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RESEARCH ARTICLE

The nexus between energy consumption, carbon dioxide emission and technological innovation in the Global panel: Evidence from Panel quantile regression

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Abstract
Expanding the capability of technological innovations is curial in acquiring renewable energy sources, enhancing the efficiency of energy and lowering carbon dioxide emissions which can leads to environmental sustainability however the factors effecting the level of technological innovations needs to be explored. Consequently, this study explores the effect of carbon dioxide emission, energy consumption and foreign direct investment on technological innovations in 179 global countries from 1980 to 2019. The results indicate that foreign direct investment significantly and negatively affect technological innovations proxy by patent nonresidents in the lower quantiles while this effect is negative and insignificant at the highest quantiles. Carbon dioxide emission and financial development significantly and positively effect technological innovations proxy by patent nonresidents while energy consumption and trade significantly decrease technological innovations. In case of dependent variable research and development, the effect of foreign direct investment on technological innovations and international trade is negative while financial development and energy consumption positively and significantly affect technological innovations. The effect of financial development is negative significant and negative insignificant across quantile while the highest quantile gives positive coefficient thus shows that its increase technological innovations proxy by research and development. The findings have considerable policy implications for the sample countries regarding economic growth, foreign direct investment inflow, energy consumption and technological innovations.

Keywords: Technological innovations; carbon dioxide emission; energy consumption; economic growth; foreign direct investment

Introduction

Rising the capability of technological innovations in today's modern era is considered important to enhance energy efficiency, acquire renewable energy sources, lower carbon dioxide emissions and achieve long term economic growth. Theoretical literature shows that innovations enhance economic growth (Aghion & Howitt, 1990), and it's also indicated by empirical studies such as (Fagerberg, Srholec, & Knell, 2007). Due to the importance of innovations in economic growth, researchers have focused to investigate the determinants of innovations which indicate that an increase in research and development cannot be the only source to enhance technological innovation while technology transfer and spillovers, international trade, education, institutions and foreign direct investment (Chunying, 2011); (Varsakelis, 2006); (Furman, Porter, & Stern, 2002). (Yang & Qi, 2001) and (Haddad & Harrison, 1993) argues that there is no association between foreign direct investment and technology innovations. However, several others argue that technological innovation negatively affects foreign direct investment when it is below the level threshold while positive when it is above the threshold level (Loukil, 2016). The empirical literature has not considered carbon emission and energy consumption in such a case however, it is commonly believed that technological innovation affects energy consumption, economic growth, foreign direct investment and

environmental quality. Such investigation has not been done which investigated the effect of carbon dioxide, energy and foreign direct investment on technological innovation. Both foreign direct investment and technological innovations are linked such as innovation facilitates foreign direct investment while foreign direct investment brings new management skills, new technology and capital that affect the level of innovation. Energy is used for production and other economic activities such as foreign direct investment which in turn boosts economic growth thus a rise in the use of energy, foreign direct investment and economic growth increase carbon dioxide emission. However, this effect can be varied in different countries due to different environmental regulations, the level of energy use and foreign direct investment. Innovations are required in these activities such as a rise in innovation level facilitated foreign direct investment, raising energy efficiency and increasing economic growth while these factors in turn influence technological innovations. Consequently, it is important to study the effect of foreign direct investment, carbon emission and economic growth on technological innovation. Based on the above discussion and statements, we believe that such a complex study has not been done in prevailing literature however, some studies have only considered the effect of foreign direct investment or economic growth on technological innovations. Likewise, commonly used proxies of innovations such as patent application residents or high technology export are used however this study used four indicators to proxy for technological innovations. Similarly, carbon dioxide, energy consumption, and foreign direct investment have not been taken in the same study to examine their impact on technological innovation as these factors are very important to each other. By considering all these factors this study, it will deeply examine the effect of these variables on each indicator of technological innovations which has not been attempted before. Consequently, this study examines the effect of carbon dioxide, energy consumption and foreign direct investment on technological innovation indicators by considering other most important factors in a sample of 179 global countries. Panel quantile regression were used to investigate the effect of variables on technological innovations across different quantiles and achieve efficient results. The results indicate that foreign direct investment significantly and negatively affect technological innovations proxy by patent nonresidents in the lower quantiles while this effect is negative insignificant at the highest. Carbon dioxide emission and financial development significantly and positively effect technological innovations proxy by patent nonresidents while energy consumption and trade significantly decrease technological innovations. In case of dependent variable research and development, the effect of foreign direct investment on technological innovations and international trade is negative while financial development and energy consumption positively and significantly affect technological innovations proxy by research and development. The effect of financial development is negative significant and negative insignificant across quantile while the highest quantile gives positive coefficient thus shows that its increase technological innovations proxy by research and development. Such analysis in the previous studies has not been done while our findings are very beneficial for the sample countries regarding technology, innovation, enhancing economic growth and environmental policies as well foreign direct investment attraction.

The remaining parts of the study are structured as follows; section 2 is composed of a literature review, part 3 present the variables and methods, section 4 presents discussions and results while section 5 gives recommendation, suggestions and conclude the study.

Literature review

Several factors such as energy consumption, economic growth, foreign direct investment and international trade affect technological innovations. In preceding literature, a large number of researchers explore the effect of technological innovations, foreign direct investment, energy consumption and related factors on carbon emission however the effect of these factors on technological innovation is limited. Even in some studies conducted in the preceding literature on the impact of these factors on innovation or technology but with little accord such as the previous studies have used some commonly used indicators of innovation or have to find the effect of single factor on innovation such as foreign direct investment. For example, a study conducted by (Adikari, Liu, & Marasinghe, 2021) examine the relationship between foreign direct investment and innovation in Sri Lanka for the period 1990 to 2019 using the ARDL model. The authors illustrate that there was a negative effect of foreign direct investment on innovations however education and research and development were positive. The authors claim that research and development are vital factors that effectively explain technological innovation. A similar study on the effect of foreign direct investment on technological innovation in Chinese provincial data from 2009 to 2018 is conducted by (W. Li, 2021). The authors used a threshold regression model where the results show that regional innovation capability intellectual property intensity is significantly affected by foreign direct investment. They further indicate that foreign direct investment maximizes regional innovations capability when the intellectual property protection intensity is maintained near the level threshold. Likewise, another study also considered the effect of foreign direct investment on innovation. (Loukil, 2016) studied the developing countries' foreign direct investment and innovations from 1980 to 2009. The study also uses the threshold model and found that foreign direct investment has a negative effect on innovation below the threshold while positive when the value is above the threshold value. They indicate that such a level of innovation is not enough for economic policy to

attract foreign direct investment. (Wang, Liu, & Wang, 2021) studied the technological innovation effect in China enterprises produced by Foreign direct investment from 2015 to 2017. They found that improvement in Foreign direct investment activities in Chinese enterprises promotes the level of technological innovations. They further indicate that the research and development-related activities of Foreign direct investment perform a very active role in promoting the enterprises' technological innovation ability. Similarly, (Chunying, 2011) investigated the technological from and foreign direct investment nexus in China from 1987 to 2009 by using the quantile regression method. The results of their study show that foreign direct investment positively affects technological innovation in China at the bottom distribution while this effect was found negative at the top conditional distribution. They further indicate the low-level effect of foreign direct investment on only low-level innovations while the negative role of foreign direct investment on high-level technological innovation. In the case of developing and emerging countries, financial development has also been considered as (Loukil, 2020) examined the financial development effect on innovation in developing and emerging countries from 1980 to 2009. The author found that there is a nonlinear effect between innovation and financial development. They found that there is a threshold value of economic growth below, the effect of financial development on innovation was insignificant, while the effect is positive of financial development on economic growth above the threshold value. Their findings suggest that financial institutions can promote innovations in presence of healthy economic development. Likewise, economic growth has also been added to such associations as (Pala, 2019) studied economic growth and technological innovation in 25 developing countries and employed a random coefficient model to the data for analysis. The authors found that economic growth is affected negatively by research and development in some of the sample countries while positive in a group of some countries. On the other hand, several studies indicate that there is an association between carbon dioxide, foreign direct investment, economic growth and technological innovation as a study on the linkage between foreign direct investment, technological innovation and economic growth is conducted by(Sheng Yin & Hussain, 2021). The study findings reveal that these indicators positively affect economic growth and foreign direct investment. They also argue that economic growth, foreign direct investment and tourism were also the positive factors contributing to the ecological footprint. They further confirm the two-way casual association between tourism and ecological footprint, technological innovation and ecological footprint, and a one-way casual association between technological innovation, foreign direct investment inflow, and tourism. A similar study is conducted by (Sheng, Miao, Song, & Shen, 2019) who examined the linkage between innovation, carbon emission, and urbanization in 48 cities in China from 2001 to 2015 using a spatial econometric model. They found a U-shaped and N-shaped curve across different cities and found that innovation positively affects the carbon dioxide reduction in some of the cities while this effect is insignificant in some of the sample cities however they confirm that innovation play moderating role between carbon emission and urbanization. Likewise, (Hu et al., 2021) studied the effect of innovation and economic openness on the environment for the period 1990 to 2014 in Asian countries. By using dynamic and fully modified OLS estimators, the authors found that energy consumption and trade openness increase the level of emission while GDP, foreign direct investment, and patents depress carbon dioxide emission in Asian countries. Likewise, different proxies for innovation have been used and found its impact on economic growth as (Pece, Simona, & Salisteanu, 2015) studied the long-term effect of innovation on economic growth. They used multiple regression models and investigated such associations in CEE countries. The authors found that innovation and economic growth were positively linked. The effect of technology innovation on carbon emission was also studied by (R. Li, Lin, Jiang, Liu, & Lee, 2021) in 66 countries considering economic development in this association. The authors show that the relationship between technological innovations and carbon dioxide was U-shaped and this relationship was positively and negatively affected by economic development cases when economic growth crosses the threshold level. The authors found both N and U-shape correction in the sample of OECD and High-income countries and argue that technological innovations and advancement have a dynamic influence on carbon emission in a different sample of countries. (Uddin, Pan, Saima, & Zhang, 2021) considered the changes in socio-economic factors and examine the effect of energy intensity and technological innovations in 23 countries of Europe. By using threshold regression, the authors found that both stock and banks affect energy intensity and rely on the level of technological innovations.

Methodology

Using panel data set of 179 world countries, this study explores the effect of carbon dioxide and energy consumption and technological innovations from 1980 to 2019. Data for the study variables were collected from the world bank development indicator. The baseline model is as follows;

$$TIN_{it} = \beta_0 + \beta_1 TIN_{it-1} + \beta_2 FDI_{it} + \beta_3 CO2_{it} + \beta_4 GDPC_{it} + \beta_5 FND_{it} + \beta_6 ENR_{it} + \beta_7 TO_{it} + \varepsilon_{it} \quad (1)$$

TIN represent technological innovations which is the dependent variable. Research and development and patent application nonrodents were used to as a proxy for

technological innovations. Patent application nonresidents is measured as (number per thousand population) (Qamruzzaman, Tayachi, Mehta, & Ali, 2021). Likewise, research and development expenditure is measured as (percentage of real gross domestic product) (Coluccia, Dabić, Del Giudice, Fontana, & Solimene, 2020); (Knott & Vieregger, 2018) ; (Chunying, 2011; Maradana et al., 2017). Descriptive statistics and variables are shown in Table 1 while the correlation matrix is given in Table 2.

FDI represent the inflow of foreign direct investment taken as a percent of GDP. Its been debated by large number of researcher's that the inflow of foreign direct investment effect the level of technological innovations of a country. GDP is per capita gross domestic product used to represent economic growth and CO2 is carbon dioxide emission (metric tons per capita). Economic growth has been stated by several researchers that a rise in economic growth increases carbon dioxide emission and lower environmental quality such as (Gorus & Aslan, 2019) and this positive effect of economic growth on carbon emission in the reason of high amount of energy use (Aust, Morais, & Pinto, 2020). Likewise, a rise in economic growth effect technological innovations. FND is financial development proxy by domestic credit to the private sector by the bank as % of GDP. Financial development can rise technological innovations of a countries and contribute to sustainable development. ENR is energy consumption taken as total final energy consumption. Energy consumption effect both technological innovations and effect carbon dioxide emission. It's been argued that improved level of technology innovation increases energy efficiency which is beneficial for environmental quality. It's also acquired renewable energy which is environmentally friendly. However, advance technology and innovation are required to rise the energy efficiency and obtain renewable energy sources. Renewable energy is considered beneficial for environmental quality to be used as substitute for energy from nonrenewable energy sources Khan et al (2021). Likewise, TO represents international trade where an increase or decrease in international trade effect technological innovations and its also linked with economic growth and sustainable development.

For analysis purpose, this study employed quantile regression to evaluate the concomitant relationship in the conditional distribution. (Balsvik & Haller, 2011) also used quantile regression to investigate the effect of foreign direct investment on innovation. The choice of quantile regression methods is also inspired by existing non-contemporary and contemporary studies that show the importance of using empirical strategies to clarify countries with different levels of outcome variables (Roger Koenker & Gilbert Bassett Jr, 1978); (Tchamyou & Asongu, 2017). Compared with alternative techniques based on the average of outcome variables, these studies acknowledge that the methods are also consistent in their robustness in providing conditional survey results. These alternative methods provide survey results with comprehensive policy implications (Koenker & Ng, 2005); (Okada & Samreth, 2012); (Hao & Naiman, 2007); (Asongu & Odhiambo, 2019). Using traditional regression methods may result in overestimation or underestimation of correlation coefficients, or may fail to successfully detect important relationships because these techniques focus on average effects (Binder & Coad, 2011). Panel quantile regression was introduced by (R Koenker & G Bassett Jr, 1978) in their seminal work. Quantile regression in redistribution is more robust, but it cannot deal with heterogeneity that is not observed in a country. Therefore, the current paper uses panel quantile fixed effects to examine conditional heterogeneity and unobserved individual heterogeneity. (Lamarche, 2010) and (Galvao Jr, 2011) have considered econometric theory to apply quantitative regression to panel data. The generalized form of the median regression analysis for other quantiles can be expressed in the following form in equation 2, while the fixed effect panel quantile regression can be explained as in equation 3;

$$Q_{yi}(\tau \mid x_i) = x_i^T{}_{\beta_\tau} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

$$Q_{yi}(\tau_k \mid \alpha_i x_{it}) = \alpha_i + x'_{it}(\tau_k) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

There is a major problem with fixed-effect panel quantile regression. The existence of a large number of fixed-effects is due to incidental parameter problems (Lancaster, 2000); (Neyman & Scott, 1948). When individuals tend to infinity, there will be inconsistencies, but each cross-section has a fixed observation value. The purpose of the fixed effect is to eliminate the unobserved effects of the fixed effect. These methods are expected to be linear and its not the reason of conditional quantiles (Canay, 2011). In order to overcome with these problems, (Koenker, 2004) proposed a method which deals with the unobserved fixed effects. The author fixes this with parameters and estimates them collectively with the covariate effects of different quantiles. Penalty term is used in this problem of calculation is minimized of estimated parameter. The calculation meted of parameter estimation is as follows;

$$\min_{(\alpha,\beta)} \sum_{k=1}^{K} \sum_{t=1}^{T} \sum_{i=1}^{N} w_k P_{\tau k}\left(y_{it} - \alpha_i - x_{it}^T \beta(\tau_k)\right) + \lambda \sum_{I}^{N} \mid \alpha_I \mid, \dots\dots\dots (4)$$

In the given equation, the country (N) index is represented by I where T, *K* represent the number of country observation in the quantile index. Likewise, x represents the explanatory variables matrix and P_{tk} is the quantile of the loss function. W_k given in the equation is the *k-th*, the weight of the quantile is used to control the contribution of the *k-th*

quantile to the fixed effect estimate. Equal weight quantile in this research is focused which is given by (Alexander, Harding, & Lamarche, 2011). In addition, λ represents the tuning parameter which is used to improve the β estimation and reduce individual effects to zero. When λ becomes zero, the penalty term will disappear, and then the usual fixed effect estimator can be obtained. However, if the λ term tends to infinity, we will get model estimates without individual influence. The current paper λ has been set equal to 1 (Damette & Delacote, 2012). The specification of the τ quantile function of the baseline model variables in the current research can be as follows:

$$Q_{yi}(\tau \mid \alpha_i, \xi_t, x_{it}) = \alpha_i + \xi_t + \beta_{i\tau} RD_{it} + \beta_{2\tau} FDI_{it} + \beta_{3\tau} CO2_{it} + \beta_{4\tau} GDP_{it} + \beta_{5\tau} FND_{it} + \beta_{6\tau} ENR_{it} + \beta_{7\tau} TO_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where *i* represent countries, time is t, y_{it} is the indicator TIN, the description of all other symbols is given above.

Table.1. Descriptive statistics

Variable	Description	Mean	Std. Dev	Min	Max
DI	Foreign direct investment	5.095	38.537	-1275.19	1282.633
GDP	Economic growth	1.842	6.006	-64.992	140.367
PT2	Patent application nonresidents	4926.64	21020.49	1.000	336
RD	Research and development	0.938	0.946	0.005	4.952
CO2	Carbon dioxide emission	4.488	7.914	0.0001	266.483
FND	Financial development	38.904	35.27	0.001	304.575
ENR	Energy consumption	2404.708	2951.99	9.548	28902.85
TO	International trade	81.98762	49.836	0.02	437.326

Table.2. Correlation matrix

Variables	FDI	PT2	RD	CO2	GDP	FND	ENR	TO
FDI	1.0000							
PT2	-0.0567	1.0000						
RD	-0.0872	0.2916	1.0000					
CO2	0.0436	0.3236	0.4597	1.0000				
GDP	-0.0428	0.0409	-0.1999	-0.1658	1.0000			
FND	0.2462	0.0258	0.5001	0.2897	-0.2730	1.0000		
ENR	-0.0040	0.1861	0.5044	0.6802	-0.1773	0.3545	1.0000	
TO	0.2693	-0.2099	0.0160	0.2649	0.0343	0.1268	0.1931	1.0000

Results and Discussions

This study uses panel quantile regression to examine the effect of the explanatory variables on each innovation indicator across different quantiles.

Table 3 presents the results of Quantile regression on the impact of explanatory variables on innovations (patent nonresidents) where the effect of foreign direct investment on patent applications nonresidents is negative significant from the 5th quantile to the 60th higher quantile while it becomes insignificant at the highest quantile from 70th to 95th quantile. The results are almost similar to the system GMM model however, the quantile regression results show that this effect becomes insignificant in the highest quantiles. The results indicate that foreign direct investment significantly reduces innovations in the first quantiles till 60th while this effect becomes insignificant when reaches the higher quantile after the 70th. The coefficients of carbon dioxide from the 5th quantile to the last quantile 95th are highly significant and positive which indicates that carbon dioxide emission significantly increases patent applications for nonresidents. The estimated coefficients of economic growth are insignificant in the first two quantiles while it's become positive and significant in the 20th and 30th quantiles while again becomes insignificant in the 40th and 50th quantiles. Again, the effect is positive and significant when reaches the 60th and 70th while in the highest quantiles the effect becomes insignificant.

The coefficient of financial development is positive and significant in all quantiles from the 5th to the 95th quantile which indicates that financial development significantly increases patent applications for nonresidents. The coefficient of energy consumption is negative significant mostly in all quantiles except 10th, and highest 80th, 90th while again it becomes negative significant at the highest quantile 95th. This result indicates that energy consumption significantly reduces patent applications' nonresidents. The effect of international trade in all quantiles is highly significant and negative which indicates that it significantly reduces patent applications for nonresidents.

Table 3: Results of Quantile regression

Dependent variable: Patent Nonresidents											
Variables	5th	10th	20th	30th	40th	50th	60th	70th	80th	90th	95th
FDI	-21.24***	-1.093***	-1.885***	-2.973***	-7.313*	-21.24***	-14.91**	-10.64	-12.59	-30.45	-26.43
	(6.962)	(0.361)	(0.528)	(1.071)	(4.085)	(6.962)	(6.150)	(10.41)	(29.75)	(62.52)	(96.14)
CO2	368.9***	7.247***	18.14***	35.10***	103.5***	368.9***	590.2***	763.4***	1,277***	3,523***	5,795***
	(42.69)	(2.214)	(3.237)	(6.568)	(25.05)	(42.69)	(37.71)	(63.83)	(182.4)	(383.4)	(589.5)
GDP	41.50	1.039	3.313*	7.586*	19.95	41.50	61.43***	87.92**	119.6	178.8	347.4
	(26.42)	(1.370)	(2.003)	(4.064)	(15.50)	(26.42)	(23.33)	(39.49)	(112.9)	(237.2)	(364.8)
FND	23.27***	0.534***	1.593***	3.481***	8.476***	23.27***	32.67***	44.75***	52.39***	49.16*	93.51**
	(3.015)	(0.156)	(0.229)	(0.464)	(1.769)	(3.015)	(2.663)	(4.508)	(12.88)	(27.07)	(41.63)
ENR	-0.305***	-0.00530	-0.0135**	-0.0295**	-0.0990*	-0.305***	-0.454***	-0.573***	-0.609	-1.288	-2.228*
	(0.0906)	(0.00470)	(0.00687)	(0.0139)	(0.0532)	(0.0906)	(0.0801)	(0.135)	(0.387)	(0.814)	(1.251)
TO	-17.24***	-0.802***	-1.694***	-3.163***	-6.607***	-17.24***	-22.96***	-28.01***	-33.39***	-61.37***	-111.0***
	(2.258)	(0.117)	(0.171)	(0.347)	(1.325)	(2.258)	(1.995)	(3.377)	(9.649)	(20.28)	(31.18)
Constant	606.4***	59.36***	122.5***	205.3***	334.7**	606.4***	705.1***	820.0**	1,007	2,994	6,206*
	(231.2)	(11.99)	(17.53)	(35.57)	(135.7)	(231.2)	(204.2)	(345.7)	(987.9)	(2,076)	(3,193)
Obs	2,339	2,339	2,339	2,339	2,339	2,339	2,339	2,339	2,339	2,339	2,339

Note. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 4 presents the results of Quantile regression on the impact of explanatory variables on research and development where the effect of foreign direct investment on research and development is negative significant which is almost similar to the impact of foreign direct investment on patent applications nonresidents however the coefficient is insignificant at the top highest quantiles 90th and 95th. The results are also similar to the dynamic model results given in the above tables. The results indicate that the inflow of foreign direct investment significantly reduces research and development in the 1st quantile while when it reaches the top, then exerts an insignificant impact on research and development. This means that foreign direct investment reduces innovation proxies by research and development. The coefficient of carbon dioxide is also negative mostly in all quantiles however the effect of carbon dioxide in the 5th quantile is insignificant and then it is negative significant at the 10th. Again from 20th to the 50th quantile the coefficients are insignificant and from 60th to the 80th are negative significant while at the top highest quantile, 95th, it becomes positive. The results indicate that carbon dioxide significantly reduces research and development until it reaches the highest quantile.

Table 4: Quantile regression

Dependent variable: research and development											
Variables	5th	10th	20th	30th	40th	50th	60th	70th	80th	90th	95th
FDI	-0.002***	-0.001	-0.003***	-0.003***	-0.004***	-0.002***	-0.001	-0.001*	-0.001*	-0.002	-0.003
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.002)
CO2	-0.0039	-0.039**	-0.001	-0.002	-2.050	-0.003	-0.041***	-0.079***	-0.081***	-0.005	0.066***
	(0.0070)	(0.006)	(0.009)	(0.005)	(0.005)	(0.007)	(0.009)	(0.006)	(0.007)	(0.0157)	(0.017)
GDP	0.0012	0.006	0.006	0.005	0.003	0.001	0.003	0.0040	-0.001	-0.008	-0.015
	(0.0053)	(0.004)	(0.007)	(0.004)	(0.003)	(0.005)	(0.007)	(0.005)	(0.006)	(0.0120)	(0.013)
FND	0.006***	0.003***	0.005***	0.005***	0.005***	0.006***	0.006***	0.009***	0.010***	0.0118***	0.0135***
	(0.0005)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.0013)
ENR	0.0002***	0.000***	0.000***	0.000***	0.0001***	0.000***	0.0003***	0.000***	0.000***	0.000***	0.0002***
	(1.480)	(1.330)	(2.050)	(1.240)	(1.110)	(1.480)	(1.980)	(1.470)	(1.680)	(3.320)	(3.760)
TO	-0.000**	-0.001**	-0.000	-0.000**	-0.000*	-0.000**	-0.001**	-0.001***	-0.002***	-0.002***	-0.002**
	(0.0003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.0003)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.0244	0.0274	-0.046	-0.035	-0.009	0.024	0.0010	0.078	0.135**	0.237**	0.344***
	(0.0500)	(0.044)	(0.0691)	(0.0416)	(0.037)	(0.0500)	(0.066)	(0.0497)	(0.0567)	(0.112)	(0.127)
Obser	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318	1,318

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

The effect of financial development in all quantiles is positively significant which indicates that financial development significantly increases research and development in the panel countries. This result is similar to the System GMM results which confirm that financial

development strongly affects research and development and an increase in financial development by the bank will enhance research and development. Likewise, energy consumption and trade are highly significant while the sign for energy consumption is positive and negative for trade which indicates that energy consumption significantly increases research and development while trade lowers it.

Conclusion

This study investigates the impact of foreign direct investment, carbon dioxide emission, economic growth, and energy consumption on technological innovation in the global panel for the period of 1980-2019. Panel quantile regression have been used for analysis where the results indicate that FDI significantly and negatively affect technological innovations proxy by patent nonresidents in from 5^{th} to 60^{th} quantile while this effect is negative insignificant at the highest quantile from 70^{th}. Carbon dioxide emission and financial development significantly and positively effect technological innovations proxy by patent nonresidents in all quantiles while energy consumption and trade significantly decrease technological innovations. In case of dependent variable research and development, the effect of FDI on technological innovations and international trade is negative while financial development and energy consumption positively and significantly effect technological innovations proxy by research and development. The effect of financial development is negative significant and negative insignificant across quantile while the highest quantile 95^{th} gives positive coefficient thus shows that its increase technological innovations proxy by research and development. Our findings indicate that foreign direct investment reduces innovations which can be the reason that countries in the panel still didn't reach the desired level to attract foreign direct investment with advanced technology and foreign direct investment yet didn't contribute to the host countries' innovations. Energy consumption has also not contributed yet to enhancing innovation level however energy consumption has raised research and development innovation. Carbon dioxide, economic growth, and financial development are enhancing innovations which indicates that they have a high contribution to enhancing the level of innovation. The findings also conclude that foreign direct investment should be improved through strong policies which can bring new technologies and new knowledge and in turn this can enhance the level of innovations as well promote economic growth. The energy sector should be improved which is related to innovation and an increase in innovation can in turn enhance energy efficiency by lowering the use of energy use. Innovation can also help acquire renewable energy sources and thus enhance environmental quality. Its means that innovations are very important in this modern world, as it enhances most of the economic activities such as foreign direct investment, trade, enhance energy efficiency, acquire renewable energy sources and may help reduce carbon emission and enhance environmental quality. In this regard, the factors used in this study should be considered to enhance the level of innovation and an improvement in innovation will raise environmental quality as well economic growth. That's why our study suggests the sample countries consider the weak factors for each indicator of innovation analyzed in our study to enhance innovation level. Our study is limited to the global panel, future studies should conduct such studies on different samples such as developing and developed countries as the level of innovation, foreign direct investment, and other related factors are different in developing and developed countries and thus can get very useful recommendation and policy implication for developing and developed countries. Future studies may also include other closely related factors such as institutions and education level in such study as institutions can be linked with foreign direct investment, financial sectors, and other related factors to find its role in innovation while findings the effect of these factors on innovation.

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