}^{q_2-1} \delta_{EEF_i}(\tau)\Delta EEF_{t-1} + \gamma_{EEF}(\tau)EEF_t \\
 & + \sum_{i=1}^{q_3-1} \delta_{GDP_i}(\tau)\Delta GDP_{t-1} + \gamma_{GDP}(\tau)GDP_t + \varepsilon_t(\tau)
 \end{aligned}
 \tag{3}$$

$$\begin{aligned}
 \text{Whereas, } \gamma_{F\&D}(\tau) &= \sum_{i=0}^{q_1} \omega_i(\tau), \quad \delta_{F\&D_i}(\tau) = - \sum_{j=i+1}^{q_1} \omega_j(\tau), \quad \gamma_{EEF}(\tau) = \sum_{i=0}^{q_1} \lambda_i(\tau), \quad \delta_{EEF_i}(\tau) \\
 &= - \sum_{j=i+1}^{q_1} \lambda_j(\tau), \quad \gamma_{GDP}(\tau) = \sum_{i=0}^{q_1} \theta_i(\tau) \quad \text{and} \quad \delta_{GDP_i}(\tau) = - \sum_{j=i+1}^{q_1} \theta_j(\tau)
 \end{aligned}$$

Notably, the estimated parameters reflected in equation 3 is further utilized to assess the short-run dynamics. For the association, in the long-run, these are being assessed by reformulating equation 3 as done and reflected in equation 4.

$$Q_{GIN_t} = \mu(\tau) + X'_t\beta(\tau) + M_t(\tau)
 \tag{4}$$

In Equation 4,  $X = [F\&D, EEF, GDP]$  and  $\beta_{F\&D}(\tau) = \gamma_{F\&D}(\tau)[1 - \sum_{i=1}^p \emptyset_G(\tau)]^{-1}$  and  $M_t(\tau) = \sum_{j=0}^{\infty} \vartheta_{F\&D_j}(\tau)\Delta F\&D_{t-1} + \sum_{j=0}^{\infty} \theta_{F\&D_j}(\tau)\Delta \varepsilon_{t-1}$  along with  $\mu(\tau) = \alpha(\tau)[1 - \sum_{i=1}^p \emptyset_G(\tau)]^{-1}$  and  $\vartheta_j(\tau) = \sum_{i=j+1}^{\infty} \pi_i(\tau)$ . The estimation of  $\beta_{EEF}(\tau)$  and  $\beta_{GDP}(\tau)$  is made identical to F&D.  $\{\theta_0(\tau), \theta_1(\tau), \dots$  and  $\{\pi_0(\tau), \pi_1(\tau), \dots$  which is further described as  $\sum_{i=0}^{\infty} \theta_i(\tau)L^i = (1 - \sum_{i=1}^p \emptyset_i(\tau)L^i)^{-1}$  and  $\sum_{i=0}^{\infty} \pi_i(\tau)L^i = (1 - L)^{-1} \left( \frac{\sum_{i=0}^{q_1} \omega_i(\tau)L^i}{1 - \sum_{i=0}^{q_1} \omega_i(\tau)L^i} - \frac{\sum_{i=0}^{q_1} \omega_i(\tau)}{1 - \sum_{i=0}^{q_1} \omega_i(\tau)} \right)$ .

On the other hand, it should also be noted that there is a likelihood of serial correlations  $\varepsilon$  which is accordingly addressed through generalising the QARDL, which is reflected as equation 5.

$$\begin{aligned}
 Q_{\Delta GIN_t} = & \alpha + \rho GIN_{t-1} + \emptyset_{F\&D}F\&D_{t-1} + \emptyset_{EEF}EEF_{t-1} + \emptyset_{GDP}GDP_{t-1} + \sum_{i=1}^p \emptyset_i \Delta GIN_{t-1} \\
 & + \sum_{i=1}^{q_1-1} \omega_i \Delta F\&D_{t-1} + \sum_{i=1}^{q_2-1} \lambda_i \Delta EEF_{t-1} + \sum_{i=1}^{q_3-1} \theta_i \Delta GDP_{t-1} + \nu_t(\tau)
 \end{aligned}
 \tag{5}$$

Though the QARDL equations have been restructured as mentioned in Equation 5, the generation of ambiguous and inferior outcomes is still possible because of the continuous type of correlations across the  $\Delta F\&D_t$ ,  $\Delta EFF_t$ ,  $\Delta GDP_t$  and  $v_t$ . The avoidance of this type of correlation is possible by utilising the estimated projections of  $v_t$  above  $\Delta F\&D_t$ ,  $\Delta EFF_t$ ,  $\Delta GDP_t$  by formulating  $v_t = \gamma_{F\&D}\Delta F\&D_t + \gamma_{EFF}\Delta EFF_t + \gamma_{GDP}\Delta GDP_t + \varepsilon_t$ . With the help of this, the variance reflected through  $\varepsilon_t$  will be controlled of having an impact on predictor variables  $\Delta F\&D_t$ ,  $\Delta EFF_t$ ,  $\Delta GDP_t$ . Previously, the estimated projections were included in equation 5, which further helps generalise within the dynamics and outline of the quantile regression. Hence, the estimated QARDL-ECM is accordingly structured, which is noted below:

$$\begin{aligned} Q_{\Delta GIN_t} = & \alpha(\tau) + \rho(\tau)(GIN_{t-1} - \beta_{F\&D}(\tau)F\&D_{t-1} - \beta_{EFF}(\tau)EFF_{t-1} - \beta_{GDP}(\tau)GDP_{t-1}) \\ & + \sum_{i=1}^{p-1} \vartheta_i(\tau)\Delta GIN_{t-1} + \sum_{i=1}^{q_1-1} \omega_i(\tau)\Delta F\&D_{t-1} + \sum_{i=1}^{q_2-1} \lambda_i(\tau)\Delta EFF_{t-1} \\ & + \sum_{i=1}^{q_3-1} \theta_i(\tau)\Delta GDP_{t-1} + \varepsilon_t(\tau) \end{aligned} \tag{6}$$

The consolidated short-run effect is computed with the help of earlier data point of GIN on the subsequent data point of GIN by  $\vartheta_* = \sum_{j=1}^{p-1} \vartheta_j$ . The consolidated short-run effect of current and previous data points for F&D, EEF, and GDP over GIN is computed accordingly by  $\omega_* = \sum_{j=1}^{q_1-1} \omega_j$ ,  $\lambda_* = \sum_{j=1}^{q_2-1} \lambda_j$  and  $\theta_* = \sum_{j=1}^{q_3-1} \theta_j$ . In addition to this, the long-run cointegration effects for F&D, EEF, and GDP is accordingly computed by  $\beta_{F\&D} = \frac{\vartheta_{F\&D}}{\rho}$ ,  $\beta_{EFF} = \frac{\vartheta_{EFF}}{\rho}$  and  $\beta_{GDP} = \frac{\vartheta_{GDP}}{\rho}$  respectively. On the other hand, the consolidated estimations of the parameters along with the cointegration level of parameters for both long-run and short-run are accordingly computed through the application of the Delta Method. Moreover, ECM, which is reflected through parameter  $\rho$  needs to be significant for the estimations, whereas it should also be negative.

In addition to this, to evaluate the predictor effects on the criterion variable, which may be non-linear and asymmetric, they are computed through the Wald Test, which follows the operational principles of Chi-Square for assessing the respective significance statistically. Through the application of the Wald Test, the parameters in the long-run and short and their respective null and alternative hypothesis  $\vartheta_*$ ,  $\omega_*$ ,  $\beta_*$  and  $\rho_*$  are:

$$\begin{aligned} H_0^\vartheta &= F\vartheta_*(\tau) = f \quad \text{Against } H_1^\vartheta = F\vartheta_*(\tau) \neq f \\ H_0^\omega &= S\omega_*(\tau) = s \quad \text{Against } H_1^\omega = S\omega_*(\tau) \neq s \\ H_0^\lambda &= S\lambda_*(\tau) = s \quad \text{Against } H_1^\lambda = S\lambda_*(\tau) \neq s \\ H_0^\theta &= S\theta_*(\tau) = s \quad \text{Against } H_1^\theta = S\theta_*(\tau) \neq s \end{aligned}$$

Referring to the above hypothesis illustrations, the pre-defined matrices, i.e. F and f, are  $h^*p_s$  and  $h^*1$ . Furthermore, S and s are also alike:  $h^*s$  and  $h^*1$  where the constraints and restrictions are reflected by  $h$  (Cho et al., 2015). Moreover, the predictor variables are reflected by  $i$ , which are F&D, EEF, and GDP. In addition to this, the application of the Wald test is made with an objective to ascertain the relationships



which are non-linear and are in alignment with the level of adjustment incurred by the parameter while computing the integration for the long-run. Furthermore, four different kinds of tests are accordingly applied for parameters individually and the group as a whole.

### 3. Estimations and results

At the initial stage, the descriptive statistics of the data were evaluated, reflecting the overall quality attributes of the dataset. After the evaluation of descriptive statistics, the average value of GIN was estimated at 1.201, while having the lowest value of 0.105 and highest value of 1.310, respectively. In contrast, the deviation from the mean was estimated at 1.044. Moreover, the average value of F&D was estimated at 0.202, while having the lowest value of 0.687 and highest value of 1.542, respectively, whereas the deviation from the mean was estimated at 0.025. Furthermore, the average value of EEF was estimated at 2.891 while having the lowest value of 1.284 and highest value of 3.881, respectively, whereas the deviation from the mean was estimated at 1.054. Lastly, the average value of GDP was estimated at 0.562, while having the lowest value of 0.010 and highest value of 1.010, respectively, whereas the deviation from the mean was estimated at 0.015. In addition to this, the normality of the dataset was evaluated by the application of Jarque-Bera (J-B) Stats. The hypothesis statements of this test reflect that the acceptance of the null hypothesis reflects the absence of the normality in the dataset variable-wise. In contrast, the acceptance of the alternative hypothesis reflects the presence of normality in the dataset variable-wise. The application revealed the presence of the normality for all of the studied variables at a 1% level of significance (Shahbaz et al., 2018; Sharif et al., 2019). The summarised outcome of the descriptive statistics and J-B Stats are shown in Table 1.

After the assessment of descriptive analysis, in the later stage, the level of integration, its respective significance, and their respective order was assessed in the later stage, which is essential to be assessed before applying QARDL. Therefore, the application of two-unit root tests is made, namely ‘Augmented Dickey-Fuller (ADF)’ as well as a test of (Zivot & Andrews, 2002) (ZA) was applied. These two tests have also been applied in different other related studies (Godil et al., 2020). Moreover, capturing structural breaks is the differentiating quality attribute that makes the test superior to other kinds of tests applied for a similar objective. Referring to Table 2, the summarized outcome reflects the absence of unit root issues as all of the variables are found stationary at a 1% level of significance. In addition to this, the test by ZA has also captured the structural breaks, which are also shown in Table 2. The clearance from the possibility of the presence of unit root issues paves the way for the

**Table 1.** Results of descriptive statistics.

Variables	Mean	Min.	Max.	Std. Dev.	J-B Stats
GIN	1.201	0.105	1.310	1.044	27.009***
F&D	0.202	0.687	1.542	0.025	32.020***
EEF	2.891	1.281	3.881	1.054	19.015***
GDP	0.562	0.010	1.010	0.015	25.021***

Note: The asterisk \*\*\*, \*\* and \* represent the level of significance at 1%, 5%, and 10% respectively.

Source: Author's estimation.

**Table 2.** Results of Unit root test.

Variables	ADF (Level)	ADF ( $\Delta$ )	ZA (Level)	Break Year	ZA ( $\Delta$ )	Break Year
GIN	-0.046	-3.021***	-1.001	2003 Q2	-7.009***	2017 Q1
F&D	-1.173	-5.010***	-2.009	2013 Q1	-9.010***	2010 Q1
EEF	-0.062	-3.023***	-1.017	2008 Q4	-6.100***	2016 Q1
GDP	-2.084	-6.012***	-3.013	2017 Q1	-8.019***	2006 Q4

Note: The values in the table specify statistical values of the ADF and ZA test. The asterisk \*\*\*, \*\* and \* represent the level of significance at 1%, 5%, and 10% respectively.

Source: Author Estimation.

application of QARDL as the dataset possesses sufficient quality attributes. Though the application of QARDL is also capable to generate robust outcomes even with the presence of trends which could be dynamic and multiple, structural breaks, and non-normality, however assessing them is always good for having the least biased and contaminated outcome (Aziz, Mihardjo, et al., 2020; Aziz, Sharif, et al., 2020). The summarized outcome of the unit root tests, structural breaks, and their respective values are shown in Table 2.

After establishing the legitimacy and reliability of the data, the application of QARDL is finally made to explain the effects of predictor variables in the current research are F&D, EEF, and GDP, on the different quantiles of the criterion variable the current research is GIN. Considering the evaluation of the effects of F&D on the quantile of GIN, in the long-run, the nature of the relationship and its strength was reported similar across all of the quantile, however in terms of its significance though it was reported to be significant across all of the quantiles as it, intensity significance improves from lower to the upper level of quantiles. In other words, at lower quantiles, it was significant at a 10% level of significance. It was significant at a 5% significance level for middle quantiles, and for a higher level of quantiles, it was significant at a 1% significance level. These results highlighted the role and the respective significance of the F&D in improving the GIN.

Considering the relationship between EEF and GNI, the nature of the effects of the EEF on the quantiles of GIN remains the same, which is positive throughout all of the quantiles. However, its strength and significance change as there is an increase in the level of the quantiles. Based on the results computed, at the lower and middle quantiles of GNI, the EEF has positive but insignificant relationships. However, for the higher quantiles, it becomes significant at 10% significance level and then 5% level of significance.

As the current research is also assessing the relevance and appropriateness of the Environment Kuznets Curve (EKC), therefore GDP and its square were also included in the estimations of QARDL. Considering the relationship with GDP with the quantiles of EEF, the nature and strengths of the relationships were reported to be positive throughout the quantiles of GNI. However, in terms of significance, the relationship was insignificant at the lower quantiles, whereas it becomes significant for the middle and upper quantiles. The complete results of the QARDL in the longer period of time among the studied variables are shown in Table 3.

Considering the relationships among the studied variables in the shorter period of time, the nature of the relationships in terms of positive and negative are reported to be the same as found in the outcome of the long-run. In terms of strength, all of the

**Table 3.** Results of Quantile Autoregressive Distributed Lag (QARDL).

Quantiles ( $\tau$ )	Constant		Long-Run Estimation				Short-Run Estimation				
	$\alpha_*(\tau)$	$\rho_*(\tau)$	$\beta_{F\&D}(\tau)$	$\beta_{EEF}(\tau)$	$\beta_{GDP}(\tau)$	$\beta_{GDP2}(\tau)$	$\varphi_1(\tau)$	$\omega_0(\tau)$	$\lambda_0(\tau)$	$\theta_0(\tau)$	$\hat{\epsilon}_0(\tau)$
<b>0.05</b>	0.021 (0.505)	-0.137 (-0.753)	0.230* (1.646)	0.111 (0.810)	0.150 (1.634)	-0.025 (-0.655)	0.408*** (2.992)	0.021** (2.326)	0.023** (2.315)	0.005 (0.662)	-0.025 (-0.033)
<b>0.10</b>	0.012 (0.609)	-0.110 (-0.612)	0.244* (1.853)	0.112 (0.508)	0.161 (1.628)	-0.015 (-0.541)	0.399*** (3.002)	0.030** (2.320)	0.020** (2.422)	0.023 (1.566)	-0.017 (-0.029)
<b>0.20</b>	0.018 (0.654)	-0.108 (-1.619)	0.231* (1.800)	0.107 (0.311)	0.145 (1.638)	-0.011 (-0.733)	0.418** (2.880)	0.060** (1.992)	0.014 (1.516)	0.037* (1.649)	-0.012 (-0.008)
<b>0.30</b>	0.025 (0.957)	-0.126 (-1.515)	0.265** (1.994)	0.113 (0.409)	0.167* (1.648)	-0.018 (-1.240)	0.429** (1.972)	0.042** (1.963)	0.029 (1.219)	0.021* (1.810)	-0.022 (-0.021)
<b>0.40</b>	0.019 (1.610)	-0.103 (-1.545)	0.242** (2.192)	0.115 (1.212)	0.156* (1.766)	-0.028 (-0.949)	0.400* (1.754)	0.051* (1.867)	0.040 (0.813)	0.041* (1.746)	-0.008 (-0.047)
<b>0.50</b>	0.007 (1.201)	-0.114* (-1.735)	0.224** (2.398)	0.136 (0.405)	0.139** (1.983)	-0.024 (-1.548)	0.410* (1.819)	0.019 (1.553)	0.021 (1.528)	0.021* (1.692)	-0.018 (-0.036)
<b>0.60</b>	0.017 (1.302)	-0.124*** (-3.552)	0.236** (2.794)	0.185 (1.307)	0.159** (1.994)	-0.029* (-1.728)	0.402** (2.651)	0.043 (0.974)	0.045 (1.414)	0.042** (1.969)	-0.021 (-0.018)
<b>0.70</b>	0.010 (1.613)	-0.112*** (-3.759)	0.241*** (2.994)	0.216* (1.813)	0.151*** (2.994)	-0.017** (-2.031)	0.428** (2.483)	0.067 (0.563)	0.030 (1.634)	0.034** (1.994)	-0.016 (-0.009)
<b>0.80</b>	0.016* (1.705)	-0.130*** (-4.448)	0.256*** (3.002)	0.210* (1.854)	0.165*** (3.004)	-0.029** (-2.316)	0.439** (2.522)	0.031 (1.030)	0.051* (1.826)	0.027** (1.990)	-0.009 (-0.016)
<b>0.90</b>	0.011* (1.808)	-0.123*** (-3.556)	0.250*** (2.995)	0.214** (2.206)	0.157*** (2.995)	-0.033** (-2.823)	0.425** (2.614)	0.049 (0.421)	0.039** (2.437)	0.018** (1.980)	-0.014 (-0.001)
<b>0.95</b>	0.022* (1.756)	-0.156*** (-3.221)	0.261*** (3.003)	0.208** (2.315)	0.169*** (3.003)	-0.023** (-2.613)	0.434** (2.541)	0.034 (0.140)	0.060** (2.725)	0.022** (1.997)	-0.007 (-0.005)

Note: The table reports the quantile estimation results. The t-statistics are between brackets. \*\*\*, \*\* and \* indicate significance at the 1%, 5% and 10% levels, respectively.

Source: Author's estimation.

coefficients are comparatively lower than the outcome generated in the long-run because these outcomes are generated for a shorter period of time. However, there is a difference in terms of significance in all of the studied variables and their respective relationships. For F&D, the relationship is significant in lower quantiles and becomes insignificant in the middle and higher quantiles. For EEF, the relationship was significant at lower quantiles, insignificant in middle quantiles, and significant in higher quantiles in a shorter period of time. In terms of outcome generated for evaluating the relevancy and appropriateness of the EKC curve, the results computed neglected the idea of having the EKC in a shorter period of time. The complete results of the QARDL in the shorter period of time among the studied variables are shown in Table 3.

After the estimations of the QARDL, the Wald Test's application is made to assess the existence of asymmetries in the focussed variables of the present study. Despite the fact that outcome generated nullify the probability of having any particular distributional relationship, of which the nature could be asymptotic, however, by the Wald Test's help, the presence of uncertainties (if any) are also explained at both levels, including intercepts and the coefficients. In addition to this, this test can also identify the probability of alteration in the nature of structural breaks irrespective of the sufficiency of the magnitude of being recognised or not (Godil et al., 2020). The application of the Wald Test and its respective outcome revealed the presence of symmetries for both longer and shorter periods of time, accordingly computed for all of the focussed variables. The complete results of the Wald Tests are shown in Table 4.

In the last step, the nature of the causality between predictors and the criterion variable was assessed with the help of Granger Causality tests. Since the current study

**Table 4.** Results of the Wald test for the constancy of parameters.

Variables	Wald-statistics
$\rho$	18.681*** [0.000]
$\beta_{F\&D}$	9.657*** [0.000]
$\beta_{EEF}$	64.547*** [0.000]
$\beta_{GDP}$	8.693** [0.000]
$\beta_{GDP^2}$	1.199 [0.166]
$\varphi_1$	8.612*** [0.000]
$\omega_0$	24.642*** [0.000]
$\lambda_0$	6.658*** [0.000]
$\theta_0$	3.565*** [0.000]
$\dot{\epsilon}_0$	0.219 [0.999]

The  $p$ -values are between square brackets. \*\*\*, \*\* and \* indicate significance at the 1%, 5% and 10% levels, respectively.

Source: Author Estimations.

is based on evaluating the effects of the criterion variable's quantiles, a similar understanding was assessed on the quantiles level. The direction from all of the predictors leading the criterion is already established from the findings of the QARDL. Through this test, the presence of causality from criterion to predictors was also assessed. The generated outcome reported bi-directional causalities among all of the focussed relationships. Precisely, focussing on the causality from GIN to F&D, it is obvious as with the help of GIN, the overall quality of F&D will eventually be improved and increased as it helps the F&D to optimise the resources consumption and strengthen their operational excellence.

Similarly, focussing on the causality from GIN to EEF, it is obvious as with the help of GIN, the overall quality of EEF will eventually be improved and increased as it helps the EEF to optimise and enhance the overall productivity of EEF. Similar findings were also reported in terms of Causality from GIN to GDP and from GIN to square of GDP, which highlights the importance of GIN for economic development and prosperity. The complete results of the tests are shown in [Table 5](#).

### 3.1. Discussion

In accordance with the previous discussion, there are two kinds of roles that F&D plays in the fostering of GIN. Firstly, by improving its operational excellence level, this industry needs to improve its productivity and efficiency level in terms of the consumption of resources. The second aspect of this industry is the actual face and mouth of the creation and setting of the norms as through this industry, and the overall narrative building is made and by this power and capability, the nationwide shaping of the culture, values, and principles are outlined sketched and drawn. Therefore, based on the findings, this country could also help nurture the GIN not

**Table 5.** Granger causality in quantile test results.

Quantiles	$\Delta \text{GIN}_t$	$\Delta \text{F\&D}_t$	$\Delta \text{GIN}_t$	$\Delta \text{EEF}_t$	$\Delta \text{GIN}_t$	$\Delta \text{GDP}_t$	$\Delta \text{GIN}_t$	$\Delta \text{GDP}^2_t$
	$\Delta \text{F\&D}_t$	$\Delta \text{GIN}_t$	$\Delta \text{EEF}_t$	$\Delta \text{GIN}_t$	$\Delta \text{GDP}_t$	$\Delta \text{GIN}_t$	$\Delta \text{GDP}^2_t$	$\Delta \text{GIN}_t$
[0.05-0.95]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.05	0.000	0.000	0.000	0.000	0.010	0.000	0.000	0.000
0.1	0.000	0.000	0.000	0.000	0.012	0.000	0.000	0.000
0.2	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000
0.3	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000
0.4	0.000	0.000	0.000	0.000	0.013	0.000	0.000	0.000
0.5	0.000	0.000	0.000	0.000	0.017	0.000	0.000	0.000
0.6	0.000	0.000	0.000	0.000	0.014	0.000	0.000	0.000
0.7	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000
0.8	0.000	0.000	0.000	0.000	0.015	0.000	0.000	0.000
0.9	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000
0.95	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Source: Authors Estimation.

within themselves but by creating awareness, educating, cultivating, and teaching knowledge to the general public through their content, documentaries, promotional campaigns, short films, etc. Considering the relationship of EEF, the generated outcome means that in the long-run, there is a need to have a higher level of EEF in order to have GIN; otherwise, the EEF could be playing a role but will not have a sufficient and materialist outcome. In other words, in order to have sufficient GIN, the level of EEF needs to be enhanced, which makes the EEF qualified for improving GIN.

Furthermore, based on the outcome related to the associations of GDP and its square, it means that when there is a higher level of GDP, there will be a higher focus towards GNI, the economy will move towards GNI. On the other hand, considering the relationship of the square of GDP with the quantiles of EEF, the relationships' nature and strengths were reported to be negative throughout the quantiles of GNI. However, in terms of significance, the relationship was insignificant at the lower quantiles, whereas it becomes significant for the middle-upper and upper quantiles. In the long-run, it means that there will be a decline in the level of GNI as long as there is a progression in the level of square GDP. BY considering the relationships of both GDP and its square with the quantiles of GNI in the theoretical foundations of EKC, the overall results mean that with the improvement and progression in the level of GDP, the economy will tend to have a higher level of GIN and it will accordingly strive, accept, invest and acknowledge the role of GNI, however after reaching to a certain point, there will be a decline in the relationship, which further shows a point to ponder for the strategist to restructure and accordingly improve the level of GNI. Hence based on the findings, the relevance and appropriateness of EKC are also validated through the findings of the results of the present study.

While discussing the relationships in the short-run, for F&D, the relationship is significant in lower quantiles and becomes insignificant in the middle and higher quantiles. This relationship identifies a deficit in the relationship in terms of significance as in transitioning the environment from shorter to longer, and the relationship is insignificant. Moreover, for EEF, the reason for having insignificant in the middle quantiles could be the transitioning and expecting outcome from the strategies put at the lower quantiles that are revisited in the middle quantiles and tend to get quality output in the higher quantiles.

## 4. Conclusion and recommendations

### 4.1. Conclusion

According to environmental scientists, negligence in handling the environment is extremely detrimental as it alters the other natural process like rainfall, frequency of storms and droughts, etc., and could be far dangerous and destructive in terms of their scale and magnitude for the mitigation of global warming and promoting a culture to have acceptance towards GIN so that pollution alleviation and environment preservation are ensured. The popularity of Green Innovation (GIN) has dramatically increased in recent times because of the potential benefits attached with it. Conventionally, it is assumed that environmentally friendly technology is comparatively dearer, especially for developing countries; however, such technologies do have future sustainable benefits. In order to make the technology affordable, GIN is the key that can enhance the affordability in terms of costs and finances. On the other hand, for environment safeguarding, the role of media is of fundamental importance. In addition to being the consumer of the resources, F&D also helps in drawing and outlining the norms related to environmental protection.

Though as the consumer, there are several kinds of unsustainable practices incurred by the F&D that somehow are getting unnoticed. This includes abusing natural resources for their content development, excessive production of clothes, overconsumption of energy, and excessive incurring the non-recyclable decoration in the set and location designs. However, on the other side, there are also certain examples from this sector in which sustainable measures were taken to reduce the footprints and optimise the resources. On the other hand, energy consumption is often regarded as an indicator of economic prosperity at the cost of the environment. However, there is a need to have investments in improving and advancing the quality of the technology for the purpose of energy efficiency. Hence, the present study attempts to explore the asymmetric effect of F&D, EEF, and economic growth (GDP) on GIN with the help of the latest QARDL.

Considering the evaluation of the effects of F&D on the quantile of GIN, in the long-run, the nature of the relationship and its strength was reported similar across all of the quantile, however in terms of its significance though it reported being significant across all of the quantiles as its intensity significance improves from lower to the upper level of quantiles. Considering the relationship between EEF and GNI, the nature of the effects of the EEF on the quantiles of GIN remains the same, which is positive throughout all of the quantiles. However, its strength and significance change as there is an increase in the level of the quantiles. Based on the results computed, at the lower and middle quantiles of GNI, the EEF has positive but insignificant relationships. However, for the higher quantiles, it becomes significant. In addition to this, the relevance and appropriateness of EKC are also validated through the findings of the results of the present study.

### 4.2. Policy recommendations

Based on the findings, it is recommended that the utilisation of F&D should be made efficiently as it is the face, mouth, and word of society. Precisely, there is a need to

have content that promotes the GIN by sharing the best practices being used in the industries. By that, the industry lacking can learn from the best practices of the industry's leading in terms of GIN. Moreover, for individual levels, the content that nurtures the knowledge and understandings of the GIN needs to be made. For EEF, there is a need to have a culture of innovation, research, and development to curtail environmental pollution. In contrast, there is a need to develop indexes and matrices through which the environment-related accountability is ensured, reported, and accordingly communicated to the stakeholders.

### **4.3. Limitations**

The current study has certain limitations. Firstly, the current study is focussed on explaining only two determinants through which the GIN can be efficiently be achieved, which are F&D and EFF. Secondly, the dataset of the current study is a time-series, which ignores the cross-sectional comparisons which are possible in the panel studies. Thirdly, the time frame of the data set will remain a huge limitation in the time-series studies, as we are limited to generating limited projections for possible future events. Lastly, the application of the Quantile-based technique itself is the limitation, in which the average value of the predictors is linked with the quantiles of the criterion variable.

### **4.4. Directions for future research**

Based on the limitations, there is a need to explore further determinants of GIN so that its enablers for implementation and adaptation are identified, and barriers and hindrances can be removed. Moreover, the results' robustness also needs to be re-checked through other econometric techniques like BARDL, CS-ARDL, and NARDL. Lastly, more insights of the estimations can be extracted by applying Quantile on Quantile Regression, in which the linkage is developed between the quantiles of predictors with the quantiles of the criterion variable.

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