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Estimating the Nexus Among Demographic Dividend, Economic Growth, and Environmental Degradation for Pakistan

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Abstract

Sustainable developmental goal eight (SDG-8) focuses on economic growth and decent work, the primary key to accelerating any country's economic growth. Likewise, reaping the demographic dividend of any country to its optimum level may exacerbate the level of sustainable cities and communities (SDG-11) through the responsible group of production and consumption (SDG-12) hence to raise the economic pace. However, neglecting the environment by focusing on economic growth may induce environmental issues, a significant climate change agent. To achieve the set targets of sustainable development, the reorientation of policies in Pakistan is required to address the climate-based problems by not halting the economic growth process. Accordingly, this study aims to analyze the role of Pakistan's demographic dividend by controlling the impacts of technological innovations, capital formation on Pakistan's economic growth, and environmental degradation-based climate issues from 1980-2018. Therefore, the study plans to use heterogenous econometric algorithms. After identifying the degree of integration between the variables, the study tests the cointegration and found that the variables are cointegrated in the long run. The empirical estimates from the dynamic ARDL estimator reveal that economic growth and innovations are still rising the environmental degradation, while the role of demographic dividend is declined its impact on the environment. Further, the role of demographic dividend and innovations are increasing the economic pace, while more degradation tends to raise concerns about the economic performance of the country. Based on the results obtained from the study, new and updated policies are provided to the policymakers of Pakistan for theory and practice.

Key Words: Demographic Dividends; Economic Growth; Environmental Degradation; Technological Innovations; Pakistan

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1. INTRODUCTION

The debate on the relationship between economic growth and the environment remains contentious. Some are of the view that the emergence of new environmental problems and the rising population in the under-developed world is a failure in coping with the global warming issues, while some are of the view that technological development and economic growth have improved the standard of living (Brock and Taylor 2005). However, environmentalists believe that economic development cannot be achieved without affecting the environment (Cohen 2020). Economists recognized that with the involvement of physical capital, environmental and natural resources should be observed because of their economic significance. Thus, the key question is whether the environment plays a prominent role in sustainable economic growth and the welfare of human beings. The theory of the Environmental Kuznets Curve (EKC) has given an Inverted U-shaped connection among the indicators of environmental pollution. It has also been argued that the countries with low-income economies having a large amount of natural resources will develop fast as compared to the economies that have less amount of natural resources (Shabbir, Kousar, and Kousar 2020).

The rise in temperature and global warming has attracted researchers to find out the factors that are contributing to environmental degradation in the short and long run. A vast majority of the researchers have tested the outcome of environmental degradation using various economic factors including population growth, foreign direct investment (FDI), urbanization, and level of income. Environmental economists have discovered a nonlinear relationship between CO_2 emission and income (A. Khan, Chenggang, et al. 2020). The changes in the global environment have highly adverse consequences for human well-being and is raised serious questions about the world, whether they are on a sustainable path or consuming too many resources by reducing important natural capital. The upsurge in economic growth and the impacts on limited earth arises from demographic changes that include the growth in the population, the changes in age structure, urbanization and the rise in per capita income has change the pattern of consumption (Polasky et al. 2019). In this age of economic consideration, every state wants to maximize its economic growth and the human activities in achieving that maximum growth are the responsible elements that are involved in ecological and environmental degradation. The last two decades have observed a rise in the global temperature up to 0.9 C. The

CO_2 emission is continuously increasing day by day which is increasing the global temperature (Bano et al. 2021).

The pessimist and optimist approaches to population growth have prominence in the 20th century. After a thorough investigation it has been observed that population growth does not have significant positive or negative implications on the economic growth. The results from the population neutralists are surprising and they divide them into two different components that is mortality and fertility and tested their independent impacts on the growth of the economy (Bloom et al. 1998). The overall change in the structure of a nation`s population due to a decline in fertility will enhance the economic growth through the rise in working age population output which will boost their per capita income. The importance of the demographic dividend is that the young and the old age populations consume more than their share in production while the working age population consumes less and contributes more to the output and savings.

The demographic dividend is a temporary phenomenon and a time bond window of opportunity that will not last forever (Durr-e-Nayab 2006). The changes in age structure have both direct and indirect effects on the consumption of energy and environmental deterioration. The direct effect on the environmental quality due to age structure can be seen through the behavior of young people (youth) because of their preferences and choices for travel and other goods that leads to a large quantity of carbon emission. While the aged population consumes less energy and produces less carbon emission. The imbalance between these two-age structure may change the pattern of carbon emission, and economic pace. The indirect effect due to the age structure on environmental degradation occurs through a shift in the per capita income of the individuals. Per capita when increases consumers consume more energy and thus share a lot in the emission of greenhouse gases and pollution (Jafrin et al. 2021).

The significance of selecting Pakistan for this study is based on several principles, for example, the rising environmental degradation based on ecological footprints (which is the index of six different indicators, including the fishing grounds, forest products, built-up land, cropland, grazing land, and carbon footprints) developed by Wackernagel and Rees (1996) is very alarming and in the year 2016 Pakistan was ranked 184th in the world having ecological footprints of 0.79 global hectares per person and the average biocapacity remained at 0.35 global hectares per person. The ecological deficit can be seen as 0.44 global hectares per person. In the year 2018, it doubled and reached 0.89 global hectares per person. The CO_2 emissions in the same were 0.87

metric tons per capita and in 2018 it has been raised to 0.98 metric tons. It is growing at an average annual rate of 3.31% (L. Zhang et al. 2021). The environmental degradation could be observed in 2010 and the recent floods of 2022. The key player in both the disasters is La Nina. In the 21st century, the two strongest La Nina years are 2010 and 2022. La Nina works as a catalyst and intensifies the spring heat that precedes the monsoon period across the country. on 5th May Jeff Masters stated that the pre-monsoon heat in the country was fierce as the city of Nawab shah observed 49.5 degree Celsius on May 1 (Henson, 2022). As global warming continues, the fear of its impact will increase and an increase of 1 degree Celsius could observe a 5.3 percent increase in precipitation during the monsoon period. The 2010 floods affected more than 20 million people and displaced millions for quite a few months. The 2022 floods have exceeded the devastation caused by the 2010 floods. It has washed away 45% of the cropland. More than 33 million people have been affected by the recent floods (Khan, 2022).

Since 2005, the Gross Domestic Product (GDP) in Pakistan has been growing on average at 5% a year, and it is not sufficient to fulfil the demand of the whole population (Trading Economics 2021). The economic growth rate of Pakistan in 1961 was 6% while the growth rate in December 2018 was 5.84% and growth rate for 2019 was observed as 0.99% and the 4.85% decline was observed in 2018, 0.53% in the year 2020, and a decline of 0.46 from 2019 has been observed (Trading Economics 2021). Likewise, Pakistan has been ranked 6th in the world with a population of about 211.17 million and it will further increase to 344 million in 2050 if not controlled. Pakistan has been ranked 5th in terms of having a young age population (Hafeez and Fasih 2018). Having the issues of population growth Pakistan has the opportunity of the demographic dividend that started in 1990 and will be available up to 2045 (Durr-e-Nayab 2006). If the demographic dividend is not materialized or utilized properly it will have negative impacts on the economic growth of Pakistan (Chishti 2020).

This study contributes to the knowledge on the nexus among demographic dividends, economic growth, and environmental degradation for Pakistan in multiple ways; that include, quantifying the role of demographic dividends on economic development and the environmental deterioration of Pakistan. Secondly, the study further tests the impression of technological innovation and its role in the country's environmental degradation and economic growth. Thirdly, this study adopted a novel dynamic ARDL simulation model, which the previous studies have overlooked. Finally, this study produces new and updated policies that will guide Pakistan's policymakers for theory and practice.

The study is organized as follows. The next section presents a review of the literature on the nexus among demographic dividend, economic growth, and environmental degradation. The third section explains the data used, methods adopted, and econometric approaches employed for the estimation of the variables. The fourth section of the study explains the results in line with previous studies, and the final part gives the conclusion, recommendations, and limitations of the study.

2. LITERATURE REVIEW

Since 1902 studies have started shedding light on demographic dividends and their role in economic growth, and the role of demographic dividend is becoming prominent (Hosan et al. 2021). The studies which are highlighting heterogenous impacts of the demographic dividend are yet to be studied. Therefore, the following review of literature sheds light on three strands of research, the first highlights the role of demographic dividends on economic growth. The second strand discusses the role of demographic dividend and its impact on the environment, while the final strand highlights the impact of technological innovations and their role on economic growth and environmental degradation.

2.1. Demographic Dividend and Economic Growth

The demographic transition in many countries in determining the course of economic growth that brings both opportunities and challenges. The aging problem is a matter of great concern for the developed economies while the population growth will rise in the poor economies in the coming years. The developing countries will observe a rise in the working-age population and their share in the production cycle. The shifts in the working-age population will uplift the economic growth and prosperity of the country (Cruz and Ahmed 2018). Two aspects measure the impact of demographic dividends on economic growth. The first aspect emphasizes the factor of fertility acting as an independent variable that influences the working age population and in return gives high productivity and uplifts the economy. The second aspect stresses education that will decrease the fertility rate and will boost production. Both education and fertility play a prominent role in the economic growth of a country (Jafrin et al. 2021).

The fertility rate has been declining in the developed regions of the world from 2.5-3.5 to a level of 2.1 (1960-2015). In Africa, the fertility rate was 6.7 in the 1960s and it decreases to 6 children per woman in the 1990s and in 2015 it has been declined to 4.7 and in comparison, with the developed regions it is still higher than they have in the 1960s. The transition over a period of time shows that the dependent population will be replaced by the working-age population in the coming years. The decline in the young dependent population will create various economic profits that will create an opportunity for what we call the Demographic Dividend. Africa has the potential for a great demographic dividend and Africa will enjoy the benefits of this demographic dividend to boost their economic growth if they properly materialize and utilize this opportunity (Bloom, Kuhn, and Prettner 2017).

East Asian countries were the first to witness the demographic transition in Asia and got the opportunities to materialize the demographic dividend for their economic growth. The fertility rate in India is on a continuous decline and this decline has a vital role in the age structure of the country. Three important factors are observed due to the demographic transition in India i.e., life expectancy has increased, the household number has increased, and the population growth rate is changed in different regions. The demographic shift in India has created various economic opportunities and significantly boosted their economy. All these developments like the decrease in fertility rate, urbanization, number of households, and the age structure of the population, had an adverse impact on the environment. The demographic dividend has changed consumption patterns across the country. The working-age population has opportunities to earn more money and spend them on buying motor vehicles and electronic devices which has a direct impact on the environment (Lakshmana 2016). Pakistan is also going through a phase of demographic transition with a major decline in mortality and a modest decline in fertility rates. The demographic dividend is a limited-time opportunity and if correct policies are not implemented it will go away and there will be an adverse effect on the economic growth of the country. Pakistan estimated time for the demographic dividend is from 1990-2045 which means that Pakistan has spent almost half of the demographic dividend phase without any fruitful results (Durr-e-Nayab 2007).

2.2. Demographic Dividend and Environmental Degradation

A vast number of environmentalists acknowledged that population and environment are interconnected. The ARDL framework used to examine the impact of greenhouse gases emission (without considering economic growth variables) in Nigeria shows that adults and children consume more energy and are environmentally intensive, while the aged population has a negative impact which shows that the aging population will have slightly good environmental impacts. The age structure`s effect on CO_2 emission has an inverse U-shaped structure (Emmanuel O. Okona 2019).

The rapid aging society and decline in labor force growth have been observed in China. The study was conducted in 29 provinces of China on the relationship between the age structure of the population and environmental degradation. The carbon emission in the low-income provinces due to the working-age population is strong and with the current phase of economic development, the higher ratio of the working-age population has an unfavorable effect on the quality of the environment (Z. Zhang et al. 2018).

Studying the 7 South Asian countries in the STIRPAT framework from 1985-2016 (A. Khan et al. 2021) found the negative role of demographic structure on environmental degradation. The rise in the income of the youth population may change their preferences to buy durable goods and travel that are highly energy consuming, and highly toxic to the environment. The age structure affects economic growth by using fossil fuels which are the main source of greenhouse gases (Hamza and Gilroy 2011).

2.3. Technological Innovations, Growth, and Environment

There is a vast set of literature, which has already determined the relationship between technological innovation, economic growth, and environmental degradation. For instance, a study conducted in 30 countries from 1980-2014 shows that advancement in technological innovation has a vast impact on the countries that produce higher CO_2 emissions. Consequently, the countries must introduce technological innovations and financial support to produce renewable energy resources at a minimum price. Furthermore, the transformation in the economic growth approach is helpful to shift from non-renewable to renewable energy resources to overcome the demand for energy (Chen and Lei 2018).

Studying the 18 states from the developed and underdeveloped world from 1990-2016 using the cross-sectional augmented Dickey-Fuller (CADF) unit root, Dauda et al (2019) found that the consumption of energy produces CO_2 emissions in almost all the countries. Though, technological innovation in G6 countries decreases CO_2 emissions while the emissions have increased in the case of BRICS and MENA. In studying the 23 growing economies of the world from 1996-2014 using the Generalized Methods of Moments (GMM) method, Omri and Bel Hadj (2020) found that both technological innovation and foreign direct investment decrease the CO_2 emissions in almost all the projected models except those that produce CO_2 from heat and electricity and as a result the quality of the environment is enhanced.

Using the Dynamic ARDL simulations model the research focused on the effects of economic aspects, energy consumption, and globalization on CO_2 emissions from 1971-2016 in Pakistan and the results show that FDI, trade, financial growth, globalization, and energy consumption on CO_2 emissions have positive effect whereas, economic growth, urbanization, and technological innovation have a negative effect on the CO2 emissions (M. K. Khan et al. 2019). Studying the OECD countries using the STIRPAT models of the OECD countries through the period 1999-2014 Hashmi and Alam (2019) showed that CO_2 emissions decreased by 0.017% with an increase of 1% in environment friendly patent and also CO_2 emissions are reduced by 0.03% with an increase in 1% of environmental tax revenue per capita.

The discussion in the literature indicated that demographic dividend plays a vital role in economic growth of any economy; similarly, the role of technology in boosting economic growth cannot be ignored. Therefore, this study aims to find the role of demographic dividends and technological innovations on economic growth and environmental degradation in Pakistan over the 1980-2018 period. The findings of the study are likely to provide specific guidelines to policymakers in devising policies for sustainable economic growth in Pakistan.

3. MATERIALS AND METHODS

3.1. Data

For an empirical estimation of the study, we obtained the relevant data for the 1980-2018 period. The demographic dividend (DD) is measured with the working-age population between 15 & 64 ages, economic growth in real per capita GDP at 2015 US$ is taken from, capital formation as gross domestic capital formation (CF), a patent application by residents is used as a proxy for Technological Innovation (IN). All those chosen variables have been adopted by following the studies of (Hosan et al. 2021; Danish and Ulack 202; Zaman et al.2016; A. Khan, Muhammad, et al. 2020). Data on all the indicators are drawn from the online database of (World Bank 2021) excluding the ecological footprints which are gathered from the (Global Footprint Network 2021).

Before proceeding toward the formal analysis of the data, we transformed the variables into a logarithmic form to reduce any chances of heteroscedasticity (Danish and Ulucak 2021). For a clear understanding of the nature of variables, Table 1 shows the descriptive statistics, normality, and definition of the chosen variables. For the demographic indicators, we have plotted some variables and given them in Fig. 1 & 2 for clear understandings. From the descriptive statistics, we may see significant disparities between the minimum and maximum values of the considered variables. Based on the economic condition the average per capita of Pakistan is 1062.0980 for the study period, with a maximum value of 1502.8910, and a minimum of 693.3505 US$ per annum. These values indicate the significant economic disparities in the country over time. The ecological footprints of the country are not so huge; however, effects of the environmental degradation have been widely visible in the country. For example, the maximum footprints are recorded as 0.9124 and the minimum as 0.6223 with an average of 0.7690 for the study period. For the study period, the average demographic dividend of the country is recorded as 55.2746, with a maximum of 60.4174 and a minimum of 52.8059. this indicates there is a visible rate of the demographic dividend to be reaped for the economic progress of the country. The average technological innovation has been observed as 75.0183, with a maximum of 306.0000 and a minimum of 16.0000. Similarly, Jarque-Bera`s (J-B) insignificant probability values (for most of the modeled variables) imply the data is normal, so we can continue estimating the variables by applying the linear approaches of the econometric algorithm.

Table 1. Variables, Definition, and Descriptive Measurement

Variables	Average	Maximum	Minimum	J-B	Probability	Source
EF (Ecological; Footprints	0.7690	0.9124	0.6223	1.9135	0.3841	GFN
Y (GDP US $	1062.0980	1502.8910	693.3505	1.2935	0.5238	WDI
DD (Demographic Dividend)	55.2746	60.4174	52.8059	5.3837	0.0678	WDI
CF (Capital Formation)	16.0233	19.1293	12.5206	1.8374	0.3990	WDI
IN (Technological Innovation)	75.0183	306.0000	16.0000	1.3895	0.0003	WDI

Note: J-B stands for Jarque-Bera normality test, WDI is World Development indicators.

Figure 1 indicates that from 2000 to 2020 there is a continuous increase in the population growth of the country. But a decline in the population growth of the country has been observed from 3.5 in 1980 to 2.8 in 2020. Also, the proportion of the male and female population has been given in the graph. Fig.

2 explains the fertility and mortality rates in the country and the results indicate that a decline in fertility and mortality rates has been observed. The fertility rate in 1980 was observed at 6.5 children per woman, while in 2020 it was reduced to 3.3. The infant mortality rate was observed at 122 per 1000 live births in 1980 and it has reduced to 58 in 2018. The life expectancy rate has improved from 56 in 1980 to 64 in 2018.

3.2. Model Construction

Growing environmental problems, associated with climate change, are putting tremendous challenges on environmental safety. By not halting the economic progress, environmental sustainability becomes more challenging. Therefore, some measure coupled with economic growth to ensure environmental improvement is necessary. Therefore, efforts are needed to address these issues by investing in energy efficiency and innovative measures to curtail environmental problems. (Blázquez-Fernández, Cantarero-Prieto, and Pascual-Sáez 2019; Lee and Min 2015).

Figure 1. Plots of the Demographic Variables

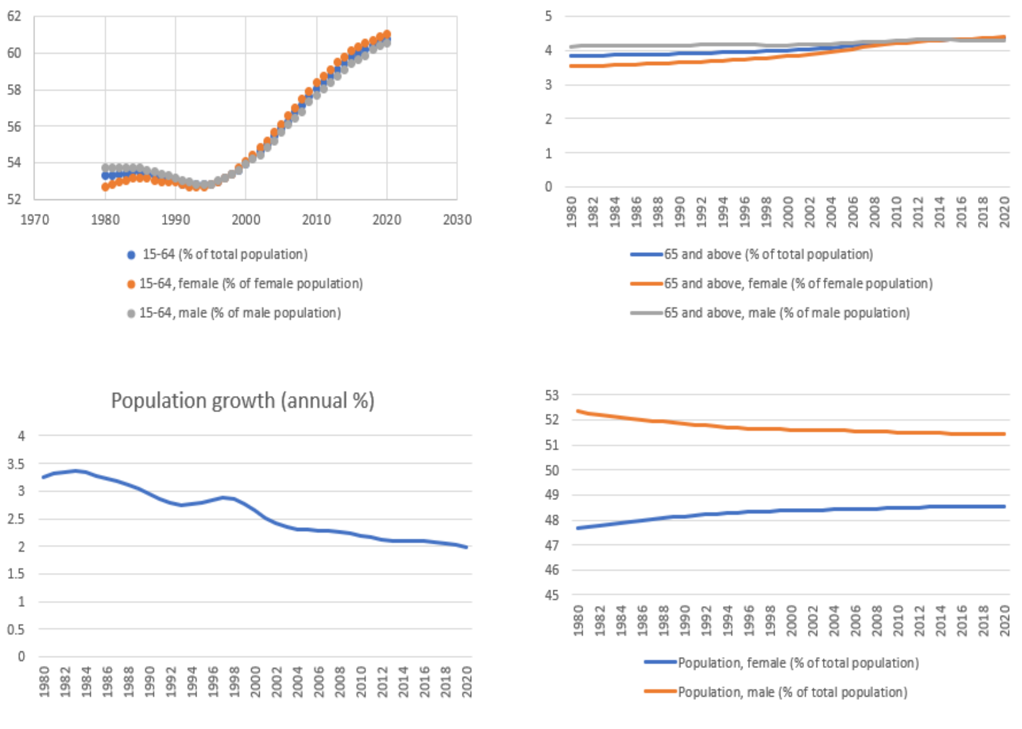
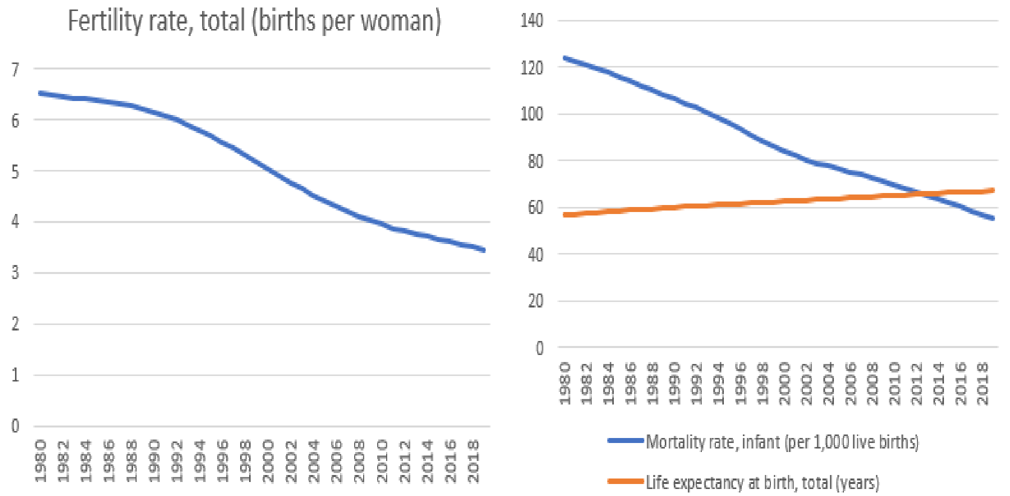


Figure 2. Fertility Rates, Mortality Rates, and Life Expectancy at Birth



Therefore, in line with the studies of (Danish and Ulucak 2021) and (Du, Li, and Yan 2019) we develop a functional form of the model to explore the economic and environmental role of demographic dividend and technological innovations in Pakistan;

$$LnEF_t = \alpha_{0t} + \beta_{1t}LnDD_{t+}\beta_{2t}LnY_t + \beta_{3t}LnIN_t + \beta_{4t}CF_t + \mu_t \quad ... 1$$

$$LnY_t = \alpha_{0t} + \beta_{1t}LnDD_{t+}\beta_{2t}LnEF_t + \beta_{3t}LnIN_t + \beta_{4t}CF_t + \mu_t \quad ... 2$$

Where $LnEF$ stands for the logarithmic value of ecological footprints, $LnDD$ is the logarithmic value of the demographic dividend. Likewise, $LnIN$ is the technological innovations, LnY is the real GDP per capita to measure the economic growth; finally, $LnCF$ stands for the capital formation in the country. μ is error term of the regression equation, α_0 is the slope coefficient, $\beta_{1,\dots,4}$ are the coefficients of the explanatory variables to be estimated, and t indicates the time dimension of the study (here it is 1980-2018).

3.3. Econometric Approaches

Following the recent studies by (Danish and Ulucak 2021; M. K. Khan et al. 2019; M. K. Khan, Teng, and Khan 2019; Sarkodie et al. 2019), we adopted the recently developed dynamic ARDL (Autoregressive Distributed Lags model) by (Jordan and Philips 2018) in the current study. The advantage of using the dynamic ARDL (DynARDL) simulation model over ARDL reduces the difficulties in the interpretation of estimations often countered in the ARDL approach for the variables (Danish and Ulucak 2021). ARDL simulation approaches are an easy way to give practical results of nonintuitive interpretations; that's why they are becoming more popular in recent times (Jordan and Philips 2018). Simultaneously, the dynamic ARDL can estimate, simulate, and automatically generate the plots of the actual negative and positive shocks in regressors and regressands, keeping other factors constant. For the empirical estimation of dynamic ARDL, it is required to have first-order integration of the dependent variable. Secondly, the integration order of the regressors must not be higher than I(1), while mixed integration order is acceptable in the regressors (Danish and Ulucak 2021). The standard form of the dynamic ARDL model is given as;

$$\Delta Y_t = \emptyset_0 + \propto_{1t} Y_{t-1} + \vartheta_{1t} X_{1,t-1} +, \dots \dots, \theta_m K_{m,t-1} + \sum_{i=1}^{l} \propto_{1t} \Delta Y_{t-1} + \sum_{i=1}^{j} \vartheta_{1t} \Delta X_{1,t-1} +, \dots \dots \dots, \sum_{i=1}^{l} \theta_m \Delta K_{m,t-1} + \varepsilon_t \quad \dots 3$$

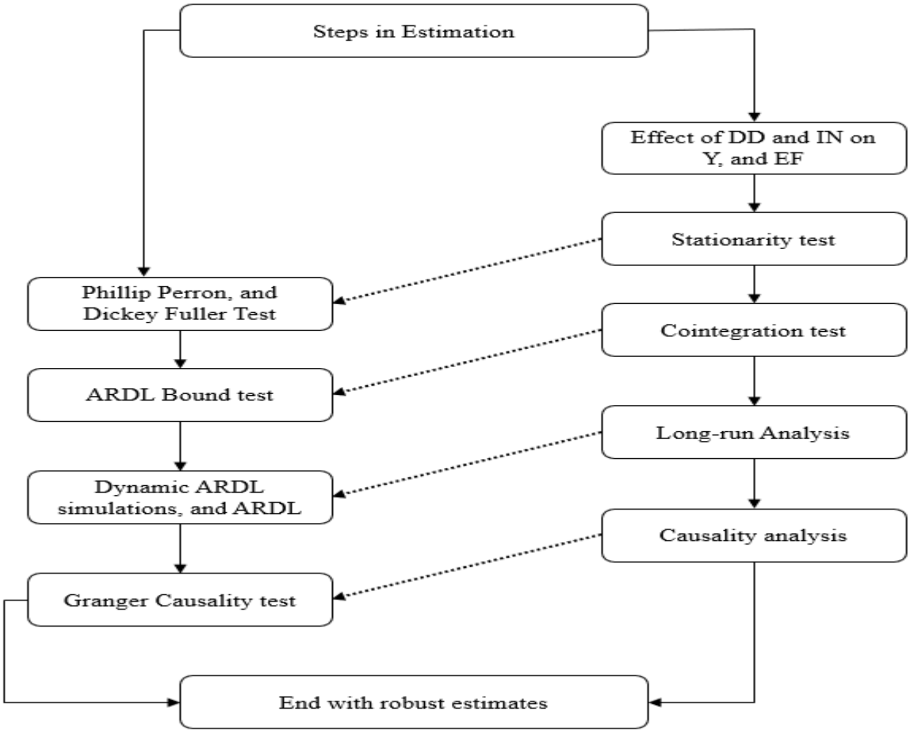
While ΔY indicates the changes occur in dependent variables, Y_{t-1} indicates the one lag period of the dependent variable, similarly, $\emptyset_0$ is the regression slope. Here X indicates a set of independent variables, Δ is the difference operator, and ε_t is the regression error term, and superscript is the time operator. Before estimating the short and long-run analysis, the ARDL bound approach of cointegration introduced by (Pesaran, Shin, and Smith 2001) is adopted in the study. The critical values for the Bound test are calculated by Kripfganz and Schneider (2020) and are used in the study. The rejection of the null hypothesis of no cointegration is based on the F-statistics of the Bound test. If the value of the F test lies below the lower bound limit, it indicates no cointegration. If the value lies between the upper and lower bound limits it implies the indecisive phenomenon, and if the F-test value is found to be greater than the upper bound limit I (1), we conclude the variables are cointegrated in the long run . Finally, the error correction mechanism of equations 4 & 5 is given below;

$$\Delta LnEF_t = \alpha_{0t} + \pi_0 LnEF_{t-1} + \beta_{1t} LnDD_t + \gamma_{1t} Ln\Delta DD_t + \beta_{2t} LnY_t + \gamma_{2t} LnY\Delta_{t-1} + \beta_{3t} LnIN_t + \gamma_{3t} Ln\Delta IN_{t-1} + \beta_{4t} LnCF_t + \gamma_{4t} Ln\Delta CF_{t-1} + \mu_t \quad \dots 4$$

$$\Delta LnY_t = \alpha_{0t} + \pi_0 LnY_{t-1} + \beta_{1t} LnDD_t + \gamma_{1t} Ln\Delta DD_t + \beta_{2t} LnEF_t + \gamma_{2t} LnEF\Delta_{t-1} + \beta_{3t} LnIN_t + \gamma_{3t} Ln\Delta IN_{t-1} + \beta_{4t} LnCF_t + \gamma_{4t} Ln\Delta CF_{t-1} + \mu_t \quad \dots 5$$

In the equations 4 & 5, $\beta_{1,\ldots,4}$ *and* $\gamma_{1,\ldots,4}$ are long and short-run coefficients to be estimated. Where μ is the residual of the regression, and t in the models stands for time dimension, which is from 1980 to 2018 in the current study. The systematic view of the estimation process is given in Figure 3 for easiness of the readers.

Figure 3. Estimation Plan



4. RESULTS AND DISCUSSIONS

4.1. Unit Roots

In the estimation process, it is mandatory to test the unit roots in the variables since the dynamic ARDL supplies efficient outcomes if the dependent variables under the study provide order one integration, and independent variables must not be greater than I(1) (Sarkodie and Owusu 2020). On these grounds, we tested the chosen variables for the unit roots by applying the conventional unit root approaches, including the Augmented Dickey-Fuller and updated version of (Dickey and Fuller 1979), and (Phillips and Perron 1988) tests. Results summarized in Table 2 imply that the dependent variable is I (1), and the integration level of all independent variables does not exceed I (1). Therefore, we found that the study's first objective was verified, and we turned towards determining the cointegration relationship between the variables.

Table 2. Unit Root Test

Variables	Statistics	Probability	Statistics	Probability
Augmented Dickey Fuller (ADF)				
EF	-1.7157	0.4155	-5.9344	0.000
Y	0.8327	0.9933	-3.1341	0.033
DD	-0.0410	0.9476	-3.9380	0.005
CF	-1.8705	0.3422	-5.2828	0.000
IN	2.4304	1.0000	-6.9830	0.000
Phillip Perron (PP)				
EF	-1.7138	0.4164	-5.9344	0.000
Y	0.5766	0.9872	-3.1341	0.033
DD	1.7003	0.9995	-5.2880	0.000
CF	-2.0245	0.2755	-5.2828	0.000
IN	2.5731	1.0000	-6.9883	0.000

4.2. Cointegration Test

After meeting the first criteria of unit roots, the further step tests an equilibrium relationship between the variables, including the ecological footprints, economic growth, demographic dividends, innovations, and capital formation. In line with the study of (Danish and Ulucak 2021), the bound testing approach instrumented by (Pesaran, Shin, and Smith 2001) together with (Jordan and Philips 2018) for critical values is adopted in the study. This test calculated the F-statistics, which are to be compared with the critical values given. If the computed values of F are higher in absolute than the critical values, we conclude a cointegration relationship between the variables. The reason for using the critical values by (Jordan and Philips 2018) is based on their efficiency in the small samples. The bound test results are given in Table 3. The results support the cointegration relationship because the calculated F-statistics are greater than the upper bound limits at the 5% level for both the growth and environmental degradation model. This supports a cointegration relationship between the variables in both models; hence we may further proceed towards applying the dynamic ARDL model in the next step.

Table 3. Results of Cointegration Test

Models tested	Test	Probability Statistics	at 5% I (0)	I (1)	at 10% I (0)	I (1)	Decision
For EF model	F	5.323	3.548	4.803	2.933	4.020	Cointegrated
	T	-4.316	-3.43	-4.803	-2,860	-3.78	Cointegrated
For Growth model	F	5.760	3.05	3.97	2.68	3.53	Cointegrated
	T	-5.743	-3.43	-4.803	-2,860	-3.78	Cointegrated

4.3. Dynamic ARDL Results

The estimated results of the environmental degradation model are given in Table 4; the significant value of lagged ecological footprints indicates a dynamic relationship between the variables in the long run. Similarly, the role of economic growth on ecological footprints generates a positive impact with 0.558 explanatory power; this indicates that a one percent rise in the economic growth in Pakistan is associated with a 0.558% rise in the ecological footprints of the country. These results are not unique, and many previous studies have exhibited similar results, for example, Danish et al. (2019). Further, the role of technological innovations in environmental degradation is positive, which indicates that a one percent rise in technological innovations tends to increase the ecological footprints by 0.075% in the long run. This association between the two variables is based on the energy used to adapt to technological innovations, which is fossil energy-intensive. While the role of demographic dividends based on the working-age population disclosed a negative response. For example, a one percent rise in the country's demographic dividend improves the environment by 2.379% in the long run. There are reasons for having a negative response to a demographic dividend of ecological footprints, firstly the working-age people feel the environment more attractive towards health, and government programs on environmental consciousness is raising awareness among the masses so that the people become environment friendly. Second may be the reason that the working age population is directly not engaged in the consumption of environmental products at large therefore, its role is becoming environmentally friendly. This decline may also contribute to improving the environment. These results contradict the studies of Anwar et al. (2020) and Tarazkar et al. (2020). The study of Hosan et al. (2021), indicated that an increase in the working-age population raises economic growth and energy consumption. In our case, we cannot deny energy consumption for economic growth; however, with time, people feel conscious about renewable energy consumption instead of focusing on fossil-based energy in production. To supplement the results obtained from the current study, we estimated the error correction model. The lagged value of the error correction term indicates a negative sign with a significant value, which implies that an impulse to the model, in the long run, tends to return towards its equilibrium position with a speed of 90.5%, which explains that the given model restores its equilibrium with high speed. Hence, the obtained outcomes are efficient and can be used for forecasting and policy implications.

Table 5 explains the empirical relationship of the economic growth model. In the first case, the role of capital formation in economic growth seems positive and significant. Similarly, innovations also indicate a positive sign, with a considerable response; this association discloses that a one percent rise in technical innovations may improve economic growth by 0.025% in the long run. Similarly, the role of demographic dividend is positive and significant; it indicates that a one percent rise in the working age of the population (between ages 15 & 64) may increase the country's economic growth by 0.101% in the long run. This is in line with the latest study by Hosan et al. (2021). The results support the view that the younger age population tends to adopt new and innovative ideas in production, technological innovations, and skills. Similarly, young people have greater intensity towards gaining new knowledge and skills to update themselves in the race of the technological world. On these grounds, the working-age population impact both energy consumption and economic growth simultaneously. While the role of ecological footprint in economic growth is negative, which indicates that a rise in environmental degradation tends to diminish the economic growth of the country by 0.168% in the long run.

Table 4. Results with Dyn ARDL for Environmental Degradation (EF-model)

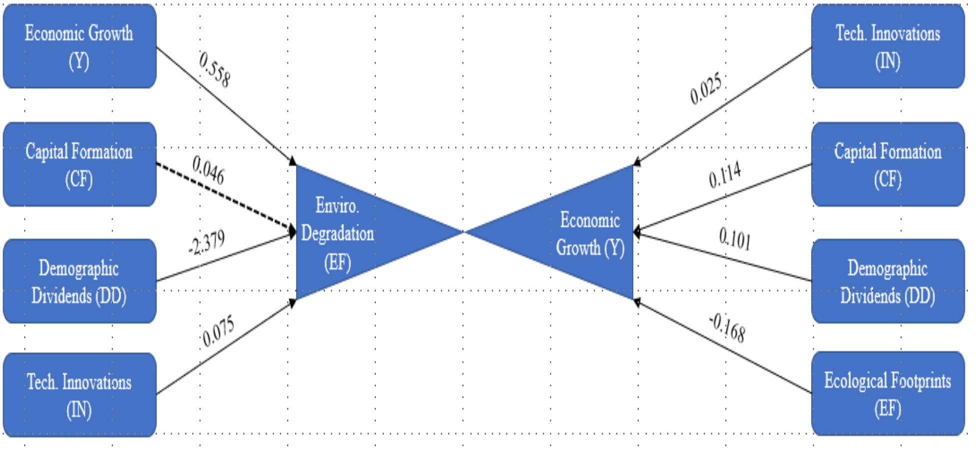
DynARDL Regressors	Coefficient	t-score	probability	ARDL Coefficient	t-score	probability
$LnEF_{-1}$	-0.867	-6.310	0.000	-0.905	-5.073	0.000
ΔLnCF	0.003	0.040	0.969	-0.144	-1.320	0.200
LnY_{-1}	0.558	5.430	0.000	0.661	9.381	0.000
$LnCF_{-1}$	0.046	0.780	0.440	0.056	0.614	0.546
$LnIN_{-1}$	0.075	4.170	0.000	0.084	2.736	0.012
$LnDD_{-2}$	-2.379	-5.480	0.000	-2.685	-4.993	0.000
ECT_{-1}				-0.905	-7.087	0.000
Diagnostics						
ARCH	1.215	--	0.270	0.263	--	0.608
BG-LM	1.539	--	0.463	4.007	--	0.135
Normality (J-B)	2.225	--	0.328	0.415	--	0.813
Stability test	Stable			Stable		
Simulations	5000					

Table 5. Results with Dyn ARDL for Economic Growth (Y-model)

DynARDL			
Regressors	Coefficient	t-score	Probability
LnY_{-1}	0.110	2.830	0.008
$\Delta LnCF$	0.114	3.1	0.004
$LnEF_{-1}$	-0.168	-2.36	0.025
$LnCF_{-1}$	0.009	0.280	0.778
$LnIN_{-1}$	0.025	2.700	0.011
$LnDD_{-2}$	0.101	1.990	0.057
ECT_{-1}	-0.824	2.270	0.001
Diagnostics			
ARCH	1.215	--	0.27
BG-LM	1.538	--	0.463
Normality (J-B)	2.225	--	0.328
Stability test	Stable		
Simulations	5000		

Results at the end of Tables 4 & 5 for diagnostics analysis explain that the residuals are homoscedastic, have no autocorrelation, and the estimated model is stable. Since the COSUM and CUSUMSQ results show, the parameters are inside the 5% band. Similarly, the application of the estimated models is also robust because the insignificant normality results obtained from the Jarque Bera (J-B) test state the residuals are normally distributed. The pictorial view of long-run results is given in Fig. 4 for easy understanding.

Fig. 4. Pictorial View of Long-run Results



4.4. Causality Analysis

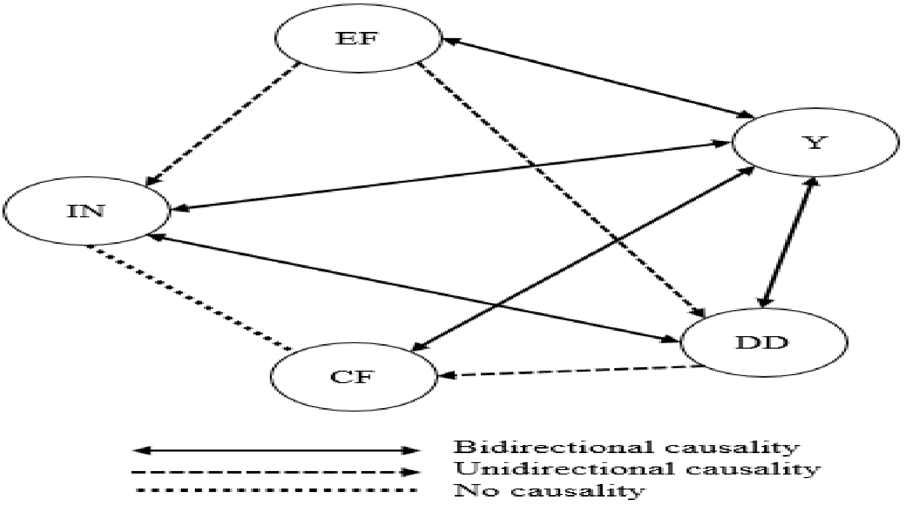
There is a drawback of long-run estimators: they give coefficient estimates of the regression and fail to provide the direction of causal relationships. Therefore, to provide the causal dimensions, we further tested the variables for causality using the Granger causality test. The causality test results shown in Table 6 indicate that economic growth is causing the ecological footprints, not vice versa. Similarly, we found bidirectional causality between ecological footprints and economic growth. Further, the results showed a unidirectional causality from environmental degradation based on ecological footprints towards demographic dividends and technological innovations in Pakistan. Simultaneously, the bidirectional causality is detected between the country's economic growth and demographic dividends, between capital formation and economic growth, and between technological innovations and economic growth. The empirical results further supported the bidirectional causality between the demographic dividends and technological innovations of Pakistan. To the easiness of the readers, we have summarized the causal linkages between the variables in Figure 5.

Table 6. Causality Test Results

Variables	EF	Y	DD	CF	IN
EF	--	5.505[b]	30.147[c]	1.143	3.980[c]
Y	3.161[c]	--	9.132[a]	2.087[c]	9.927[a]
DD	0.055	7.205[a]	--	2.879[c]	3.977[c]
CF	0.033	5.243[b]	1.015	--	1.594
IN	0.747	8.853[a]	24.220[a]	2.040	--

Note: Superscripts a, b, and c are the level of significance at 1, 5, and 10%.

Figure 5. Causal Linkages



5. CONCLUSIONS AND RECOMMENDATIONS

The main goal of this study was to find out the role of demographic dividend, capital formation, and technological innovations in economic growth and environmental degradation based on the ecological footprints of Pakistan. To this end, the study adopted the novel dynamic Autoregressive Distributed Lags (DynARDL) simulations model to explore the existing relationships between the considered variables. Before going to the short and long-run dynamic, the study tested the variables for the stationarity properties and the existence of an equilibrium relationship among the variables as major steps before applying the DynARDL model. As per requirement, the unit root test results imply that all the considered variables are stationary of the first order. Further, the bound testing approach explored that the chosen dimension of variables is cointegrated in the long run. We then applied the DynARDL model. The empirical outcome indicated that the role of demographic dividend in environmental degradation is negative, while economic growth and technological innovations are increasing the ecological footprints of the country. The results obtained from the dynamic ARDL approach are rousted by applying the linear ARDL approach.

Hence the explored outcomes are unique with respect to Pakistan, the research implies putting forth policy options in the context of the study. First, Pakistan needs concrete steps to get benefit from the working-age population for the economic betterment of the country. The government must invest in education, health, skills acquisitions, provide loans and entrepreneurial capacity building, and bring reforms in job-creating economic sectors in agriculture, industry, and services sectors to accommodate the demographic dividend in productive activities. The government must create job opportunities by facilitating the youth with human capital formation and engage them to uplift the economic conditions of the country as the already half-life span of this demographic dividend opportunity has lapsed. The government must provide technical skills to utilize the youth bulge in the production cycles of industry and agriculture to enhance the nation`s economy. The existing unskilled labor may not uplift the country to reap the socioeconomic advantages of competitiveness; so, labor market reforms are strongly recommended to engage the youth bulge into life-earning activities. The problems of poverty, malnutrition, low levels of living, and social unrest could be solved through investing in the development of the existing youth bulge of Pakistan.

The economic growth with less environmental degradation may materialize via devising sustainable development policies for our youth to contribute their parts to the process of healthy development of Pakistan. The government must introduce policies that could create awareness for the development of green technologies, sustainable production practices in industry and agriculture, the energy sector, and other projects like the China Pakistan Economic Corridor (CPEC), and other projects of national interests in Pakistan. The model of economic growth via the mediating channels of the productive demographic dividend to ensure environmental sustainability and preservation is recommended that is binding to all the economic productive processes in the agriculture, industry, and services sectors of Pakistan`s economy.

Finally, the study, besides efficient results, has also some limitations. The first limitation of the study is adding energy consumption variables in the future so that the link between environmental degradation and the mediating role of the demographic dividend can be explored. Similarly, multiple structural breaks have been observed due to the 9/11 incident and the 2008 global recession that may have affected the country, flexible economic models to absorb such external shocks are not covered in this study. Furthermore, for the empirical estimation, the reliable data on the demographic dividend by estimating over time series may give a closer look to policymakers for devising major sustainable developmental policies to the country specifically and the region in general.

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