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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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RESEARCH ARTICLE

Online Shopping: A Study of the Factors Influencing Consumer's Buying Behavior in the 4th District of Nueva Ecija

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Abstract
The fast-growing technology brought a lot of impacts on the business industry. Online shopping is one of the aftermaths of technology. The e-commerce and online retailers in the 4th District of Nueva Ecija lack awareness of the buying behavior of their consumers that affects their businesses. The primary objective of this research was to investigate and identify the factors influencing online shoppers' buying behavior in the 4th district of NE, what things encourage them to buy online and what factors as well could halt them. The study used descriptive-evaluative design to assess the level of influence of factors on consumers' buying behavior in online shopping. This design used statistical treatment such as frequencies, percentages, weighted mean, and thematic analysis treated with percentage to interpret and determine the influence of factors. The study used the purposive sampling technique, the researchers rely on their judgment when choosing members of the population to participate in their surveys. As to the results, most of the respondents strongly agreed that they are satisfied with the delivery process of online shopping. Based on the experience of respondents, online shopping is less effort and avoids consuming (physical) energy. Most of them prefer online shopping if it has special offers or discounts and they were preferring with a well-organized website. The recommendations that have been generated in the study are the fundamental basis of the ideas that would serve as a guide for the enhancement of online shopping and the e-commerce industry.

Keywords: Buying Behavior; Customer Satisfaction; Online Shopping

Introduction

Technology has a huge contribution to business marketing such as in selling/buying the products online, especially in these days of covid19 pandemic. According to Fernandes (2016), leading online retailers utilize technology since it enables them to save time and effort while increasing conversion rates for their e-commerce firm. Consideration of technology may raise concerns about the cost and inconvenience of integrating it into daily corporate processes. However, technology is now affordable for every e-commerce owner, encouraging an increasing number of sellers to go online and increase revenue for their firm.

People can now shop online as a result of the rise and influence of technology. Online shopping is a type of electronic commerce that enables consumers to purchase goods or services directly from a seller via the internet or a mobile application. Consumers locate products of interest by visiting the retailer's website directly or by utilizing a shopping search engine to compare the availability and pricing of similar products across multiple e-retailers. Customers can shop online from a variety of computers and devices, including desktop computers, laptop computers, tablet computers, and smartphones. A standard online store enables customers to browse the company's product and service offerings, as well as examine photos or images of the products, as well information about their characteristics, features, and prices. Online purchasing adds convenience to people's life. It cannot be denied that shopping online provides numerous benefits to us, such as purchasing products without hassle, being reliable for those with busy schedules at work or home, and making it easier to search for and purchase products. These are all factors that influence consumers to purchase online. However, some disadvantages of shopping online can also influence a consumer's decision to buy online, such as delayed delivery, receiving counterfeit or defective products, the possibility of encountering scammers, a lack of confidence in the products purchased because they could not see them

in person, and other circumstances that cause customers to avoid purchasing online.

In the 4th District of Nueva Ecija, the number of online retailers and e-commerce have grown particularly with the advent of this pandemic to extend their goods and services to consumers. According to Global Data (2021), the pandemic boosted e-commerce activity in the Philippines, as fearful consumers stayed at home to avoid exposure to disease vectors, and the Philippines' DTI stated that the number of online vendors jumped from 1,700 in March 2020 to 93,318 in January 2021. The online shoppers from the city of Gapan and different municipalities which are Cabiao, Gen. Tinio, Jaen, Peñaranda, San Antonio, San Isidro, and San Leonardo have dissimilar experiences and perspectives on online shopping. Some shoppers have problems with the sale of products: expensive charges for shipping, receiving wrong and damaged items, sluggish arrival of products, and many factors that affect them to earn negative perceptions. And some were saying that it brings easiness to their lives that they were able to purchase products even they were on their house or works. They also said it saves their time. According to My Advo (2018), the power of online shopping has altered the way people purchase, but consumers face a slew of issues when purchasing online, including false products, hidden fees, and so on. While online buying is convenient, users confront several challenges. However, businesses and marketers in Nueva Ecija continue to lack awareness regarding their consumers' online purchasing behavior, specifically how their purchase decisions are affected and influenced by certain events that generate varying opinions of online shopping as a result of experience. According to Clootrack (2016), understanding consumer behavior is critical for a company's present and future product releases to be successful. Each consumer approaches a purchase with a unique thought process and mindset. If a business does not comprehend how a consumer would react to a product, there is a good risk that the product will fail. Consumer behavior also evolves as fashion, technology, trends, living styles, disposable income, and similar other elements change. A marketer must understand the factors that are changing to align marketing efforts appropriately.

The objective of this research is to investigate and identify the factors influencing online shopper's buying behavior, what things drive them to buy online and what reasons as well could refrain them, which would help online sellers or retailers for earning awareness about consumer's online shopping behavior for enhancing online goods and services and share positive effect to consumer's perceptions by the ideal service manner.This study was based on the research study that was entitled "Factors Affecting Consumer's Online Shopping Buying Behavior" by Pandey and Parmar (2019) in Gujarat.

At the end of this research, the researchers aim to determine the factors influencing online shoppers' buying behavior.

This study aims to answer the following questions:

1. How may the factors influencing online consumer's buying behavior be assessed in terms of:
1.1 Customer Satisfaction;
1.2 Availability of Products;
1.3 Perceived Usefulness;
1.4 Economic;
1.5 Website Quality; and
1.6 Perceived Risk?
2. What are the factors that affect the online shoppers to purchase online in terms of:
2.1 Encouragement; and
2.2 Refrainment?

Materials and Methods

Methods

This study used is under the quantitative research design. Qualitative and descriptive research methods have been very common procedures for conducting research in many disciplines, including education, psychology, and social sciences (Nassaji, 2015). Specifically, the researchers adopt the method of survey, which is defined as the collection of information from a sample of individuals through their responses to questions (Pondo, 2015). It is a fact-finding study with adequate and accurate interpretation of the findings. This study used the percentage and frequency distribution tool and weighted mean for the interpretation of data.

Research Locale

The research was conducted in the 4th district of Nueva Ecija, Philippines where the respondents were identified. The respondents of this study came from the different municipalities and barangays that are found in district 4 Nueva Ecija.

Respondents of the Study

The target respondents of the study had at least a one-time online shopping experience that ages from 15-64 years old.

Sample and sampling procedure

The total sample size of the respondents of the study has a frequency of 384 of the total population of 534, 988. This study uses the Raosoft application to determine the sample size with a 95% confidence level and 5 % error of margin. This study used the purposive sampling technique. Purposive sampling, also known as judgmental, selective, or subjective sampling, is a form of non-probability sampling in which researchers rely on their judgment when

choosing members of the population to participate in their surveys (Alchemer,2021).

Research Instrument

The findings of this study were conducted through an online survey form, with a database that can collect and store data, it also provides statistical software analysis of the findings. Survey research is the most fundamental tool for all quantitative outcome research methodologies and studies.

Survey questionnaires are a set of questions to accomplish the objectives of the study, participants encourage to complete them over the internet via a google form. The online survey questionnaires constructed in the Google form consisted of three parts.

Part I consists of the questions that assess the factors influencing online shoppers' buying behavior in online shopping with the variables such as customer satisfaction, availability of products, perceived usefulness, economic, website quality, and perceived risk. It is formulated in the modified 4-point Likert scale (4)Strongly Agree; (3) Agree; (2) Disagree; (1) Strongly Disagree. Participants were instructed to rate the statements and answer the question. It was patterned and modified from the questionnaire of Pandey et.al. (2019) entitled “Factors Affecting Consumer’s Online Shopping Buying Behavior”.

Part II consists of an open-ended question about the factors that could refrain and encourage the shoppers to purchase online. The respondents were asked to state their honest opinions regarding the questions being asked.

The research instrument was validated; corrections and suggestions were incorporated in the final draft; interviews were done with the other consumers to check the reliability and validity of the instrument.

Data Gathering Procedure

After the approval of the research topic entitled "Online Shopping: A Study of the Factors Influencing Consumer's Buying Behavior in the 4th District of Nueva Ecija". The researchers begin by collecting related data and information from the Internet. The questionnaire was guided by the related studies and undergoes confirmation by the competent individuals for validation of the suggested opinions were included. The researchers conduct a dry run to check the reliability and validity of the formulated questionnaire. The reliability coefficient of the instrument was tested and measured to check the internal consistency. The validity of the research instrument was established by presenting the developed research instrument for the comments of the experts who rate the instrument. The reliability coefficient of the instrument was tested and measured with a score of .989 which means that the instrument has a good internal consistency. The validity of the research instrument was established by presenting the developed research instrument for the comments of the experts who rated the instrument with 4.56 as it is weighted mean having a verbal interpretation of "very good". Before the distribution of the questionnaires, the researchers obtain approvals from their subject teacher and adviser, since the survey questionnaires were sent online with some social media platforms like messenger, telegram, and email, and lastly the researchers are free to conduct a survey. After the dry run of the questionnaire, it will be tallied, and further revisions of the questionnaire will be done. After the distribution, the information that will be gathered from the answered questionnaire will be tallied for further interpretation.

Data Analysis Techniques

The data collected from the locale were encoded, tallied, and analyzed. Statistical tools such as Percentage, Frequency Distribution, Weighted Mean, and Thematic Analysis were used in analyzing the data gathered. The scale below was employed to interpret the results.

Table 1. Scales for Interpretation

Scale	Mean Range	Interpretation	Description
4	4.00-3.00	Strongly Agree	Highly In favor
3	2.99-2.00	Agree	In favor
2	1.99-1.00	Disagree	Not in favor
1	1.00-0.99	Strongly Disagree	Highly not in favor

Table 1 present the scales applied by the researchers in the interpretation and description of data under the Factors influencing online shopping buying behavior of the respondents to assess the level of impact of those factors on online shopper buying behavior. To determine the favorable using a 4-point Likert scale. The purpose of the researchers is to identify the perspective of the respondents which among the online shopping beliefs are being in highly in favor, in favor, not in favor, and highly not in favor.

Aside from the said scale, the researcher used the following statistical tools to classify, tabulate, and analyze the data following the objectives of the research study:

1. To assess and analyze the factors influencing online consumers' buying behavior in online shopping, the researchers employed weighted mean and ranking.
2. In describing and analyzing the factors that encourage and refrain the shoppers to purchase online, thematic analysis was applied and treated with frequency, percentage, and ranking.

Results And Discussion

1. Assess the Factors Influencing Online Consumer's Buying Behavior in terms of Customer Satisfaction, Availability of Products, Perceived Usefulness, Economic, Website Quality, and Perceived Risk.

1.1 Assessing the Factors Influencing Online Consumer's Buying Behavior in terms of Customer Satisfaction.

Table 2. Factors Influencing Online Consumer's Buying Behavior in terms of Customer Satisfaction

Customer satisfaction	WM	VI	Rank	VB
I am satisfied.....				
1..... with the information of products and services provided on the internet.	3.03	Strongly Agree	3.5	Highly in favor
2..... with the customer services provided by online shopping.	3.03	Strongly Agree	3.5	Highly in favor
3..... with the arrival time of products.	3.02	Strongly Agree	5	Highly in favor
4..... with provided guarantee and warranty.	3.02	Strongly Agree	5	Highly in favor
5..... with the quality of products that are offered on online shopping.	2.97	Agree	7	In favor
6..... by the product tracking process provided by online shopping.	3.12	Strongly Agree	2	Highly in favor
7..... with its delivery process.	3.18	Strongly Agree	1	Highly in favor
Average Weighted Mean	**3.05**			**Highly in favor**

Table 3. Factors Influencing Online Consumer's Buying Behavior in terms of Availability of Products

Availability of Products	WM	VI	Rank	VB
1. Online shopping is more expensive than selling in a physical retail store.	2.59	Agree	4	In favor
2. The product I need/want is always available online shopping.	3.07	Strongly Agree	3	Highly in favor
3. Online shopping provides a variety of products for purchase.	3.15	Strongly Agree	2	Highly in favor
Continuation of Table 11.				
4. The online products can be ordered at any time and any day in online shopping.	3.29	Strongly Agree	1	Highly in favor
Average Weighted Mean	**3.03**			**Highly in favor**

Table 2 shows the overall total satisfaction of the respondents in online shopping, it has a weighted mean of **3.05**. The factor for satisfaction of respondents in terms of the delivery process got the highest weighted mean of **3.18** as the verbal interpretation of **"Strongly agree"**. However, the satisfaction that got the lowest weighted mean of **2.97** is the "quality of products that are offered on online shopping" and interpreted as **"Agree".**

12. Assessing the Factors Influencing Online Consumer's Buying Behavior in terms of Availability of Products.

Table 3 shows that the result of the factors under the availability of products has a weighted mean of **3.03**. The perceptions of shoppers about the products online can be ordered any time and any day got the highest weighted mean of **3.29** which is interpreted as "**Strongly Agree**", and the perception that got the lowest weighted mean of **2.59** is that online shopping is more expensive than sold in a retail physical store and it is interpreted as "**Agree**".

13. Assessing the Factors Influencing Online Consumer's Buying Behavior in terms of Perceived Usefulness.

Table 4. Factors Influencing Online Consumer's Buying Behavior in terms of Perceived Usefulness.

Perceived Usefulness	WM	VI	Rank	VB
1. Online shopping is reliable for surprise gifts.	2.70	Agree	3	In favor
2. Buying online can save time.	3.24	Strongly Agree	2	Highly in favor
3. Online shopping can save money	2.57	Agree	4	In favor
4. Online shopping is less effort and avoids consuming energy (physical).	3.29	Strongly Agree	1	Highly in favor
Average Weighted Mean	**2.95**			**In favor**

Table 4 shows that the composite result of the factor Perceived Usefulness got **2.95** as its overall weighted mean. According to the perception and experience of respondents, online shopping is less effort and avoids consuming energy (physical) got the highest weighted mean of **3.29,** and has the interpretation of "**Strongly Agree**" and the perception about online shopping can save money getting the lowest result of **2.57** as the interpretation of "**Agree**".

14. Assessing the Factors Influencing Online Consumer's Buying Behavior in terms of Economic.

Table 5. Factors Influencing Online Consumer's Buying Behavior in terms of Economic

Economic	WM	VI	Rank	VB
1. Easy refund and return policy.	2.57	Agree	4	In favor
2. Online shopping if online prices are lower than the actual price.	3.14	Strongly Agree	2	Highly in favor
3. Online shopping if it has a free shipping voucher	2.64	Agree	3	In favor
4. Online shopping if it has special offers/discounts for the purchase.	3.32	Strongly Agree	1	Highly in favor
Average Weighted Mean	**2.92**			**In favor**

As shown in Table 5, the computed weighted mean of the economic factor is **2.92.** According to the respondents, most of them prefer online shopping if it has special offers/discounts for purchase so it has the highest weighted mean of **3.32** with the interpretation of "**Strongly agree**". And being preferred with easy refund and return policy got the lowest weighted mean of **2.57** has the interpretation of "**Agree**".

15. Assessing the Factors Influencing Online Consumer's Buying Behavior in terms of Website Quality.

Table 6. Factors Influencing Online Consumer's Buying Behavior in terms of Website Quality

Website Quality	WM	VI	Rank	VB
1. Prefer online shopping with more requirements needed for personal information while entering a website.	2.87	Agree	4	In favor
2. Prefer online shopping if it has a more secured website.	3.23	Strongly Agree	3	Highly in favor
3. Prefer online shopping if the website is professionally designed and well presented.	3.26	Strongly Agree	2	Highly in favor

4. Prefer online shopping if the information on the site is well organized.	3.29	Strongly Agree	1	Highly in favor
Average Weighted Mean	**3.41**			**Highly in favor**

Table 6 indicates the result of the website quality factor got a weighted mean of **3.41**. The respondents prefer online shopping if the information on the site is well organized and has the highest weighted mean of **3.29** with the interpretation of "**Strongly agree**"**.** On the other hand, the preferred online shopping with more requirements needed for personal information while entering the website got the lowest weighted mean which is **2.87** interpreted as "**Agree**".

2.6. Assessing the Factors Influencing Online Consumer's Buying Behavior in terms of Perceived Risk

Table 7. Factors Influencing Online Consumer's Buying Behavior in terms of Perceived Risk

Perceived Risk	**WM**	**VI**	**Rank**	**VB**
1. Hesitate to give my credit card.	2.98	Agree	5	In favor
2. Hesitate for advance payment.	2.99	Agree	4	In favor
3. Worried to receive a false product.	3.32	Strongly Agree	2	Highly in favor
4. Concerned whether a product will be good as well as it is advertised.	3.27	Strongly Agree	3	Highly in favor
5. Worried about scamming.	3.48	Strongly Agree	1	Highly in favor
Average Weighted Mean	**3.21**			**Highly in favor**

Table 7 shows that the weighted mean of perceived risk factors was estimated as **3.21**. Most of the respondents were worried about scamming with a weighted mean of **3.48** interpreted as "**Strongly agree**" while some of them hesitate to give their credit card that has a weighted mean of **2.98** has the interpretation of "**Agree**".

2. Analyze the Factors that Encourage and Refrain the Shoppers to Purchase Online.

2.1. Analyzing the Factors that Encourage the Shoppers to Purchase Online.

Table 8. Factors that Encourage the Shoppers to Purchase Online

Factors Encourage to Purchase Online	**Frequency**	**Percentage**
1. Less hassle and provide convenience for searching and purchasing products.	150	39%
2. Discounts/Special offers/Cheaper prices of products with free shipping or lower cost of shipping.	104	27%
3. Time-saving.	50	13%
4. Provide variety and trendy products.	29	8%
6. Prevent being infected /avoid Covid 19 virus.	21	6%
7. Relatives/Peer Groups	17	4%
8. Advertisement	13	3%
Total:	**384**	**100%**

Table 8 shows that **39%** or **150** of the frequency of the respondents have been encouraged to purchase the products online by the factor of it less hassle and provides convenience for searching and purchasing products. And **104** or **27%** of the respondents were encouraged by the discounts/special offers/cheaper prices of products with free shipping or lower cost of shipping. While the advertisement and peer groups/family have at least influence to encourage respondents to buy online. The advertisement has **3%** or **13** respondents and peer groups/family has **17** respondents or **4%** in its percentage.

3.2. Analyzing the Factors that Refrain the Shoppers to Purchase Online.

Table 9. Factors that Refrain the Shoppers to Purchase online

Factors Refrain to Purchase Online.	Frequency	Percentage
1. Lack of assurance in quality and authenticity appearance of products.	100	26%
2. Worried about scamming.	96	25%
3. Costly shipping service	58	15%
4. Low ratings/negative feedback	38	10%
5. Possible to receive false items	27	7%
6. Possible to receive damaged items	27	7%
7. Advance payment	19	5%
8. Delivery timeframe	12	3%
9. Difficulty in refund/returning product	7	2%
Total:	**384**	**100%**

Table 9 indicates that **100** of the frequency of the respondents or 2**6%** could be refrained to purchase online by the factor that online shoppers lack assurance in the quality and authenticity of the appearance of products in online shopping. And **96** or **25%** of the respondents have refrained from their worries about scams. **2%** or **7** of the frequency of the respondents were affected by difficulty in refund/returning products and **12** or **3%** of the respondents were refrained by the delivery timeframe.

Discussion

1. The assessment of the factors influencing online shoppers' buying behavior in terms of Customer Satisfaction, Product Availability, Perceived Usefulness, Economic, Website Quality, and Perceived Risk.

In terms of Customer Satisfaction, it can be seen that the result demonstrates that online shoppers are extremely content with the existence of online purchasing. This means that online retailers will continue to focus on their primary objective of ensuring consumer pleasure, particularly during the product delivery process. In this time of the pandemic, online shopping is providing the best service possible for their products.

Regards to Availability of Products, the 24/7 availability of products via internet shopping enables buyers to budget their time to acquire products regardless of where they are, even if they are the busiest person on the planet. Because online buyers are not required to travel but may order things from the comfort of their seats.

With the Perceived Usefulness of online shopping, this research demonstrates that, based on respondents' experiences, online buying makes life easier. Being a person entails a plethora of responsibilities that contribute to fatigue daily. Online customers accept online buying as a means of allocating their time and energy to more vital tasks.

In terms of economics, Discounts and unique offers might help you attract new customers who will purchase your products. It promotes the brand and increases the company's sales.

When it comes to Website Quality, the result indicates that respondents strongly favor a well-organized website's information. Presenting a well-organized website can assist relieve customer doubt.

And lastly, in terms of Perceived Risk Researchers believe that scammers are continually expanding in number as a result of the various tactics they employ to defraud people. The growth in their numbers correlates with the growth in the number of persons deceived by them, which causes online customers to be concerned about encountering a deceiver online.

2. The Analysis of the factors could refrain and encourage the shoppers to purchase online.

With regards to factors that encourage the shoppers to purchase online, people are constantly on the lookout for convenience. Marketers and businesses should seize this chance to provide services that align with people's tastes to ensure their business's success. Additionally, the discounts offered on products can assist advertise your brand by attracting practical consumers who raise your company's sales.

In terms of the factors that could refrain the shoppers to purchase online, it demonstrates that respondents are most concerned with the product's quality and presentation. They are hesitant to purchase things online since they cannot inspect them before purchasing. They are particularly hesitant to purchase online if the goods are expensive; therefore, they want to ensure that their money is well spent, which is why they wanted to ensure the product's quality and attractiveness. Scammers may also influence consumers to avoid purchasing online to ensure that the money they earned does not go to waste.

In line with the above discussions, the following are the researchers' recommendations:

Shopping industry should pay attention that most teens are engaged in buying online, it should be taken as an advantage by online retailers to drop their advertisements about their e-commerce with the online platforms that are popular with teens such as Facebook, Snapchat, YouTube, and Instagram, especially in these days that teens have more access on smartphones.

Online shopping is recommended to pursue their well delivery process for still attaining the trust of consumers, making them satisfied will lead to achieving customer loyalty. Sellers should be rational in shipping charges because sometimes the eagerness of shoppers to purchase could be halted by the shipping cost provided by e-commerce, even the products are lower prices these could be more expensive than those sold in a physical retail store because of the costly charges on shipping fee, so they should be considered particularly when the locations of shoppers are not too far from the site of online retailers. They should provide a sign of distinction as its legitimacy that alleviates apprehensions from online shoppers to transact online. The constant enhancement of goods and services from the overall aspects of online shopping will maintain the retention of consumers.

Online shopping should continue to its purpose of providing convenience in people's lives while shopping online to still satisfy customers. In terms of their products selling, online shopping should make sure that every product or all items they are going to post on the website and sell have good quality and appearance to ensure that even without the actual sight with customers on products while purchasing it, they have assurance with it that's because online retailers should have already assured that the product that customers would purchase is good quality and reasonable to be paid and bought by consumers.

For the future researchers, it is recommended to use this research as basis of future possible study that is related with this topic.

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RESEARCH ARTICLE

The usage of Web tools in Extension Service Delivery among agricultural extension workers in Ekiti state. Nigeria

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Abstract
The advent of Covid-19 pandemic has contributed meaningfully to ICT in terms of its relevance, those that deal with communication like agricultural extension had no choice than to flow with the current trend of communicating with their clientele with the use of certain ICT tools such as the web-based tools. This enables a free flow and continuous contact with the farmers on updated information that is useful for agricultural productivity. The study therefore was conducted to assess the usage of web tools among the agricultural extension workers in south-west Nigeria, the study was carried out to: examine the socioeconomic characteristics of extension workers, determine the extension workers on the usage of web tools in disseminating agricultural information and constraints facing the usage of web tools in disseminating of agricultural information. The study was carried out in Ekiti states Nigeria. Multi-stage sampling techniques was adopted. Primary data were collected and analyze using descriptive. The findings also show that respondents are high using of most the web tools such as facebook, whatapps, tiwtter etc for disseminate agricultural information to the farmers. Furthermore, the findings show that web tools usage has crucial role to play in promoting quality extension delivery, best agronomy practices and promoting new generation agriculture and make agriculture more lucrative and sustainable as well as improving livelihood in Nigeria. However, some constraints were identified with the use of web tools during the period of carrying out this study, such constraints are: poor internet coverage, lack of awareness of information sources available and untimely provision of information, high cost, complex to use, it requires special types of devices to use some of the webtools etc.
The study therefore concludes that if the constraints faced was solves then the level of usage webtools will increase and enhance agricultural productivity. However, the study recommended that both agricultural extension workers needs to be trained on almost all the identified web tools.

Keywords: webtools; Usage; Extension; information sharing

Introduction

Web tool technologies enable people to create, modify, and share information online (Aharony,2008). These technologies include blogs, forums, wikis, micro-messaging, cloud computing, RSS feeds, SNSs, multimedia sharing, social bookmarking, and podcasts (Baro, Ebiagbe and Godfrey 2013). Web tools are used to improve collaboration, communication, and interaction in learning contexts (Narayan and Baglow 2010). In North America and Europe, Web tool technologies are used to send course outlines, questions and answers to assignments and assessments, audio or video instructional materials to agricultural extension agents (Kumar 2008). Despite the rising use of Web tools to help education, Africa, notably Ghana, Tanzania, and Nigeria, uses them very little (Lwoga 2012; Munguatosha, Muyinda and Lubega 2011).

Wide usage of information technology (IT) in Agricultural Development Program in several parts of the nation, especially southwest Nigeria, is largely recognized (Arokoyo 2007; Adetimehin et al 2018).

The few extension officers exclusively work in metropolitan regions, ignoring rural areas. Frontline extension agents are important because they have direct interaction with agricultural technology end-users. FAO recommends that one extension agent assist 1,000 farm households in underdeveloped countries due to their role in modernizing agriculture.

Rapid social media development may be used as a learning resource and agricultural information media to address

farmer difficulties. Muslihat et al. (2015) said the community's media consumption affects the extension's competence. The more xtension agencies utilize media, the more they know and can help farmers. Some individuals may exchange ideas, operate to make inventions, sights, and arguments, and discover wonderful friends or partners and develop a community using social networking (Nasrullah 2017). Low-income agricultural extension workers. Low webtool skills among agricultural extension employees must be addressed.
Despite the promise of Web tools to facilitate knowledge generation, sharing, and collaboration, little is known about their use in Nigeria for extension delivery.

The aim of this study is to assess of usage web tools in extension services delivery among agricultural extension workers in southwestern Nigeria

The specific objectives are to:

i. Examine the socioeconomic characteristics of extension workers.
ii. Determine the usage of web tools in disseminating information among extension workers.
iii. Identify the constraints facing the usage of web tools in disseminating of agricultural information.

Methodology of the study

The study was carried out in Ekiti Nigeria due to the preponderance of extension workers. A Multi-stage approach was utilized to choose respondents from Ekiti zone to acquire a representative sample and accomplish the study's goals.
Stage 1- in the first stage, three local government randomly selected from the state which are Ikere, Ekiti west, Oye States. **Stage 2:** the second stage involved all agricultural development zones (ADP)from each of the selected states which are ikere, Aramoko, Isan Ekiti zones. **Stage 3:** The third stage involved purposively selected all the extension workers. A proportionate random sampling technique was used to obtain the sample size for each of the state based on their numerical strength and the respondents were interviewed using structured interview schedule. Data generated were analysed using appropriate descriptive and inferential statistics.

Results and Discussion

Socio-economic characteristics of extension workers

Evidence in Table 4.1 shows that 69.5% of the extension workers in the study area were males while female constituted only 30.5%. The findings reveal that extension organization in the study area is dominated by male The implication of this finding is that extension workers might find it difficult to access women in area where culture limits the interaction of men and women and if the few women extension workers are to be used to access their women farmers and rural dwellers, they might be overwhelmed with such responsibilities since women constitutes between 60 and 80% of the agricultural labour force in Sub-Saharan Africa and in Nigeria, they contribute as high as over 50% (Gebre, Isoda, and Rahut, 2020). Therefore, having few extension workers as women may be a barrier to having regular contacts with women as extension clientele, especially in areas where there is a cultural barrier to interacting with opposite sex reveal that the mean age of the extension workers in the study area was approximately 47 years and less than 1% (0.7%) were less than 30 years old while 33.1 and 64.2% were between 30 and 44 years and 45 and 59 years old, respectively and only 2.0% of the respondents were 60 years and above. The findings show that although, many of the respondents were found between 45 and 59 years but the mean age of 47 years indicates that extension workers in the study area were in their middle age that about 55.0% and 42.4% has between 12 and 16 years and 17 years and above as their years of schooling, while 2.6% of the extension workers had less than 12 years of formal education respectively. show the educational qualification of extension workers in the study area. It was revealed that about 61.6% of the agricultural extension workers had bachelor or Higher National Diploma while 33.1% had Masters degrees with only 5.3% indicating that they had either National Certificate in Education or Ordinary National Diploma It was observed that most of the agricultural extension workers were married as about 93.4% of them indicated married as their marital status while very inconsequential proportions (0.7%, 2.6%, 1.3% and 2.0%) showed that they were single, divorced, separated and widowed, respectively. The fact that most of the agricultural extension workers were married may be used to proxy their commitment to extension works as marital status had been documented by extant literature such as Kemunto, Adhiambo and Bosire (2018), Anyango, Ojera and Ochieng (2013) and Darko-Asumadu, Sika-Bright and Osei-tutu (2018) established that marital status had an influence on job satisfaction where the married were much happier in their jobs than the single. This shows that being married may positively influence commitment and involvement in extension works. The finding shows that agricultural extension workers in the study area had moderate household size of about 6. The findings conform with the studies of Ogunwande, Odefadehan and Akinrinola (2018) and Okwuokenye and Okoedo-Okojie (2014) which reported that agricultural extension workers in Nigeria had between low to moderate family size as compared to most farmers with, Results show that the mean annual income of agricultural extension workers in Nigeria based on the selected sample was approximately 1.432,280.00. This shows that on average, an extension worker receives about ₦119, 356.66 per month as salary. This is in conformity with the salary structure of civil servant in Nigeria where

the minimum wage is pegged at ₦30,000 for a level one officer without educational attainment. On the experience with the number of years spent on the job, results show that on average, extension workers in the study area had spent about 13 years on the job. Specifically, 27.2% indicated less than 10 years of experience, 58.9% showed that they had spent between 10 and 19 years while 13.9% had spent 20 years and above as agricultural extension workers in the study area. This shows that agricultural extension workers had reasonable experience in carrying out extension works and as such they would have been exposed to training on the use of web-based tools in the discharge of their duties as information experts. This study conforms with the assertions of Okwuokenye and Okoedo-Okojie (2014) who reported over 17 years of experience for the extension workers in Delta State, Nigeria while Davis et al. (2019) reported 15 years as the average years of experience among extension workers in Nigeria

Table 4.1: Socio-economic characteristics of extension Workers

Variables Deviation	Freq.	Percentage	Mean	Std. Dev.
Sex				
Male	105	69.5		
Female	46	30.5		
Age (years)				
<30.00	1	0.7		
30.00 - 44.00	50	33.1	47.25	6.32
45.00 - 59.00	97	64.2		
60.00+	3	2		
Years of formal schooling				
<12.00	4	2.6		
12.00 - 16.00	83	55	16.81	2.78
17.00+	64	42.4		
Highest Educational qualification				
Secondary school				
NCE/ND	8	5.3		
BSc/HND	93	61.6		
M.Sc	50	33.1		
Ph.D				
Attend any professional training	57	37.7		
Marital status				
Single	1	0.7		
Married	141	93.4		
Divorced	4	2.6		
Separated	2	1.3		
Widowed	3	2		
Household size				
<5.00	19	12.6		
5.00 - 9.00	122	80.8	6.13	2.17
10.00+	10	6.6		
Average income per annum (₦)				
<1000000.00	125	82.8		
1000000.00 - 1499999.00	10	6.7	1432280.00	372091.07
1500000.00+	16	10.6		
Experience (Years)				
<10.00	41	27.2		
10.00 - 19.00	89	58.9	12.64	6.10
20.00+				
	21	13.9		

Source: Field Survey, 2021.

Usage of web tools

On the usage of web tools, results in Table 4.2 show that WhatsApp (Mean = 2.03), facebook (Mean = 2.17) and Google plus (Mean = 2.11) were the only web tools that had high usage among agricultural extension workers in the study area. Usually, understanding the mode of operations of these web tools is very critical to usage. The level of usage seems low and this may not translate to low awareness as Oyakhilomen et al. (2020) and Umar et al. (2015) pointed out that awareness of a technology may not lead to usage as factors that promote usage are different from those that support awareness, although awareness is a critical and the first stage in the adoption process as documented by Rogers (1962) in the diffusion of innovation. The low level of usage of the agricultural extension agents may be due to many factors such as availability, accessibility, relative advantage and cost as opined by Ezeh (2013) and Akintonde et al. (2021) in their studies. Currently, many web tools are being social for social networking and professional engagement but the factors underling their usage differ and knowledge of the web tools also depend on the environment and age of the users.

Table 4.2: Usage of web tools by extension agents

	Ext. Workers	
Usage	**Mean**	**Std. Dev**
Twitter	1.99	0.81
Instagram	1.93	0.77
Wikis	1.81	0.89
YouTube	1.91	0.88
Soundation	1.76	1.03
WhatsApp	2.03*	0.95
Skype	1.99	0.98
Facebook	2.17*	0.96
Google plus	2.11*	0.99
Telegram	1.75	0.95
Zoom	1.97	1.36

Source: Field Survey, 2021.
Mean > 2.0 = High Usage

Constraints to the use of web tools

Evidence in Table 4.3 shows that almost all constraints identified to the use of web tools were severe except complexity in the use of the tools (Mean = 1.99), needs for special trainings (Mean = 1.97) and reduction in the family physical contact and relationships (Mean = 1.72). This means that constraints such as poor internet coverage, lack of awareness on the availability, poor or total lack of electricity or power supply and high cost among others were constraints with high level of severity to the use of web tools in information dissemination. The findings conform with the extant studies conducted by Agbo (2015), Adelakun et al. (2020), Umar et al. (2015), and Mustapha et al. (2018) that reported cost of web tools, poor or lack of internet connectivity, poor electricity supply, and lack of technical know-how as the major constraints for effective use of web tools in Nigeria.

Although, several constraints militating against the usage of web tools were identified in this study but language barriers (Mean = 2.10), electricity supply (Mean = 2.04), complexity in the usage (Mean = 2.06), limited knowledge and skills (Mean = 2.01), high cost (Mean = 2.00), requirements of certain type of conditions (Mean = 2.13) hacking problems (Mean = 2.11) and availability of irrelevant contents among others were the severe constraints to the utilization of web tools for information management from the farmers' perspective. These are serious constraints that may impede the usage of these web tools by the extension workers in Nigeria. This is because some of the constraints are generic and systemic within the context of Nigeria as a nation.

Table 4.3: Constraints to the use of web tools

	Ext. Workers	
Constraints	**Mean**	**Std. Dev**
Poor internet coverage	2.19	0.19
lack of awareness of information sources available and untimely provision of information	2.09	0.93
Language barriers (as the majority of the text is in English)	2.04	0.94
Electricity/power failure	2.28	0.82
Complex to use	1.99	0.82
Limited knowledge and skills in webtools	2.13	0.75
High cost	2.52	0.62
It requires special types of devices to use some of the webtools	2.16	0.76
Availability of irrelevant/ undesirable content	2.03	0.77
Special training is needed to use web tools	1.97	0.75
Hackers often hack into accounts created with the Web tools	2.18	0.73
Virus attack on files can cause a lot of damage	2.03	0.76
Message delivery can be delayed at times	2.13	0.72
I sometimes encounter technical barriers and malfunctioning of devices	2.11	0.74
It is reducing family physical contact and relationship	1.72	0.74

Source: Field Survey, 2021.
Mean > 2.0 = Severe

Conclusion

Based on the above findings, the study therefore concluded that, the usage of web tools among the agricultural extension workers in south-west Nigeria has a significance

positive relationship with age, annual income, house hold size and years of experience. Also, web tools usage has crucial role to play in promoting quality extension delivery, best agronomy practices and promoting new generation agriculture and make agriculture more lucrative and sustainable as well as improving livelihood in Nigeria. However, some constraints were identified with the use of web tools during the period of carrying out this study, such constraints are: poor internet coverage, lack of awareness of information sources available and untimely provision of information, high cost, complex to use, it requires special types of devices to use some of the webtools etc.

Recommendations

Following the results, the following suggestions were made:

1. Agricultural Extension workers, most especially must be trained on the use of web tools to disseminate agricultural information to their clientele.

2 Agricultural stakeholders should find a way to encourage the use of web tools among extension workers in the study area.

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RESEARCH ARTICLE

Carbon emission reduction potential of renewable energy, remittance, and technological innovation: empirical evidence from China

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Abstract
Although the effects on environmental quality have not yet been extensively studied, some studies demonstrate that renewable energy, remittances, and technical innovations contribute to a country's socioeconomic development. The current study utilizes annual data from 1990 to 2020 to evaluate the impact of renewable energy, remittances, and technical innovation on carbon dioxide (CO_2) emissions in China. By using the autoregressive distributed lag (ARDL) bounds testing, the research was able to reveal persistent associations between CO_2 and the regressors. Long- and short-run ARDL results also demonstrated that CO_2 emissions rise alongside economic development, but the using renewable energy, remittances, and technical advancement help to lower emissions in China. The reliability of these results was determined using fully modified ordinary least squares (FMOLS), dynamic ordinary least square (DOLS), and canonical cointegrating regression (CCR). Considering these significant determining, several policy suggestions are proposed.

Keywords: Carbon emission; Climate change; Renewable energy; Remittance; Technological innovation; Sustainable development

Introduction

The world is becoming more aware of environmental issues as the negative effects of environmental degradation become more noticeable (Raihan et al., 2018; Jaafar et al., 2020; Isfat & Raihan, 2022). It is because of this realization that countries are finally beginning to take action to reduce environmental destruction (Raihan et al., 2021a; Islam et al., 2022; Voumik et al., 2022a). Because ecological decline is a given result of economic growth, swift implementation of environmental regulations is challenging for policymakers (Begum et al., 2020; Raihan et al., 2021b; Raihan & Said, 2022). Therefore, macroeconomists and environmentalists alike devote their research efforts to understanding the interplay between the two (Voumik et al., 2022b). However, policymakers are still on the hunt for environmentally friendly options that will have the least impact on economic metrics (Raihan & Tuspekova, 2022a). Both developing and developed countries have spent time and resources over the years searching for answers to the environmental degradation that has led to global warming and climate change (Raihan et al., 2019; Raihan et al., 2022a). Despite having signed the Paris agreement, many countries are in danger of failing to meet their carbon reduction targets because of their focus on economic growth (Raihan et al., 2022b). A number of reports have highlighted the role that various factors, such as a flourishing economy, renewable energy sources, and cutting-edge technology, can play in lowering emissions (Raihan & Tuspekova, 2022b; Raihan & Tuspekova, 2022c).

Since the structure of production and, thus, the economy is centered mostly on fossil fuels for several nations, the earlier-mentioned studies are often feasible in terms of the efficient use of energy and the transition from fossil sources to renewable sources (Raihan et al., 2022c). Due to the high prices associated with investing in technology to improve energy efficiency and diversify the portfolio of renewable energy, the financial sector is seen as a critical resource in supporting environmental expenditures. As a result, there has been a surge in recent years in the number of studies devoted to identifying the causes of environmental degradation (Raihan et al., 2022d; Raihan et al., 2022e; Raihan & Tuspekova, 2022d). Aid for development is a crucial resource for countries that want to finance ecological investments with public funds (Wang et al., 2021; Raihan et al., 2022e). Yet, those who oppose public spending argue that subsidies like these only serve to expand the private sector and drain the economy. The value of remittances as financial aid is underappreciated. As a fundamental part of the global financial system, they aid in reducing environmental damage (Wang et al., 2021).

Since remittance's effects on the ecosystem occur indirectly through several paths, there are not many studies on the connection between the environment and remittance. The increase in remittances, which boosts individuals' discretionary money, enables the first route. Increasing wealth has negative effects on the environment because more people can afford to buy things that take a lot of energy. Conversely, an increase in disposable income stimulates the economy by simultaneously increasing the number of people working and the quantity of goods produced (Ahmad et al., 2019). The environmental impact of increased output due to economic expansion varies with the level of economic development. The second path analyzes the impact of remittances on household spending. Increased production and consumption both lead to a spike in energy consumption. As the need for energy grows, so does the likelihood that it will pollute the environment (Raihan et al., 2022f). A third option arises when more money is moved from remittances into the banking system. An intricate process of transmission was developed, with room for expansion via additional variables concerning the environment and remittances (Ahmad et al., 2019). One common belief is that migrants can use the extra cash in their pockets as a result of remittances to further their education. A better understanding of environmental issues, gained via education, may help curb practices that contribute to pollution. One potential source that is often overlooked is international trade. An overvalued currency can hurt a country's competitiveness internationally because of remittances by revealing a public moral hazard problem and limiting the range of exports. Finally, as remittances are an important source of financing for developing countries, sponsoring initiatives with a focus on promoting renewable energy technology modifies their environmental repercussions (Wang et al., 2021). Recognizing the complex interplay between remittances and other factors influencing environmental conditions is, thus, essential.

In the face of rising CO_2 emissions, China plans to embark on a low-carbon transition by working toward carbon neutrality by 2060. China has ratified the Paris Agreement under the UNFCCC and agreed to adopt CO_2 emission-reduction measures to meet the applicable targets for addressing climate change, adding to its domestic commitment to cut CO_2 emissions. At the recently concluded COP26 in Glasgow, China revised its earlier vow to phase out coal use, instead promising to minimize coal usage. Since China has set a target of reaching carbon neutrality by 2060, this adjustment reflects the country's position that CO_2 emissions will peak by 2030 and steadily fall. However, in order to reach carbon neutrality by 2060, the country has pledged to diversify its national energy portfolio by increasing the share of renewables (wind and solar) and decreasing the share of coal. To attain carbon neutrality, economies around the world are searching for the necessary components to decouple CO_2 from economic growth (Raihan et al., 2022g). To further this goal, China plans to use targeted decoupling strategies. Specifically focusing on the 2060 carbon-neutrality goal, it is committed to achieving these interconnected objectives through the implementation of novel efforts to create a modern energy system. This modernization is expected to take the form of a shift to clean energy, increased energy efficiency, and reduced reliance on fossil fuels for power production (Raihan et al., 2022h). Applying cutting-edge technologies across the board, not just in the energy sector, might be seen as an innovative strategy for achieving low-carbon growth in China.

Currently, technological advancement is the most significant contributor to mitigating global climate change (Raihan & Tuspekova, 2022b). The improvement of environmental legislation has resulted in a steady growth of direct environmental technologies to lower CO_2 emissions (Chen & Lee, 2020). Technological innovation plays a significant role in the economic restructuring and optimization process. It is changing conventional economic development from a production-driven mode to an innovation-driven mode aids in reducing CO_2 emissions generated by industrialization (Raihan et al., 2022b). Furthermore, technological innovation is regarded as a vital element in improving the energy efficiency of a country (Raihan et al., 2022e). Advanced technologies enable the economy to achieve a certain amount of production while consuming less energy (Raihan et al., 2022f). In addition, technical progress allows the economy to transition from depletable to renewable energy sources to fulfill energy demands. As a result, technological innovations cut energy consumption and CO_2 emissions from the burning of fossil fuels (Raihan et al., 2022h). Technological innovation may help alter and upgrade China's industrial structure, and it is an important source of driving force for high-quality economic growth. Therefore, researching the influence of technological innovation on environmental sustainability is critical both theoretically and practically for increasing China's economic growth and lowering carbon emissions.

Given these circumstances, the primary objective of this study is to draw conclusions about the potential effects of economic growth, renewable energy use, remittances, and technological innovation to reduce CO_2 emissions in China. There are three ways in which this study can enrich the current body of literature and inform policy decisions. In the first place, this study is innovative because it makes an original effort to shed light on the connection between remittances and CO_2 emissions by assessing the reduction potential of remittances. Second, we used a range of diagnostic tests and cointegration regression models (ARDL, DOLS, FMOLS, CCR) to ensure the accuracy of our findings. Finally, the study concluded with proposals and recommendations for developing effective policies on reducing emissions and promoting sustainable development. The findings of this study will be useful to researchers, politicians, environmentalists, and governments in their efforts to develop an eco-friendly

ecosystem through the responsible use of economic growth and remittances.

Literature Review

The effects of economic growth and remittances on CO_2 emissions have been documented in numerous empirical investigations. A variety of research including several countries, factors, and methodologies were considered. Zafar et al. (2022) investigated the connection between remittances, economic expansion, and CO_2 emissions from 1986 to 2017. The findings demonstrated that, in contrast to economic expansion, which increases CO_2 emissions, remittances help to slow down ecological deterioration by negatively affecting emissions. In Pakistan and Bangladesh from 1980 to 2016, Wang et al. (2021) investigated the relationship between CO_2 emissions, remittances, and economic growth. Remittances, GDP, and CO_2 emissions have a long-term relationship that was predicted using the panel cointegration approach. Its findings revealed that economic growth and an improvement in remittances received both helped the panel's chosen nations' emissions to decline. On the other hand, the short-run ARDL study showed that a rise in economic growth and remittance inflow led to a significant increase in CO_2 emissions. Additionally, Neog and Yadava (2020) examined the relationship between remittances and CO_2 emissions. The study looked at how remittances, economic development, and CO_2 were related in India in asymmetric ways between 1980 and 2014. The findings showed that a positive surprise in remittances led to an increase in CO_2 emissions, as opposed to a negative shock. In addition, Yang et al. (2020) compared CO_2 emissions, economic growth, and remittances in a selection of G-20 countries using annual data from 1990 to 2019. A selection of G-20 countries' economic growth and CO_2 emissions were positively correlated, according to two models. Furthermore, it was discovered through research that remittances greatly decreased CO_2 emissions.

Renewable energy sources including wind, hydro, solar, and many others have gained appeal as an eco-friendly alternative to traditional fuels like coal, gasoline, and oil. These forms of energy have the potential to deliver non-carbon clean energy at levels comparable to those given by carbon-based energy while simultaneously reducing atmospheric concentrations of greenhouse gases. Over the past few years, numerous research have been conducted to understand how and to what extent the use of renewable energy can reduce carbon dioxide emissions. For instance, Raihan and Tuspekova (2022a) reported a positive relationship between economic growth and CO_2 emissions while a negative relationship between renewable energy use and CO_2 emissions in Peru utilizing the data over 1990-2018. By using an advanced panel quantile regression model, Azam et al. (2022) reported a positive relationship between economic growth and CO_2 emissions, and a negative relationship between renewable energy and CO_2 emissions in the top-five emitter countries, covering the data from the period from 1995 to 2017. By utilizing data from 1990 to 2019, Raihan et al. (2022g) reported a positive relationship between economic growth and CO_2 emissions, and a negative relationship between renewable energy and CO_2 emissions in Argentina. Zoundi (2017) analyzed the relationship between CO_2 emissions and the utilization of renewable energy in 25 African economies from 1980 to 2012. Raihan and Tuspekova (2022e) utilized data over 1990-2019 and reported that economic growth increases CO_2 emissions while renewable energy reduces CO_2 emissions in Nepal. According to Cherni and Jouini (2017), renewable energy use reduced CO_2 emissions as Tunisia's economy grew, while the use of fossil fuels increased emissions. Raihan and Tuspekova (2022f) reported a positive association between economic growth and CO_2 emissions, and a negative relationship between renewable energy consumption and CO_2 emissions in India over the period 1990-2020. Chen et al. (2019) reported that the use of renewable energy sources is inversely related to China's CO_2 emissions between 1980 and 2014. By using data over 1990-2019 for Brazil, Raihan and Tuspekova (2022g) found a positive relationship between economic growth and CO_2 emissions while a negative link between renewable energy consumption and CO_2 emissions. Liu et al. (2017a) utilized time data over 1992-2013 to establish a negative association between renewable energy use and CO_2 emissions in the BRICS countries. Furthermore, by using time data over 1970-2013, Liu et al. (2017b) revealed a positive association between economic growth and CO_2 emissions while a negative association between renewable energy use and CO_2 emissions in Indonesia, Malaysia, the Philippines, and Thailand.

Furthermore, the relationship between technological innovation and CO_2 emissions has been examined comprehensively in recent years as increased research and development (R&D) spending can enhance economic production efficiency and resource usage efficiency. Technological advancements are expected to have a major effect on pollution reduction. With the help of environmental protection programs, new technologies have reduced CO_2 emissions and improved environmental performance in many countries. Previous research shows that a lot of focus has been placed on the potentially positive effect of technological innovations on CO_2 emissions. Most academics choose patents as a measure for technological innovation because they protect company and intellectual property rights that help create technologies to address environmental problems. According to Chen and Lee (2020), technical innovation in high-income nations efficiently decreases CO_2 emissions and is thus considered environmentally beneficial green technology innovation. Several studies have shown that technological innovation reduces CO_2 emissions. Raihan et al. (2022b) utilized time

data over 1990-2019 to establish a positive association between economic growth and CO_2 emissions while a negative association of renewable energy use and technological innovation with CO_2 emissions in Malaysia. In addition, by using time data over 1990-2020, Raihan et al. (2022f) reported a positive link between economic growth and CO_2 emissions whereas a negative relationship of renewable energy use and technological innovation with CO_2 emissions in Indonesia. According to Shahbaz et al. (2020), China's technological innovation efficiency have a significant positive impact on environmental performance. Raihan et al. (2022h) reported a positive association between economic growth and CO_2 emissions while a negative association of renewable energy use and technological innovation with CO_2 emissions in Bangladesh. Ahmed et al. (2016) reported that technological innovation improves environmental quality by reducing CO_2 emissions in 24 European nations. Furthermore, Raihan and Tuspekova (2022b) revealed the positive effects of economic growth on CO_2 emissions, and the negative effects of renewable energy use and technological innovation on CO_2 emissions in Kazakhstan utilizing the data over 1996-2018. It is now commonly acknowledged that technical advancements play a significant role in lowering emissions while maintaining economic growth; as a result, any improved understanding of the process of technological innovation is likely to expand our knowledge of mitigation options.

Despite the promising economic growth and remittances in China, the mechanisms of knowledge accumulation remain a mystery, and the true potential of renewable energy use and technological innovation to reduce CO_2 emissions is yet unknown. Therefore, the present study intends to fill up the existing literature gap in the case of China by examining the CO_2 emission reduction potential of economic growth, renewable energy, remittances, and technological innovation using several econometric approaches.

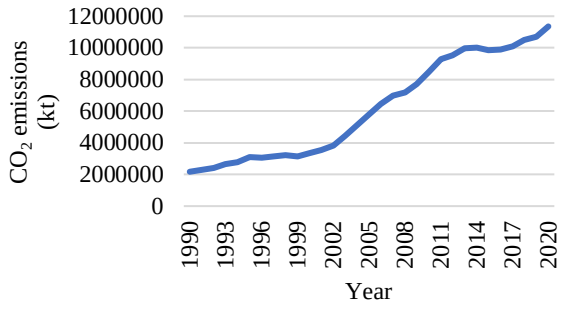
Methodology

Data

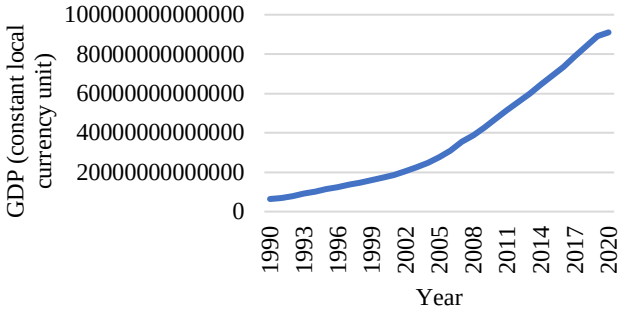
Using annual data from 1990 to 2020, this study investigated the impact of economic growth, renewable energy, remittances, and technological innovation on China's CO_2 emissions. The information came from the World Bank's World Development Indicators (WDI) (World Bank, 2022). The variable names and their measurement unit are presented in Table 1. All the variables were logged to ensure conformity to normality. Moreover, the annual trend of the study variables is presented in Figure 1.

Table 1. Variables with description

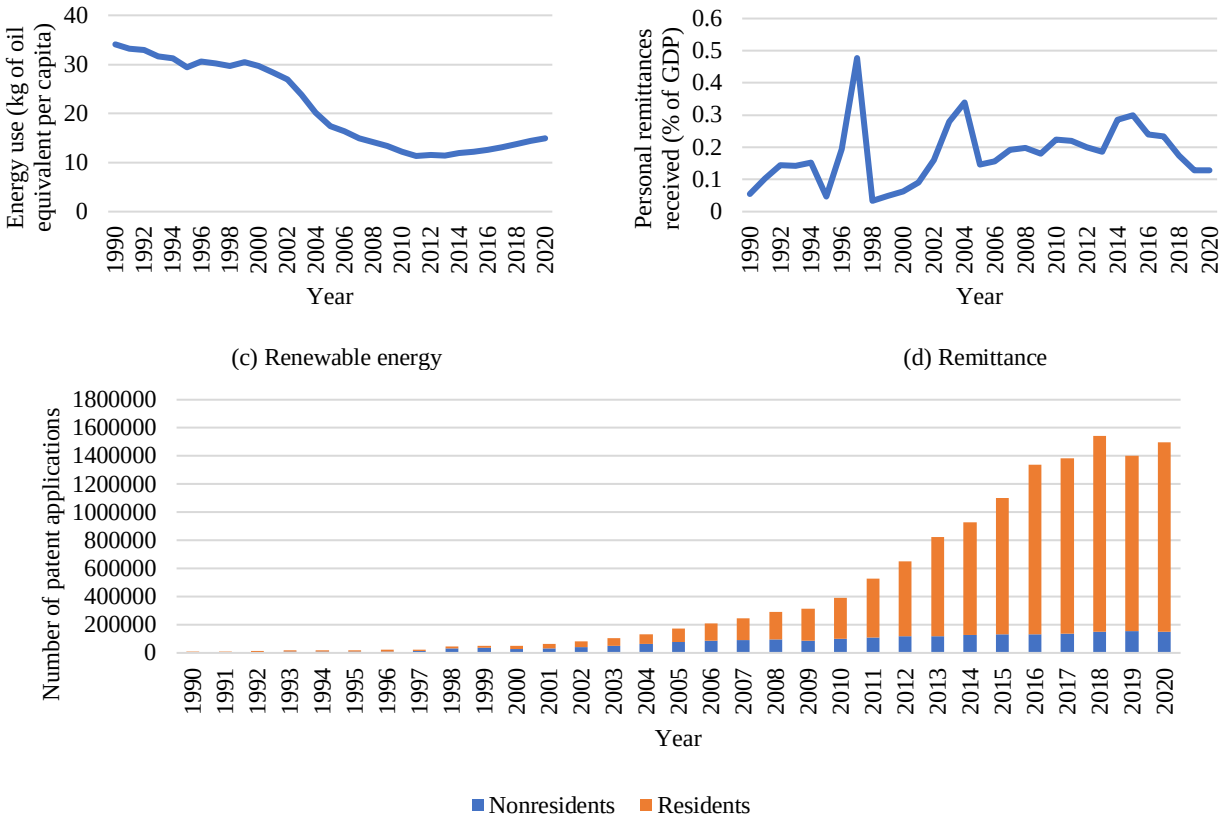
Variables	Description	Logarithmic structures	Measurement	Sources
CO_2	CO_2 emissions	LCO2	Kilotons	WDI
GDP	Economic growth	LGDP	GDP (constant local currency unit)	WDI
RE	Renewable energy	LRE	% of total final energy consumption	WDI
RM	Remittance	LRM	Personal remittances received (% of GDP)	WDI
TI	Technological innovation	LTI	Number of patent applications	WDI



(a) CO_2 emissions



(b) Economic growth



(c) Renewable energy

(d) Remittance

(e) Technological innovation

Figure 1. Annual trends of the study variables

The results of multiple normality tests are shown alongside a description of the data in Table 2. Aside from LRE, all the other variables have skewed-down values. It was clear that the dataset was normal because the skewness values were near to zero. In addition, kurtosis values below 3 were indicative of platykurtic variables. All the variables are normally distributed, as shown by the Jarque-Bera and probability values.

Table 2. Statistical summaries of the variables

Variables	LCO2	LGDP	LRE	LRM	LTI
Mean	15.49228	30.94357	2.972484	-1.885070	11.92112
Median	15.57761	30.94626	2.858766	-1.743394	12.06294
Maximum	16.24519	32.14215	3.528817	-0.739770	14.24859
Minimum	14.59178	29.48701	2.428336	-3.398328	9.223947
Std. Dev.	0.568082	0.830101	0.418653	0.619149	1.688196
Skewness	-0.113307	-0.134554	0.049932	-0.761010	-0.075365
Kurtosis	1.418219	1.752156	1.258076	2.134028	1.623464
Jarque-Bera	3.298122	2.104814	2.932183	2.015410	2.476864
Probability	0.192230	0.349096	0.140003	0.221418	0.289838

Strategies for Estimation

This investigation started with the data on all the important factors. In this study, the empirical model was then defined by drawing on previous studies. Several cutting-edge econometric techniques were applied to the defined empirical model to produce trustworthy findings for use in policymaking. Because of this, the stationarity property of the time series data was the initial focus of the inquiry. When the integration order of the series was defined, the study confirmed the stated model's long-term relationship. Following is our econometric model formulation for this investigation.

$$CO_{2t} = \tau_0 + \tau_1 GDP_t + \tau_2 RE_t + \tau_3 RM_t + \tau_4 TI_t + \varepsilon_t \quad (1)$$

where τ_1, τ_2, τ_3, and τ_4 represent the coefficients of the regressors. Moreover, εt represents an error term.

The analysis followed the method proposed by Pesaran et al. (2001), known as the ARDL model, as an effective estimating methodology to expose both short- and long-term relationships among the parameters of the specified model. This method has many advantages over the previous cointegration methods. The integration property of a series needed to be discovered before employing other cointegration procedures, whereas this method did not necessitate any such preliminary testing. By considering the lag length of the variable, the ARDL model can be utilized to account for endogeneity. Second, it is applicable in any investigational series integration scenario. Finally, the ARDL model maintains validity even with a little number of observations (Raihan & Tuspekova, 2022e). As indicated in Equation (2), the ARDL bound testing strategy can be written using the econometric model given in Equation (1).

$$\begin{aligned}\Delta LCO2_t = {} & \tau_0 + \tau_1 LCO2_{t-1} + \tau_2 LGDP_{t-1} + \tau_3 LRE_{t-1} \\ & + \tau_4 LRM_{t-1} + \tau_5 LTI_{t-1} \\ & + \sum_{i=1}^{q} \gamma_1 \Delta LCO2_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LGDP_{t-i} \\ & + \sum_{i=1}^{q} \gamma_3 \Delta LRE_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LRM_{t-i} \\ & + \sum_{i=1}^{q} \gamma_5 \Delta LTI_{t-i} + \varepsilon_t \end{aligned} \quad (2)$$

The short-run coefficient needs to be captured once the long-term relationship between series has been established. So, as indicated in Equation (3), we assessed the error-correction model and glean the short-run coefficients.

$$\begin{aligned}\Delta LCO2_t = {} & \tau_0 + \tau_1 LCO2_{t-1} + \tau_2 LGDP_{t-1} + \tau_3 LRE_{t-1} \\ & + \tau_4 LRM_{t-1} + \tau_5 LTI_{t-1} \\ & + \sum_{i=1}^{q} \gamma_1 \Delta LCO2_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta LGDP_{t-i} \\ & + \sum_{i=1}^{q} \gamma_3 \Delta LRE_{t-i} + \sum_{i=1}^{q} \gamma_4 \Delta LRM_{t-i} \\ & + \sum_{i=1}^{q} \gamma_5 \Delta LTI_{t-i} + \theta ECT_{t-1} + \varepsilon_t \end{aligned} \quad (3)$$

The error-correction dynamics and long-term linkages between the series are displayed in the aforementioned equation. The lag length of the series is denoted by q in Equations (2) and (3), and Δ stands for the first difference operator. In addition, ECT stands for the error correction term, and θ is the ECT's coefficient.

As a robustness evaluation, we also employed the FMOLS, DOLS, and CCR on the stated model to look at how different factors throughout time affected the CO_2 output. There were two main factors that prompted the need to employ these methods. To begin, the cointegration condition among the I(1) parameters must be satisfied before the FMOLS, DOLS, or CCR may be used. Second, these methods deal with endogeneity and serial correlation biases that arise from the cointegration relationship. As a result, it yields outcomes with asymptotic efficiency (Raihan & Tuspekova, 2022f; Raihan & Tuspekova, 2022g). The analysis flowchart is shown in Figure 2.

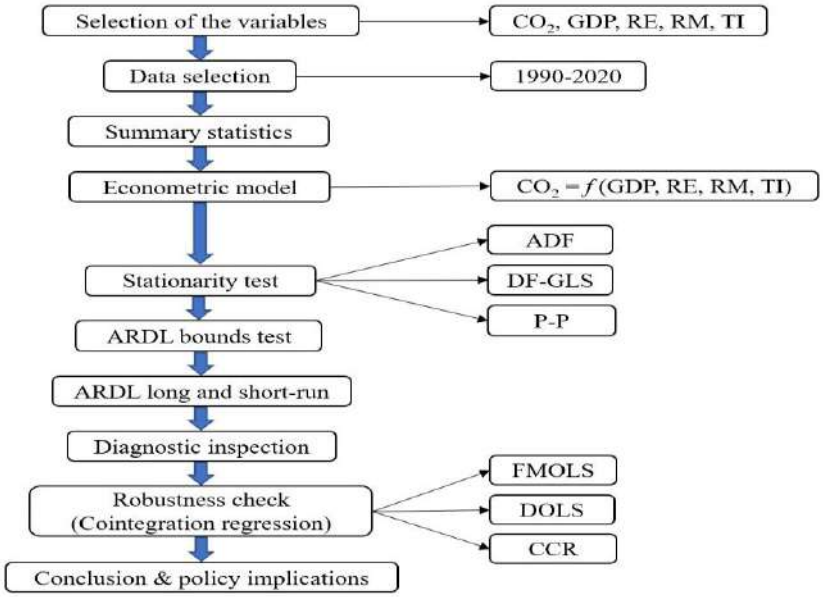


Figure 2. The analysis flowchart

Results and Discussion

The fundamental goal of this study was to investigate the development of a lasting connection between the series under consideration. The evaluation of the unit root test provides crucial information on the integration characteristic of the parameters, which is necessary for employing the approaches in the creation of a long-term interrelationship (Raihan & Tuspekova, 2022h). Therefore, the integration qualities of the series were investigated using a battery of conventional root tests, including the ADF, DF-GLS, and PP tests. The findings of the stationarity test are summarized in Table 3. According to the canonical tests of unit root output, all variables exhibited the unit root problem at level before becoming stationary after the first difference.

Table 3. Unit Root test results

Logarithmic form of the variables	ADF		DF-GLS		PP	
	Log levels	Log first difference	Log levels	Log first difference	Log levels	Log first difference
LCO2	-0.8829	-2.8147**	-0.0448	-2.8654***	-0.9402	-2.9203**
LGDP	-0.6012	-2.4312**	-0.8286	-2.5336**	-0.7498	-2.9232**
LRE	-1.4653	-2.9182***	-1.1148	-2.9076***	-1.1832	-2.9214***
LRM	-0.5267	-3.9012***	-0.6062	-3.1304***	-0.7682	-3.9222***
LTI	-1.0675	-5.1546***	-1.0832	-5.1112***	-1.1694	-5.1609***

The significance levels depicted by *, **, and *** are 1%, 5%, and 10% respectively.

Based on our unit root observations, we found that the series under examination is an I(1) series. Therefore, we used the ARDL-based bounds test technique to evaluate the long- and short-term connections between the series under investigation. Our model's consistent results from each alternative's information criterion led us to settle on the AIC as our lag specification. Table 4 shows that the calculated F-statistic (6.94) for the cointegration analysis is significantly higher than the upper critical threshold. We, therefore, conclude that the independent variable and the regressors are cointegrated.

Table 4. ARDL bounds test results

F-bounds test		Null hypothesis: No degrees of relationship		
Test statistic	Estimate	Significance	I(0)	I(1)
F-statistic	6.942595	At 10%	2.57	3.86
K	5	At 5%	2.86	4.19
		At 2.5%	3.13	4.46
		At 1%	3.43	4.79

Table 5. ARDL long and short-run results

Variables	Long-run			Short-run		
	Coefficient	t-Statistic	p-value	Coefficient	t-Statistic	p-value
LGDP	1.183***	2.342	0.002	0.369***	2.428	0.001
LRE	-0.881***	-3.671	0.000	-0.911**	-3.713	0.013
LRM	-0.754**	-1.467	0.029	-0.667**	-1.376	0.032
LTI	-0.445*	-1.672	0.059	-0.013*	-1.002	0.061
C	19.113	4.494	0.111	-	-	-
ECT (-1)	-	-	-	-0.464	-3.214	0.000
R^2	0.9913					
Adjusted R^2	0.9854					

The significance levels depicted by *, **, and *** are 1%, 5%, and 10% respectively.

Table 5 displays the findings of the ARDL long- and short-run estimation. The empirical results demonstrated a positive and statistically significant coefficient of LGDP, which means that a 1% increase in GDP leads to a 1.18% (long-term) and 0.37% (short-term) increase in CO_2 emissions, respectively. In assertion, China's rapid economic development has negative effects on the environment both immediately and over the long term. In addition, the coefficient of LRE was negative and statistically significant, indicating that a 1% increase in the

usage of renewable energy might lead to a 0.88% (long-term) and 0.91% (short-term) reduction in CO_2 emissions. Inferences about renewable energy being beneficial to environmental sustainability were drawn from the outcome. The coefficient of LRM was also negative and statistically significant, showing that an increase of 1 percentage point in LRM results in a decrease of 0.75 percentage points in CO_2 emissions in the long run and 0.67 percentage points in the short run. Both the short-term and the long-term estimates showed that remittances to China have a positive effect on environmental sustainability. In addition, the coefficient of LTI was negative and statistically significant, suggesting that a 1% increase in LTI contributes to the reduction of CO_2 emissions by 0.45% (long-term) and 0.01% (short-term). The results showed that if China invests more in technical innovation, it may be able to slow the rate of environmental deterioration.

The ECT was also found to have very detrimental results. This estimate of 0.464 showed how the short-run equilibrium evolved as it moved toward a stable long-run equilibrium, with annual adjustments of 46%. It demonstrated the value of the feedback system in maintaining stable CO_2 emissions in China. Finally, there was no evidence of serial correlation or heteroskedasticity in the residuals, and the residuals followed a normal distribution without any signs of misspecification, as shown in Table 6 of the diagnostic test findings. Figure 3 further displays the results of the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMSQ) stability tests, which demonstrated the model's stability at the 5% significance level.

The findings of the ARDL framework were also tested over the long term with the help of the FMOLS, DOLS, and CCR tests. Table 7 displays the projected results from the use of FMOLS, DOLS, and CCR. The sign and reliability of the FMOLS, DOLS, and CCR results were all shown to be consistent and dependable. This causes them to produce the same results as the ARDL simulations in the long term. Specifically, the data showed that increasing GDP increased CO_2 while increasing renewable energy, remittances, and technical innovation decreased CO_2 emissions. As a result, decisions can be made with an element of certainty based on the findings.

Table 6. Diagnostic tests results

Diagnostic tests	Coefficient	p-value	Decision
Serial Correlation	1.8972	0.277	No serial correlation exits
Heteroskedasticity Test	1.2356	0.187	No heteroscedasticity exists
Normality Test	0.9235	0.234	Residuals are normally distributed

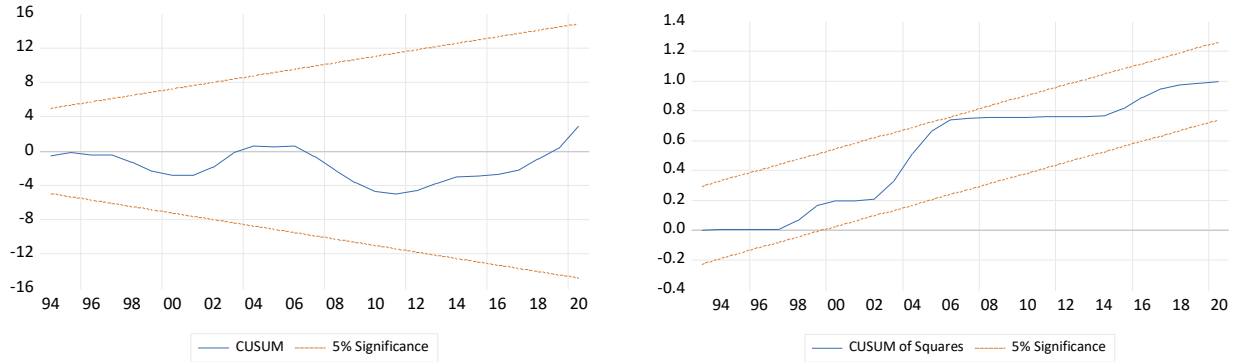


Figure 3. Results of the CUSUM and CUSUMQ test

Table 7. Results of the robustness check

Variables	FMOLS		DOLS		CCR	
	Coefficient	t-Statistic	Coefficient	t-Statistic	Coefficient	t-Statistic
LGDP	1.124***	2.418	1.132***	2.154	1.211***	2.223
LRE	-0.819***	-3.864	-0.798***	-3.156	-0.818***	-3.369
LRM	-0.881**	-1.436	-0.862***	-1.723	-0.895***	-1.121
LTI	-0.234*	-1.478	-0.493**	-2.154	-0.359**	-1.953
C	21.713	3.982	19.699	3.294	20.801	3.815
R^2	0.9956		0.9943		0.9967	
Adjusted R^2	0.9813		0.9801		0.9809	

The significance levels depicted by *, **, and *** are 1%, 5%, and 10% respectively.

The present study's result show that as the economy grows, so does the incentive to increase CO_2 emissions, as measured by the gross domestic product (GDP). This indicates that China's efforts to stimulate its economy through techniques that aren't environmentally friendly are counterproductive to the country's efforts to achieve carbon neutrality. This result is consistent with the claims made by Liu et al. (2017b), Azam et al. (2022), Raihan et al. (2022b), Raihan et al. (2022f), Raihan et al. (2022h), Raihan and Tuspekova (2022b), Raihan and Tuspekova (2022e), Raihan and Tuspekova (2022f), Raihan and Voumik (2022), Raihan and Tuspekova (2022g), Raihan et al. (2022g), Raihan and Tuspekova (2022i), and Zafar et al. (2022) in which the authors argued that economic development degrades environmental quality. The availability of affordable, reliable energy sources is also crucial to the success of any economy (Raihan & Tuspekova, 2022j). It's a primary factor in both the final product and the final consumer. There is no denying the importance of energy to people's day-to-day lives. Thus, we included renewable energy sources to test their potential impact on the model's projected CO_2 output. Findings demonstrated that adjustments in China's use of renewable energy resulted in lower CO_2 emissions. Our findings are supported by Liu et al. (2017a), Zoundi (2017), Chen et al. (2019), Liu et al. (2017b), Azam et al. (2022), Raihan et al. (2022b), Raihan et al. (2022f), Raihan et al. (2022h), Raihan and Tuspekova (2022b), Raihan and Tuspekova (2022e), Raihan and Tuspekova (2022f), Raihan and Tuspekova (2022g), Raihan and Voumik (2022), Raihan and Tuspekova (2022k), and Raihan et al. (2022g) who reported that green energy improves environmental conditions.

The present study's result on the negative association between remittances and carbon emissions is in line with the results of Zafar et al. (2022), Wang et al. (2021), Yang et al. (2020) and Ahmad et al. (2019). An increase in remittances in this example has resulted in lower CO_2 emissions through scale-dependent consequences in the production process, namely, a shift toward energy-efficient inputs at the small and medium enterprises (SME) and industrial levels. A person's disposable income can be increased by receiving remittances. Doubtlessly, a household's newfound financial flexibility can be put to use in one of two ways. The first is concerned with financial outlays, and the second is with financial reserves. When the spending pattern is in place, the demand for goods rises, influencing the manufacturing sector and, by extension, the demand for energy. When consumers are actively saving, they spend more of their increased income on interest payments to financial organizations. These businesses lend the money they have raised to industrial groups in order to make interest revenue, which again results in indirect energy consumption. Our results show that, when all the data is considered, remittances tend to move in the direction of renewable energy sources.

Findings from this study indicated that technological progress was inversely related to carbon dioxide emissions. These results stress the need for the government to invest in new technology for the country's manufacturing sector in order to create a setting that is receptive to industrial change. These findings provide essential data for designing policies that adhere to the resolutions adopted at the global climate change conference. The present study's finding is aligned with the previous studied. For example, Ahmed et al. (2016), Raihan et al. (2022b), Chen and Lee (2020), Raihan and Tuspekova (2022b), Raihan and Voumik (2022), Raihan et al. (2022f), Raihan et al. (2022h), and Shahbaz et al. (2020) demonstrated how new technologies can aid in cutting down on carbon dioxide emissions. On the other hand, the results of our study provide useful insight for policymaking and may be trusted because they were derived from state-of-the-art research techniques. These findings can serve as a foundation around which China can build its future technological advancements and environmental policies.

Conclusions and Policy Implications

Using data from 1990 to 2020, this study analyzed the impact of economic growth, renewable energy, remittances, and technical innovation on China's CO_2 emissions. For this reason, the investigation used the FMOLS, DOLS, and CCR long-run estimators in addition to the ARDL model to ensure the reliability of the findings. The economic expansion increases CO_2 emissions, but renewable energy, remittances, and technical innovation reduce CO_2 emissions over the long term, as shown by the outcomes of the ARDL, FMOLS, DOLS, and CCR. There may be major policy implications resulting from this study's conclusions. The study's finding of an inverse relationship between emissions and remittances may motivate governments to take steps to mitigate remittances' detrimental effects on the environment. People can be encouraged, for instance, to invest their remittances in energy-efficient household gadgets. In a similar vein, China may tighten up its existing regulations on controlling emissions. In conclusion, the current research suggests expanding ecological quality improvement efforts in response to a rise in remittance payments.

This study has important policy implications, as it recommends that China implement R&D and technology innovation related to its 2060 carbon neutrality aim. The government of China should increase spending on research and development while simultaneously encouraging private sector funding of R&D to develop technologies that improve environmental well-being. For China to achieve low-carbon growth as soon as possible, the government should prioritize the development of green technologies in this area. China should also look ahead to fostering green economic activities in order to gradually eradicate the negative consequences of economic expansion on the

ecosystem. Investment in renewable energy facilities, as opposed to new coal power plants, is one suggestion for China to consider.

This investigation found conclusive evidence that using renewable energy sources helps reduce pollution. Renewable energy sources cut emissions in any scenario, regardless of a country's current emission position. However, there are substantial infrastructure requirements for renewable energy. Once implemented, however, these technologies pay for themselves over time. Energy supply stability in China is essential, and it must begin with the use of renewable energy sources because of their lower cost. Therefore, China requires investment in renewable energy. Moreover, investment in green technologies will increase renewable energy, leading to better ecological quality because renewable energy is driven by technological advancements in the fields of biomass, geothermal, wind, and solar. Finally, green growth has not yet begun in China, as environmental deterioration has increased alongside economic development. Right now, transitioning to a green economy is crucial for long-term prosperity. This study suggests Chinese policymakers use the following tools: (i) reducing or eliminating tax cuts to increase remittances; (ii) encouraging and aiding the financial industry in developing internet applications; and (iii) providing training on ecological consciousness to all private and public sectors, especially educational institutions.

Despite the fact that the current study yielded substantial empirical findings in the case of China, our analysis has some flaws that might be addressed in future research. One of the critical drawbacks of our analysis is the unavailability of the data related to renewable energy use and technological innovation beyond the period of study, which limits the power of the econometric techniques used. However, this study has examined the nexus among economic growth, renewable energy use, remittance, technological innovation, and CO_2 emissions in China. Further studies can explore the potential of other determinants of emission reduction, such as increasing forested areas, recycling products, reducing water and electricity use, changing food habits to organic food, etc. Furthermore, this study utilized CO_2 as an indicator for environmental degradation from GHGs emissions. More research could be done utilizing consumption-based carbon emissions as a proxy for environmental deterioration, as well as other emission indicators, including nitrous oxide (N_2O), sulfur dioxide (SO_2), methane (CH_4), and other short-lived climate forces (SLCF). Nevertheless, CO_2 emission is regarded as a proxy for environmental pollution in this study, which is not the only cause of declining environmental sustainability. Future research might investigate more environmental pollution indicators, such as water pollution, land pollution.

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RESEARCH ARTICLE

An empirical analysis of Climate Change mitigation by Solar Energy

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Abstract

The study is based on the data collected from the Ministry of New & Renewable Energy - Government of India to assess energy consumption across the country. This study also collected data from relevant agencies responsible for energy supply to various residential, commercial, industrial, and transportation sectors. The equivalent carbon emissions from the selected fuel and energy sources operations are calculated using Gen Less Tools, a unique and customised emissions calculation tool. India has surpassed Germany to become the world's fourth-largest solar power installation country. Solar power capacity has increased more than sevenfold in the last five years, from 6.7 GW in 2016 to 44 GW in August 2021. Solar tariffs in India are highly competitive and have reached grid parity. In nine states with a considerable percentage of solar power installed, emissions were reduced by 42227 thousand tonnes.

Keywords: Climate Change; solar energy; mitigation; fossil fuels; technology

Introduction

Climate change is a cause for concern in India. For survival, a large portion of the country's population relies on climate-sensitive industries, including agriculture, forestry, and fishing. Increased severity of drought and flooding may jeopardise food security and economic viability due to climate change's adverse effects, such as decreasing rainfall and rising temperatures. In addition, the country's adaptive capacity to climate change is harmed by poor infrastructure, weak institutional systems, a lack of financial resources, and significant sectoral and regional diversity. Climate change might put even more strain on ecological and socio-economic systems already under enormous strain due to increasing urbanisation and economic expansion (Wei & Ye, 2014). Climate change has been regarded as a scientific, economic, or ethical concern at various periods. Climate change is now considered a development concern in India to attain high levels of economic growth (Stern, 2013). It was securing improvements in the standard of living of the people in India that required increased economic growth. However, herein lies the paradox of the climate change-development nexus.

Energy demand and consumption are driven by economic growth. For both power generation and transportation, most of this energy comes from the combustion of fossil fuels. Sulphur dioxide (SO_2) and carbon dioxide (CO_2) are produced by fossil fuels (CO). These compounds contribute to acidification and climate change (Armaroli & Balzani, 2011). Electricity is a powerful infrastructural resource that contributes to climate change when generated by thermal power stations. As of August 2021, India's national electric grid had an installed capacity of 388.134 GW(Lee & Lee, 2019). Of this current installed generation capacity, as of August 2021, India has a total Thermal installed capacity of 234 GW, of which 53% of the thermal power is obtained from coal and the rest from Lignite, Diesel, and Gas, meeting the lion's share of the nation's power demand. This indicates a grave problem of air pollution due to power generation by fossil fuel.

Electricity generation through solar energy is an environmentally friendly option. It has been used as a substitute for thermal power stations. Though solar energy is considered a substitute for thermal power, India cannot withdraw the existing thermal power stations. As the size and rate of growth of the population in India is at a high rate, and as the nation has the responsibility of providing its subjects with an uninterrupted power supply, it is forced to allow the existing thermal power stations to operate. The nation ought to do that the further increase in power demand ought to be met by solar power energy has significantly impacted the Indian energy market in recent years. Solar energy-based localised and distributed

applications have helped millions of people in Indian communities, allowing them to meet their cooking, lighting, and other energy needs in an ecologically benign manner. As a result, this study aims to investigate the potential of solar energy in India to mitigate climate change. Furthermore, because solar energy may replace coal-based thermal power plants, this research examines the potential of solar energy to reduce climate change.

In climate change, mitigation refers to human actions that reduce greenhouse gas sources or increase greenhouse gas sinks. Using fossil fuels more effectively for industrial operations or electricity generation, transitioning to solar or wind power, increasing building insulation, and growing trees and other sinks to take more CO_2 from the atmosphere are just a few examples (Fawzy et al., 2020)

Review of literature

Consumption of fossil fuels and CO emission In India

India is ranked third globally, with 2.46 billion metric tonnes of carbon emissions, or 6.8% worldwide. However, India's carbon emissions per capita are still low, at 1.84 tonnes, compared to the US's 16.21 tonnes. Though India is the third-largest CO emitter globally, it managed to control the CO emissions into the atmosphere thanks to the hectic efforts to develop renewable energy technologies (Pathak & Shah, 2019). It believes that higher economic development and a stress-free environment can achieve with renewable options like solar energy. Therefore, its economic development efforts have always been guided by the principles of sustainable development, with a commitment to a greener environment.

World Solar energy Scenario

Solar energy is the world's fastest-growing alternative energy source. Ten nations accounted for about 90 per cent of the solar power installed capacity in the world. India is one of the world's most important countries and has occupied fourth place in the top ten nations. The installed solar power capacity of the top ten nations is depicted in Table 1 (*Statista - The Statistics Portal for Market Data, Market Research)*

Table 1. Country-wise solar energy installed capacity

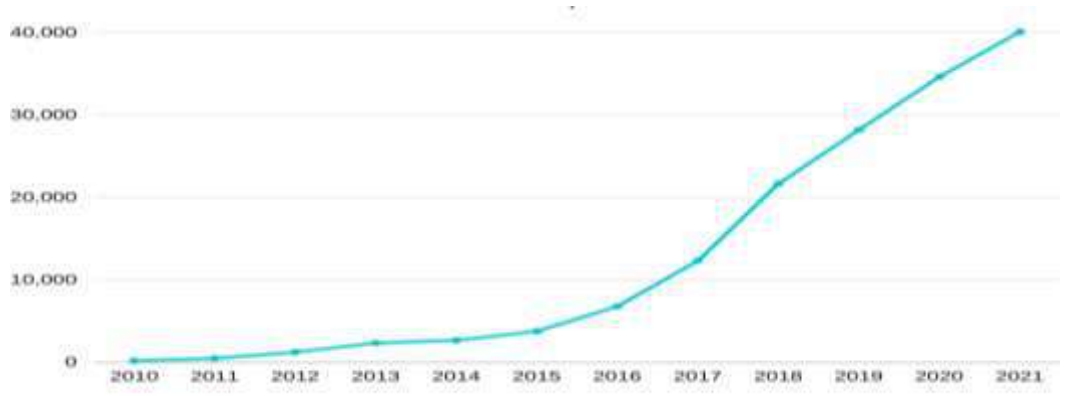
SNo	Country	Capacity in Gigawatts
1	China	895
2	USA	292
3	Brazil	150
4	India	134
5	Germany	132
6	Canada	101
7	Japan	101
8	Italy	55
9	France	55
10	UK	50

Source:Statistica

India's performance is well above Germany, Canada, and Japan. Though India ranks fourth, its installed capacity is nearly six times lower than the installed capacity of China, which stands first. Anyhow, the solar power development of India can not be undermined. It is a promising one. So, studying the climate change potential of solar energy in India will help the nation maintain an emission-free environment.

Solar energy Scenario in India

In the recent decade, solar power has received much interest and priority. Solar farms became operational in India in the last five years, and it took a few more years for this technology to be fully established. By the beginning of the twenty-oneth century, solar technology overcame most of the teething problems faced in the field and pronged its technical viability. Since then, it has received significant thrust and backup from industries, technocrats, policymakers, financial organisations, and other agencies. As of August 2021, the country's solar installed capacity was 44.3 GW, and further additions are expected to be faster in the coming years (*Solar Panel Making Company In India, Solar Companies In India | IBEF*, n.d.). The CO emission can be reduced to the extent of solar power projects installed in India. So, the solar power installed capacity is of grave concern here. Considering the importance of solar power installed capacity in mitigating the CO2 emission, India's year-wise installed capacity is examined in graph 1.



Source: renewable India, yearly solar energy power installation in India

Graph 1 shows a clear picture of India's year-wise solar power installed capacity. On the X-axis, the years 2010 through 2021 are represented, while on the Y-axis, the change in installation measured in megawatts (MW) is shown. Year after year, the installed capacity increased at a remarkable rate. The solar power installed capacity was 161 MW in 2010. It increased to 40,085 MW from 2020 to 21 (Suganthi & Williams, 2000). During the years between 2015 to 2018, the installed capacity had been raised by more than doubled. From 2010 to 2021, the annual solar power installed capacity exhibited a rising trend, as seen in the table above. The annual increase in the installed capacity is 411 MW. The annual Compound Growth Rate of the installed capacity from 2010-2021 is 154 per cent.

Methodology

CO Emission Reduction Potential of Solar energy in India

Solar energy is one of the most efficient forms of renewable energy. It is essential to the maintenance of a pollution-free environment. Estimating the environmental advantages of solar energy-generated electric power is based on coal displacement in power generation. One unit of electric power generated by solar energy can displace one unit from coal-based electricity generation. So, one unit of power generated by solar energy can mitigate environmental pollution emissions caused by coal combustion to generate one unit of power in coal-based thermal power stations. The CO emissions mitigated by solar energy depend upon the total annual useful energy and the amount and type of fossil fuel replaced. This analysis accentuated that increased use of solar power can reduce the need for new coal-fired power plants, thereby slowing down both coal depletion and atmospheric pollution. The CO emission reduction calculation has been based on the following formula (Marques et al., 2015).

$EC(t) = C(t) \times O_c \times N_c \times M$

Where EC(t) is the carbon dioxide emission from coal combustion.

C(t) is coal consumption in Tera joules.

Oc is the carbon emission factor of coal (25.8/TJ)

Nc is the fraction of carbon oxidised of coal (0.98) and M is the molecular ratio of carbon dioxide to carbon (44/12)

In table 3, the state-wise CO_2 emission abatement potentials of solar power in India is examined.

Table 3. Statewise CO2 emission mitigation potential of solar energy in India

State	*solar power Generation (MW)	Coal saving in Thousand Tonnes	Energy Content in (TJ)	*CO_2 emissions reduction (in thousand tonnes)
Rajasthan	8076.70	3052.99	91193.00	8182.00
Karnataka	7469.01	2823.28	84331.00	7566.00
Gujarat	5987.39	2263.23	67603.00	6065.00

Tamil Nadu	4675.23	1767.15	52785.00	4736.00
Andhra Pradesh	4380.28	1655.74	49457.00	4437.00
Telangana	3992.13	1509.10	45077.00	4044.00
Madhya Pradesh	2633.60	995.50	29736.00	2668.00
Maharashtra	2444.64	924.07	27602.00	2477.00
Uttar Pradesh	2025.48	765.63	22869.00	2052.00

Source: computed/ *mnre.gov.in/

Results and Discussion

India is a tropical country that gets a lot of sunlight year-round. About 5,000 trillion kilowatt-hours of electricity are delivered to India annually, with most areas receiving between 4 and 7 kilowatt-hours per square meter. During the past several years, solar energy has dramatically impacted India's energy landscape (Jin et al., 2022). According to the CEA 2021, India's solar energy generation increased to around 12%of the increasing renewable energy capacity, implying that India needs to raise this to fulfil the 50% electricity generation objective by 2030. Rajasthan, Karnataka, Gujarat, and Tamil Nadu have significantly reduced CO2 emissions through solar power. The emission reduction potential of solar energy in these states is 26,549 thousand tonnes. Andhra Pradesh and Telangana have a percentage share of the total CO_2 emission reduction capacity of 10.12 and 9.52, respectively. Madhya Pradesh, Maharashtra, and Uttar Pradesh have a minimal share of the total. High sulphur, volatile matter, vitrinite, and low ash content are just a few of the peculiar Physico-chemical features of northeast Indian coals (Arjunan et al., 2009). As a result of its rarity and widespread industrial use, mining it has a reputation for leaving a more significant ecological footprint. Large-scale landscape degradation, soil erosion, deforestation, declining wildlife populations, and air, water, and soil pollution are only a few environmental problems (CRK & VK, 2019). Therefore, a considerable shift in demand for the remaining power-producing units results from the widespread adoption of solar energy as an alternative to coal. Therefore, solar electricity is India's ideal alternative to coal, which is undergoing significant socio-economic development.

The state of Rajasthan has long enjoyed a climate ideal for producing renewable energy, and recent policy changes have helped to further encourage this trend. In addition to funding infrastructure improvements in the renewable energy industry, the state government offers numerous incentives for such initiatives (Dogan et al., 2022). There is now a more favourable climate for investors partly due to efforts like the Rajasthan Investment Promotion Scheme 2019 and others. The RIPS 2019 emphasises renewable energy as a critical industry, per the state's directive. The 26th United Nations climate change conference saw the adoption of policies that have since been shown to have far-reaching social and economic benefits (Clémençon, 2016). After COP26, India made a promise to increase its use of renewable energy to cover half of the country's energy needs by 2030, as well as to double its ability to generate power from sources other than fossil fuels to 500 GW by the end of the decade.

Conclusion

Solar power can help reduce CO_2 emissions into the atmosphere and save the environment from acute air pollution and global warming. As there is no possibility of replacing the existing thermal power stations, solar farms may replace new thermal power stations. As CO emission poses global warming, every country has to take strenuous steps to develop this new strategy faster. India has much scope for solar power installation. However, it has miles to go to tap it fully. So far, private investment has been responsible for the growth of India's solar industry. The government is also doing its part to promote the solar energy business in the country by providing a number of incentives and new programmes. That guarantees a sustained increase in solar power capacity to meet the nation's energy needs without negatively impacting society, the economy, or the environment. So, India is improving its Solar energy technology to accomplish the goal of fuller utilisation of the available Solar potential. If these positive trends persist, solar energy will be the only Source of electricity that doesn't contribute to global warming.

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beliefs) in the subject matter or materials discussed in this manuscript.

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RESEARCH ARTICLE

Novel Blade Design and Performance Evaluation of a Single-Stage Savanious Horizontal Water Turbine

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Abstract
A type of micro-hydropower turbine known Savanious horizontal water turbine operates in freely flowing water of streams, canal, rivers etc. In a current study, blade shape and flow rates were used as the basis for an experimental assessment of a single- stage savanious horizontal water turbine. Numerical, experimental and statistical methods have used to examine the impact of blade shape and flow rates on performance metrics like rotational speed, torque and efficiency. The finding indicates that round curved blades performed better than semicircular and straight curved in terms of overall performance such as torque, rotational speed and efficiency. The performance comparison in term of efficiency amongst round curve blade, semicircular blade, and straight curve blade is carried out and found the maximum efficiency of 47.7%, 39.5%, and 36.5% at respectively at their corresponding speed of water 0.004 m^3/s. However, the turbine's performance over optimum flow rates of 0.004 m^3/s was found to be decreased due to the increase of water depth and higher water pressure. Moreover, output response was found to be significantly impact by all input parameters through ANOVA method.

Keyword: Savanious turbine; Blade shape; Numerical analysis; Torque; Rotational speed; Efficiency

Introduction

Among all renewable energy sources such as; solar, geothermal, hydropower, and wind, the most powerful and cost-effective is micro-hydropower (Sharif, Siddiqi et al. , Tipu, Arif et al. , Ekanayake 2002). A micro-turbines such as Kaplan turbines (10-70 m), Francis turbines (40-600 m) and Cross flow turbines (1.5-100 m) are a rich source of renewable energy but their heads are greater and need higher flow rates which depend upon the availability of larger water fall and rivers (Nasir 2013, Shoukat, Noon et al. 2021). To address these issues, a possible way is to design a savanious horizontal water turbine that should extract power from low flow rates beneath the water. Savanious horizontal water turbine (SHWT) is a small micro-hydropower in which the turbine lies under-water. It is a self-starting turbine and generates more power at low water speed (Wanchat, Suntivarakorn et al. 2013). A SHWT generates electrical energy from natural flowing water. It operates on a low volume of water and is installed inside the canal and river water (Banshwar, Sharma et al. 2017). The basic construction of a SHWT consists of two drums and having a rotor between them. A rotor consists of blades and a shaft attached to the blades. When the water directs the rotor, the water introduces rotational energy to the rotor. A generator is then used to convert the shaft rotational energy into electrical energy (Roth 1985, Iio, Katayama et al. 2011). A SHWT needed zero civil work, lower maintenance costs, and a minimum depth of water (Ullah, Siddiqi et al. , Williams 2003).

In the past, several authors worked on SHWT. (Khan, Islam et al. 2009) et al. used different Reynolds numbers for aspect ratios of α=1.82 and overlap ratio of β=0.207 to achieve the maximum efficiency. (Nakajima, Iio et al. 2008) worked on a conventional savonius water rotor with α=1.48, β=0.36, and Reynolds number of 1.1×10^3 and found the maximum power by changing the distance between the bottom wall of the channel and rotor. (Huda, Selim et al. 1992) enhanced efficiency through reduction of drag force on the returning blade through deflector plate to minimize reversing torque on returning blade. (Abulnaga 1988) et al. compared the wind turbine and water rotor turbine and investigated that a savanious horizontal water turbine needs nine-times less water speed than that of air speed for wind turbines. (Blackwell, Feltz et al. 1977) absorbed that blade overlapping is the important parameter for SHWT. Blade overlap is dominantly associated with the turbine performance. (Fujisawa 1992, Fujisawa 1996) reported that overlapping of blades could significantly affect the performance of

savanious horizontal water turbines. Savonius turbine with overlapping blades has lower performance compared to SHWT without overlapping blades. (Kamoji, Kedare et al. 2009) enhanced the average power of a SHWT by decreasing number of blades overlap to minimize negative torque on returning blades. (Nasef, El-Askary et al. 2013) has performed study and improved overall performance of SHWT with an overlap ratio of 0.15.

In the previous literature, limited work was performed on blade shape of SHWT. Therefore it is need to evaluate and maximize the performance of SHWT by designing a novel blade shape with varying water flow rates. The aim of this work is to investigate the influence of blade shape and flow rates on the performance evaluation of the SHWT.

Material and Method

Modeling of Savanious Horizontal Water Turbine

The blade are fabricated having thickness of 3 mm and blade radius of 45 mm in the form of a straight, semi-circular and round curve with an inside stiffener plate and without a stiffener plate. Then the fabricated turbine blade is attached to the turbine runner of diameter 30 mm. The diameter and length of turbine are 120 mm and 100 mm.

Numerical Analysis

Computational Domain and Boundary Condition

The challenging and time-consuming task for numerical analysis is the creation of the computational domain. In a current study, a 3D model of the savonius horizontal water turbine is generated in ANSYS Design Modeler. The cylindrical volume is generated in Z-axis that enclosure the savonius horizontal water turbine because the turbine can rotate in specified angular velocity. Furthermore, the interface is created between the flow field and the rotating zone to ensure flow field continuity. Fig 1 shows the complete computational domain of the system.

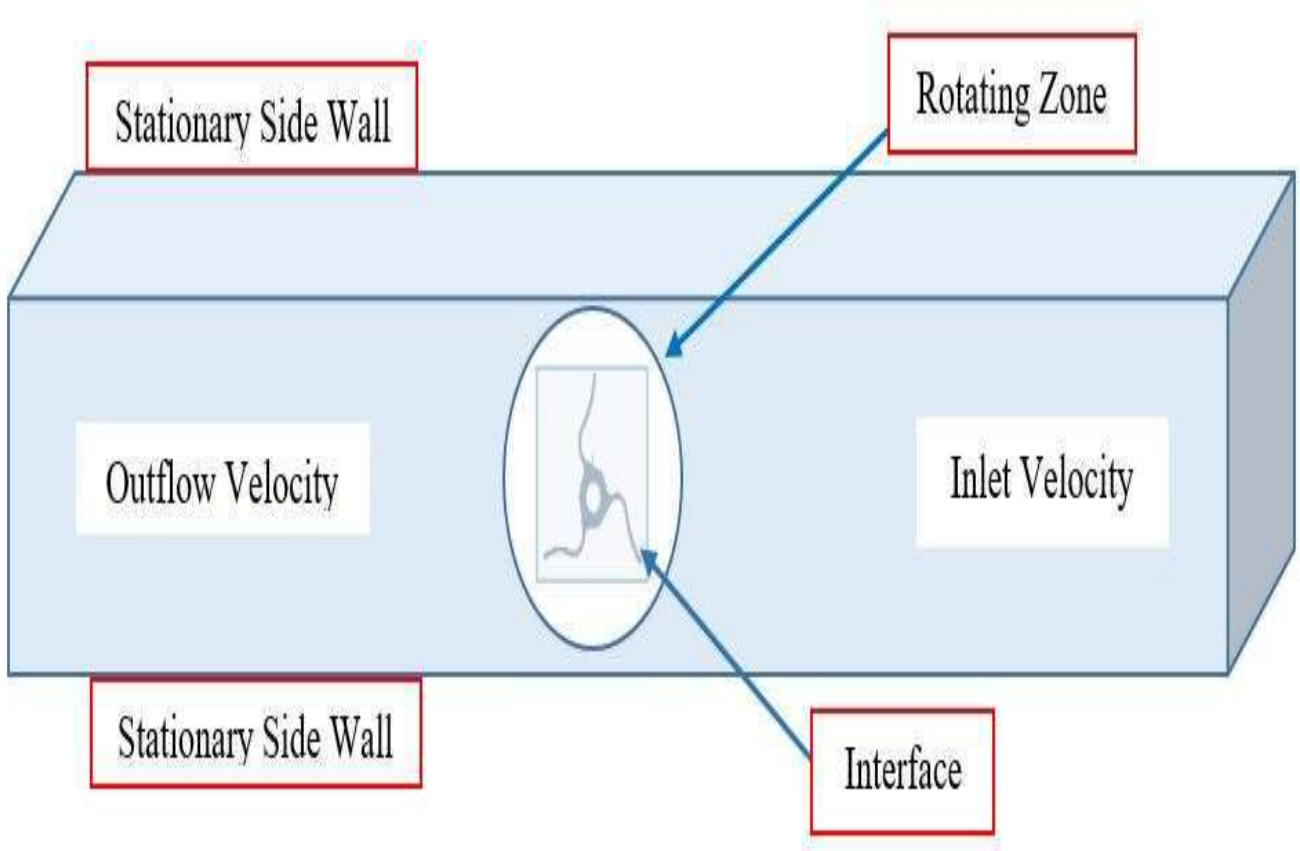

Figure-1: Computational Domain of the system

Simulation

Geometry of the turbine is imported into ANSYS Fluent and used as a flow solver with the help of finite volume

discretization to solve the unsteady incompressible Navier Stokes equation. During initialization, stationary and rotating domains are required. The fluid domain is stationary domain and the geometry is the rotating domain. The rpm of the turbine depends upon the input parameter of the current study. The rpm of the rotating domain is set as 200 rpm and inlet velocity of water is taken 1 m/s. The inlet velocity of water is fixed to get the result of water pressure inserted on turbine blades. The time step size of 0.015 is selected and run the calculation. In a current numerical analysis the number of step is 100 and number of iteration is 10. The water pressure inserted on the blades of savanious horizontal turbine can set as a output parameter. Moreover, the shapes of the blades were selected the basis of water pressure inserted on the blades of SHWT. A total of 30 different conceptual designs were generated in which 20 best models were design in solid work. 10 out of 20 models were recommended for simulation. Three different types of blades shape such as round curved turbine, semicircular turbine and straight curved turbine were selected from the simulation. According to simulation shown in figure 2, the water pressure inserted on the round curved turbine is higher than semicircular turbine and straight curved turbine. A more water pressure is inserted on the maximum surface of round curved turbine. This is due to the shape of round curved blades which enhance to absorb maximum water pressure. Furthermore, a maximum water pressure enhances to generate maximum torque with higher rotational speed.

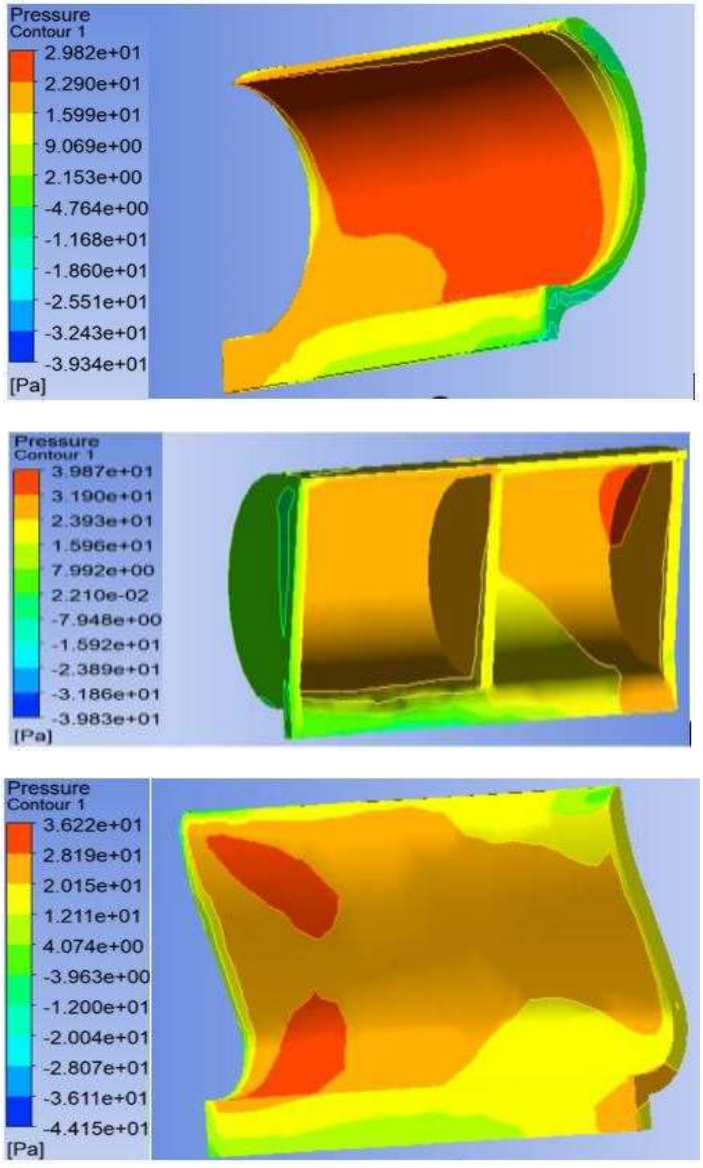

Figure 2: Simulation Result for three blade shapes

Design of Experiment and Analysis of Variance

Design of Experiment (DOE) is a statistical method used to identify process parameters that affect the output variable significantly (Habib, Sharif et al. 2021, Habib, Sharif et al. 2022). Moreover, it is used to study the behavior of two or more factors and identify the significant level (Hussain, Sharif et al.) . In a current study, Minitab 19 software was used to design a factorial approach to analyze each factor properly. The number of factors includes blade shape and flow rates, and each has three levels, as shown in table 1. Finally, Analysis of variance (ANOVA) was performed to investigate the effect of input parameters effects and their percentage contributions on the output response. ANOVA is a valuable statistical tool for determining the impact of input parameters on experimental findings in any process using an adequate design of experiments. It is a decision-making method for detecting the significance of process parameters and how they affect the response. In this work, input parameters were blade shape and flow rates whereas the output parameters were rotational speed, torque, and efficiency.

Experimental Set up

The experimental setup is placed in the titling fume of 350 mm x 150 mm. Water is supplied from a water storage tank with the help of a centrifugal pump through a 125 mm diameter pipe and then circulated back to the water storage tank after passing through a titling fume. The experimental setup for the SHWT consists of a structured house. The SHWT is placed in the structure house with the help of two bearings and a central shaft in between them. Using nylon thread, two digital spring balances with an accuracy of 0.02% are attached to the braking pulley mounted on the turbine central shaft to form a prony brake dynamometer for measuring torque. A digital tachometer has an accuracy of ±0.01% and an operating range of 1.0–20000 RPM (Lotron DT-2236B) to measure the rotational speed. Friction is another critical parameter that must be minimized because it affects the torque measurement. Moreover, the lubricant is used to reduce the friction of the bearing. The flow rates are measured with water flow meter having an accuracy of ±0.02%. The following equations are used to express these parameters (Golecha, Eldho et al. 2011, Elbatran, Ahmed et al. 2017, Patel, Bhat et al. 2017, Sharif, Siddiqi et al. 2020).

$$C_p = \frac{P_{out}}{P_{in}} \quad (1)$$

$$P_{in} = \tfrac{1}{2} \rho A V_3 \quad (2)$$

$$P_{out} = \frac{2\pi NT}{60} \quad (3)$$

$$T = 9.81 \times (W-S) \times (r_p + d_r) \quad (4)$$

$$C_q = \frac{T}{\frac{1}{2}\rho A V_{2R}} \quad (5)$$

Where T is the torque of the turbine, N is the rpm of the turbine, T and S are the tension in tight and slack sides, r_p is the pulley radius, and d_r is the string diameter.The experimental set-up and systematic of a single-stage SHWT is as shown in figs.3 and 4.

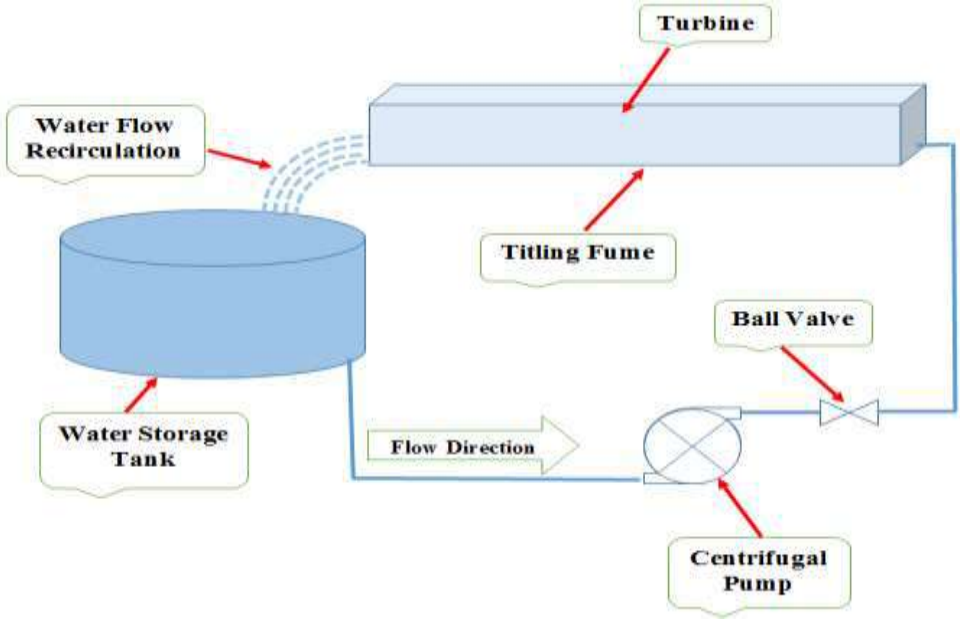

Figure 3: Schematic of experimental set up

Figure 4: Experimental Set Up of SHWT

Results and Discussion

Effect of Blade Shape and Flow rate on Rotational Speed

The SHWT is designed to run on a low-flow water stream and has a low-efficiency rating. As a result, improving the turbine's performance, either by augmentation techniques or changing the blade shape, is crucial. Changing the blade shape of wind turbines has been proven effective (Banerjee, Roy et al. 2014, Alom, Kolaparthi et al. 2016). However, minimal studies were performed on the effects of changing blade shape on SHWT. It is found that round curved blade shape has a higher rotational speed than the semi-circular blade profile and straight blade profile. The round curved blade shape turbine, semi-circular blade shape, and straight blade shape turbine rotate at 40 rpm and 76 rpm, 38 rpm, and 68 rpm, and 36 and 64 rpm, respectively, at no-load conditions. Moreover, the rotational speed has a more significant concern with flow rates (Banerjee, Roy et al. 2014) . The rotational speed increases as the water flow rate increases, decreasing at maximum flow rates. At three different levels of water flow rates, the maximum rotational speeds of three different profile-shaped turbines are achieved at 76 rpm, 68 rpm, and 64 rpm at flow rates of 0.003 m^3/s. The turbines rpm initially increases and then decreases at maximum water flow rates. As the flow of water increases in a water channel, the depth of water also increases. As a result, the static water pressure increases at the lower portion of the channel on the turbine, and the resultant rpm of the turbine decreases due to the increase in water static pressure. This causes the rpm of the SHWT to decrease. In table 1, both blade shape and flow rates significantly affect rotational speed. However, the P values in the table show that flow rates are more significant than blade shape. Moreover, figure 5 shows that a round curved blade has more significant rotational speed than a semi-circular and straight curved blade.

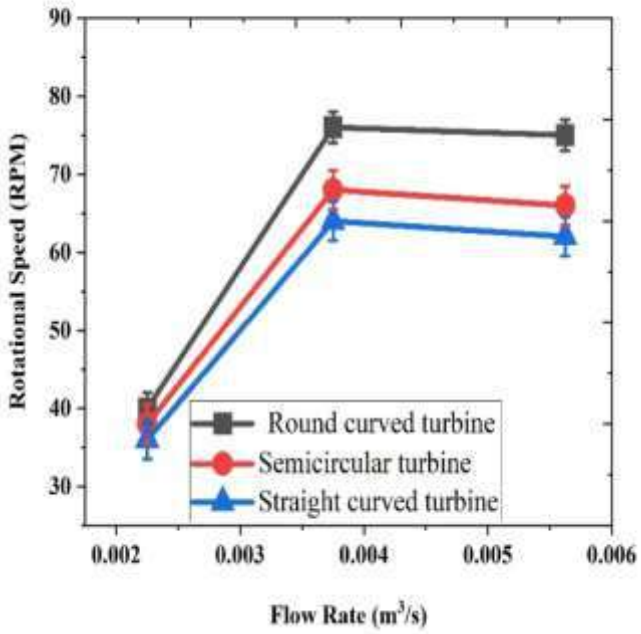

Figure 5: Flow rates vs. rpm

Table 1: ANOVA for RPM

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value
Blade shape	2	144.67	144.67	72.333	10.85	0.002
Flow rates	2	1864.67	1864.67	932.333	139.85	0.000
Error	4	26.67	26.67	6.667		
Total	8	2036.00	2036.00			

Effect of Blade Shape and Flow rate on Torque

As per the experimental result, it is observed that the round curved blade shape generates higher torque under the same flow condition as compared to the semicircular and straight blade shape turbines. The maximum torque obtained by round curved blades, semicircular blades, and straight blade shapes is 0.55 Nm, 0.66 Nm, and 0.65 Nm, 0.51 Nm, 0.61 Nm, and 0.60 Nm, and 0.48 Nm, 0.60 Nm, and 0.59 Nm, respectively at a water velocity of 0.1 m/s, 0.125 m/s, and 0.15 m/s. The torque generated first increases and then significantly decreases by increasing the water velocity and depth. The optimum water velocities where all three turbines generate higher torque are 0.125 m/s. Above and below, the optimum velocity torque generated decreases. Moreover, it is found that the rpm of the turbine decreases if mechanical load is applied to the braking shaft of turbine (Alom, Kolaparthi et al. 2016). The mechanical load increases as the net force on the brake shaft increases, which enhanced to rises brake torque. The torque generated first rises and then significantly reduces at maximum flow rates shown in figure 6. The depth of water in a flow channel of constant volume is directly proportional to the water flow rate. If the flow rates increase, the depth of water increases, as a result, the velocity of water at the bottom slows down, this causes higher static pressure of water inserted into the turbine, and the resultant torque of the turbine decreases. From ANOVA table 2, it is absorbed that both the blade's shape and flow rates have a highly significant impact on torque. However, the F values in the table show that flow rates are more significant compared to blade shape. Moreover, figure 6 shows at maximum torque as absorbed on a round curved blade having 0.003 m³/s then to semi-circular and straight curved blades, respectively.

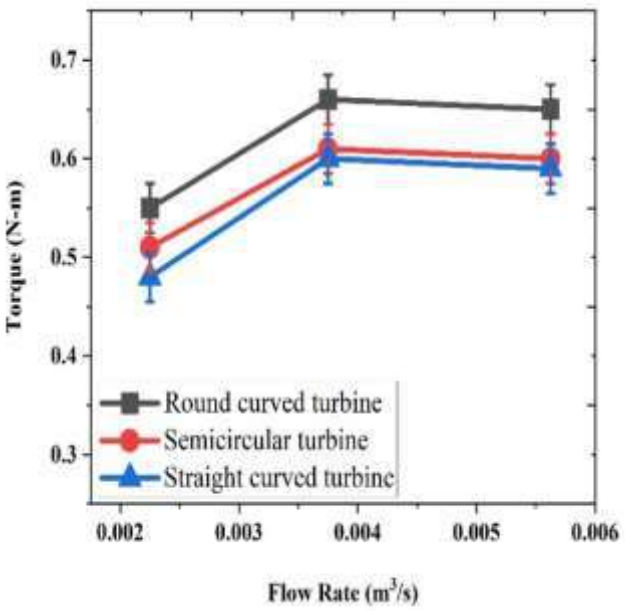

Figure 6: Flow rate vs. torque

Table 2: ANOVA for torque

Source	DF	Seq SS	Adj SS	Adj MS	F-Value	P-Value
Blade shape	2	0.006467	0.006467	0.003233	97.00	0.000
Flow rates	2	0.022200	0.022200	0.011100	333.00	0.000
Error	4	0.000133	0.000133	0.000033		
Total	8	0.028800	0.028800			

Effect of Blade Shape and Flow rate on Efficiency

The turbine efficiency is a concern with blade shape (Mohamed, Janiga et al. 2011) . The turbine's efficiency initially increases and then decreases at maximum flow rates. The round curved shape turbine, semi-circular shape turbine, and straight shape turbine achieved higher efficiencies of 47.7%, 39.5%, and 36.5% at the same flow rate. The round curved blade has higher performance because of the roundness of the blades, which can contact more surface area of the water, and the water will deviate back. As a result, pushing the blade ahead, the concaveness of the blades can strike more surfaces with water. On the other hand, the convex side of the blade can reduced the negative torque on reversing blades. The turbine's rpm increases with the increase of flow rates (Fujisawa and Gotoh 1994). It is observed that the turbine's efficiency first increases and then decreases. The maximum efficiency obtained was 47.7%. However, at maximum flow rates, the efficiency obtained is 26.6%. As a result, the turbine's submergence in water is increased where the static pressure on the turbine inserted is more significant, and the rotational speed of the turbine is at its minimum due to the worse velocity of water at the bottom of the water channel over the turbine. It is absorbed from the ANOVA table 3 that both blades shape and flow rates have a highly significant impact on efficiency. However, the P values in the table show that flow rates are more significant compared to blade shape. Moreover, figure 7 shows that maximum efficiency was absorbed on round curved blades having 0.003 m³/s then to semi-circular and straight curved blades, respectively.

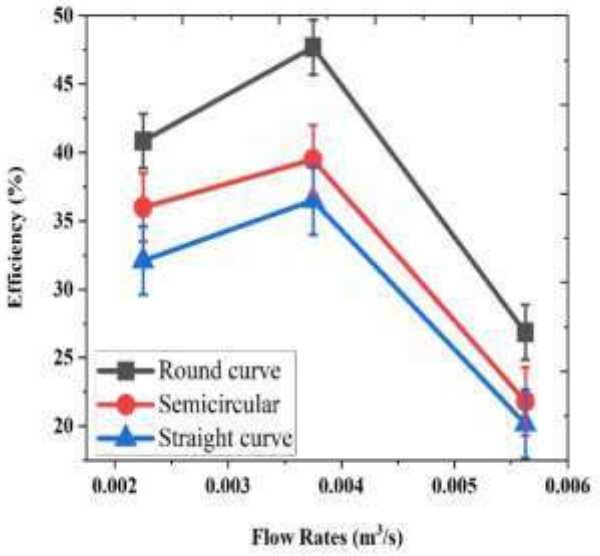

Figure 7: Flow rate vs. efficiency

Table-3: ANOVA for Efficiency

Source	DF	Adj SS	Adj SS	Adj MS	F-Value	P-Value
Blade shape	2	123.537	123.537	61.768	37.53	0.003
Flow rates	2	538.064	538.064	269.032	163.44	0.000
Error	4	6.584	6.584	1.646		
Total	8	668.185	668.185			

Conclusion

In the current research work, the parametric study of the Savonius horizontal water turbine is conducted based on blade shape and flow rates at various levels. CFD analysis was carried out to analyze the flow characteristics. The following conclusion is drawn from the current study.

The numerical analysis showed that higher pressure is inserted on a round curved blade than on a semicircular and straight curved blade shape. The round curved shape turbine shows higher efficiency of 47.7% than semi-circular shape turbine, and straight shape turbine having efficiencies of 39.5%, and 36.5% respectively. The performance of the above turbine is maximum at optimum flow rates. Increasing the flow rate in the channel, the rotational speed and torque of the turbine first increases and then decreases due to rises in static pressure inserted on the turbine as a result, minimizes the efficiency. The ANOVA method reported that both blade shape and flow rates have a high effect on the overall performance of the horizontal axis Savonius water turbine. However, flow rates are more significant than blade shape.

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