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Analyzing the Impact of Technological Progress, Innovation, R&D investment and Human capital on per capita income growth

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Abstract-

The purpose of this research is to analyze the relationship between technological progress, innovation, R&D, gross capital formation and per capita income growth, using 31 years' time series data from 1991-2022 and sourced from World Development Indicators, International Labor Organization (ILO), Pakistan Economic Survey and the State Bank of Pakistan. The study employed econometric tools such as Correlation Matrix and ARDL Model to determine long run relationship between variables. According to the findings, R&D expenditures and innovation have insignificant impact on per capita income growth in Pakistan due to low rate of domestic investment, political instability and low literacy rate, while labor productivity has negative impact due to illiterate and unskilled labor. The investment in fixed capital is low, which reduces total output of goods and services.

Keywords: Technological Progress; Innovation; labor productivity; R&D; gross capital formation; gross national income per capita.

Type of study: Original research Article

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1. Introduction

1.1 Economic Growth

Economic growth reflects the expansion of an economy's productive capacity over time. This translates to an increase in the inflation-adjusted market value of the goods and services produced in a specific period. To measure this growth, economists primarily rely on Gross Domestic Product (GDP), which represents total value of a country's output (Pradhan, et al., 2016). There are two methods to measure GDP growth: nominal and real. Nominal GDP growth refers to total market value, including the effects of inflation. A high nominal growth rate might simply mean rising prices, not necessarily more output. To get a more accurate estimate, economists use real GDP growth. This metric adjusts for inflation, giving a true picture of how much output has increased. There are three main sources of economic growth: accumulation of capital stock, labor force and technological advancement. But the growth depends upon the quality of capital stock, skilled labor and nature of technological advancement. If a country has accumulated capital stock in the form of machinery and equipment as well human capital it can execrate growth process. The role of labor is also very important particularly when the labor is skilled, trained and motivated, it can significantly contribute into economic growth. In this respect the example of China can be cited. China utilized its labor force efficiently and improved its skill through education and training and recorded impressive growth during last four decades (Xu, 2007). Economic growth is measured in GDP at current US dollar in percentage point. If we looked at last 50 years data of World GDP, we are surprised that some regions have recorded impressive growth, while others lagged behind. For example, in 1970, the value of total world GDP was around US$21.90 trillion in which Western Europe (MPD) shares was $5.69 trillion, Eastern Europe (MPD) was 2.92 trillion, Western offshore countries (MPD) were $5.62 trillion, East Asia was $2.99, South Asia was $1.54 trillion, Latin America was $1.75 trillion, Middle East was $ 833.16 billion and Sub-Saharan Africa was $565.33 billion. But this scenario has significantly been changed and Centre of growth has shifted from Western hemisphere to Asian hemisphere. In the new growth scenario, the wealth of East Asia in which China, Hong Kong, Japan, South Korea, North Korea, Taiwan. Mongolia and Macao are located, was increased from just $2.99 trillion in 1970 to $32.31 trillion in 2020 and in this region, China is the major gainer and Centre of growth (Li, et al., 2023).

Thus, we can conclude that growth and wealth creation in the different regions of the world originated from technological progress, accumulation of physical and human capital, productivity and introduction of new methods in business. The countries that focused on technological progress, improvement of labor skilled, innovation performed far better while countries which performed poorly, and where growth process remain stagnant lagged behind.

1.2 Background of study

Pakistan's average annual economic growth rate in the 1960s was 6.8%, but the political unrest and the secession of East Pakistan caused it to fall to 4.8% in the 1970s. In the fiscal year 2012-2013, Pakistani government invested 4.6 billion in IT projects. Less than 1% of Pakistan's GDP was allocated to science and technological development, which was extremely low compared to other countries in the region. In the recent years, information technology has had a considerable impact on Pakistan's industrial sector. The usage of technology was 9% in consumer goods, 13% in financial services, 9% in e-commerce, and 8% in professional services. In Pakistan, usage of technology in non-profit organizations was only 3%, while it was 4% in media and heath care. In 1997, Pakistan spent 0.16% of GDP on R&D. In the following four years, R&D spending decreased, but there was a slight uptick in 2001. Recognizing the significance of R&D, Pakistan raised spending on R&D to 0.68% of GDP in 2007, which was decreased to 0.17% in 2021.This allocation is still very low compared to China (2.41%), India (0.65%), Iran (0.79%), Malaysia (0.95%), Nepal (0.30%), Thailand (1.33% of GDP). According to World Bank (2017), Pakistan was estimated to contribute 0.44 percent in total global GDP. The average GDP growth rate of Pakistan was approximately 4.91% from 1952 to 201 and its highest GDP growth was 10.22% in 1954 and lowest -1.27% in 1920. According to Pakistan Economic Survey, (2020), Pakistan is facing serious issue of growth and so far, has failed to keep the growth process in accordance with its population growth rate (1.9% in 2020). The historical trends of GDP per capita of Pakistan is displayed in Figure 1 to visualize growth in gross national income per capita.

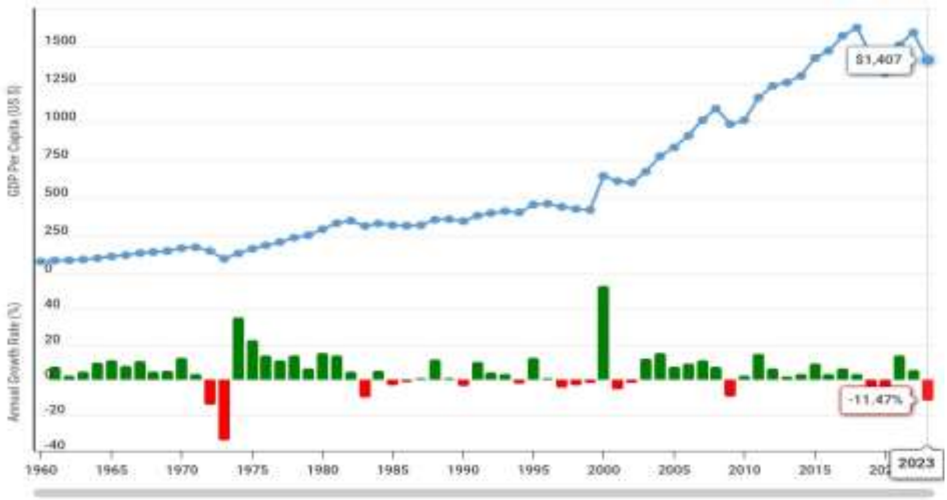

Fig 1: Trends of GDP per capita in Pakistan from 1960 to 2020.

1.3 Link between innovation and economic growth

The theory of creative destruction is originally extracted from the Marxist economic theory (The Communist Manifesto of Marx and Engels, 1848, Grundrisse of Marx, 1857 and Das Capital, 1863), which termed the capitalist processes of destroying and reconfiguring previous economic structures by introducing new economic structure. Schumpeter (1934) in his theory of innovation, postulates that new innovation disrupts the market and forces the companies either to adapt change or exit the market. He termed innovation as "creative destruction" which disrupts the market in which the firms, making innovations kick out inefficient companies from the market. This theory also applies on counties and divide them into two groups: knowledge economies, producing innovative high-tech products and traditional economies, producing old and traditional primary goods. He discussed three stages of the process: invention, innovation and diffusion. According to Schumpeter, invention is the first demonstration of an idea, while innovation is the first commercialization of an innovative product; and diffusion is the dissemination of the new technology, product or process in the market. Innovation also speeds up economic growth by triggering competition among business firms which strive hard to develop and introduce new products and services and, in this way, they push each other to make innovation continuously (Svahn, et al..2017). This competition leads to quality and low-cost products and services for customers. Additionally, when a firm innovate, they create more new jobs, which is crucial for economic growth. The outcomes of innovation results in lower cost, better customer services, wide product range and improvement of existing products (Salman, et al., 2019). The benefits of innovation include improvement of organizational performance, better profitability, competitiveness, value of customers and expansion in market shares. According to Kemp and Foxon, (2007), the main drivers for innovation include improving technical efficiency, increasing market shares, cost reduction, regulations, profit from expansion of business and building company image. There is close link between innovation and economic growth in a dynamic growth process, leading to increase output, higher living standard and the development of new customers, new markets and new industries (Hussain, Jun & Radulescu, 2024).

1.4 Link between Research & Development and innovation

During the 1950s and 60s main focused was on the sources of innovation, and how to promote innovation in the firms through development of Research and Development (R&D) (Xu, 2007). Moreover, the macro-economic significance of innovation was explored by Robert Solow (1957), who predicted in his model that the largest contribution to economic growth comes from a residual, which he termed as “Technical change” due to advances in knowledge, not from traditional sources, labor and capital productivity. He estimated that 40% of US’s productivity and national income originates from this source. Examining the linear model of innovation, the economists, Richard Nelson (1959) and Kenneth Arrow (1962) investigated into the question of whether investment levels in R&D were enough to meet national economic demand. They viewed that the social returns on investment in R&D exceed the private returns made by the individual, business firm because copying of innovative product is easy and less costly for competitors and the innovative firms might not be able to fully avail the benefits of investment because of spillover effect (Foxon, 2003). This reflects the state of “market failure“ as potential barrier to innovation, although this problem has been addressed through patenting and copyright. The Romer’s (1990) theory of innovation examines the relationship between economic growth and research and development (R&D). The motive behind Romer’s R&D theory is profit in contrast to the Solow model. Investment in R&D is encouraged by inventors' ability to command a premium for their creations (Meysami, et al. (2023). This theory emphasizes that that technological change is the result of efforts by researchers and entrepreneurs who respond to economic incentives. This is the reason that this theory is known as “Endogenous growth theory.” In the current research we will investigate into the state of R&D investment and innovation in Pakistan.

1.5 Link between Technological Advancement and labor productivity

Technological advancements make business transaction very easy and quick on national and international level (Hussain,et al, 2024). The digital divide which generated gaps in digital access and usage between the different groups in society and countries is the main issues in the developing economies (Shenglin et al., 2017). These digital divide narrows gradually due to dissemination of digital knowledge, leading to sustainable growth and economic development. that is getting wider every day, which may be the stepping stone for increasing economic growth (Zhang et al., 2022). The major problem in the inclusive information society is the upgradation of physical infrastructure and enhancing digital literacy. Digital innovations need inclusiveness of every member of society (Shenglin et al., 2017). The role of innovation is very crucial in increasing productivity and fostering innovation in manufacturing sector. The innovative infrastructure is the backbone of manufacturing system and contribute significantly in improving the capacity of human capital for innovation (Fichman et al., 2014). Similarly, including e-knowledge is a core attribute that sustains and promote technological advancement in different fields (Kostadinova, 2019; Norris et al., 2003). The previous research disclosed how information technology trigger productivity and efficiency (Scuotto et al., 2017). Digital innovations demonstrate technological capability of an organization (Nambisan et al., 2017). It can be seen in various segments of an organization such as team communication, corporate culture, workflows, creativity, and the broader economic and creative working environment (Sofka and Grimpe, 2010). The optimization of innovation infrastructure bridges the knowledge gaps and trigger innovation, producing an environment where socio-economic integration is achieved, and the productivity is significantly improved (Träskman, & Skoog, (2022). Thus, technological process and productivity has close association, leading to high economic growth. Current research will explore the relationship between technological progress and productivity through empirical analysis.

1.6 Link between human capital and productivity

The human capital theory was initially presented by Schultz, (1961), Becker (1962) and Eosen (1976), pleading that workers possess a set of skills or capabilities which they can enhance further through education and training. Most of the studies have confirmed that length of experience is significant predictor of success (Bruederl et al.1992 and Frese 2000). The endogenous growth model presented by Romer (1990), postulates that creation of new ideas is the core function of human capital, which is the result of knowledge accumulation. Therefore, investment in human capital generates growth in physical capital that ends in economic growth. The continuous skill improvement through learning by doing bolster workers' productivity (Locas (1988), Azariades and Drazen (1990).

The above heoretical literature has confirmed a close link between innovation and economic growth, between research and development and innovation, between technological advancement and productivity, and between human capital and productivity. Therefore, current research explores the following research questions:

RQ1: Innovation positively correlates to economic growth.

RQ2: Research & Development (R&D) positively correlates to innovation.

RQ3: Technological advancement positively correlates to productivity of labor.

RQ4: Human capital positively correlated to productivity.

Exploring these research question will enable to understanding the intricate relationship between innovation and economic growth, between research and development and innovation, between technological advancement, human capital and productivity. Further, the results of this research will also provide evidence-based policy suggestions with an emphasis on leveraging innovation, human capital, and technical advancement to solve the problem of low economic growth in the developing countries like Pakistan. Through an analysis of the productivity obstacles that exist in spite of technological advancements, the research will provide insight into the particular obstacles that must be overcome in order to boost productivity across various industries. It will be possible to make more informed decisions about technology adoption and investment thanks to the research's improved understanding of how Pakistan's economic growth is impacted by technological advancement. The study will uncover the obstacles in the innovation ecosystem by examining the limited influence of innovation on economic growth. This will facilitate policymakers in devising effective policy framework to encourage innovation-driven development. It will also be a useful resource for the future studies in the area and contribute to the corpus of scholarly work on Pakistan's economic progress. In short, this study looks at the interactions between technological development, the creation of physical and human capital, and human capital development in order to understand the intricacies situation of economic growth in Pakistan. In this way, this research will provide a fresh insight about the importance of innovation, technological progress, R&D and human capital for sustainable growth not only in Pakistan but around the globe where economic growth is stagnant.

The remainder of this paper is organized as follows: section 2 reviews the relevant literature, develop hypothesis, identified research gap and novelty of study; section 3 delineates the research data, sources and selection of variables; section 4th outlines empirical results; section 5th contains discussions, theoretical contribution, practical implications, limitations and suggestions for further research.

2. Theoretical framework and literature alignment

Previous literature provides a valuable guide to new researchers and enable them to make their study unique by identifying a gap in the literature. It also provides insights to the researchers to see how other authors have solved their research questions through statistical techniques. Here we delve in current relevant studies and identity research gap for this analysis.

The effect of human capital development on economic growth in Pakistan has been explored by Ali et al. (2012). The era covered by the secondary data was 1972–1973–2010–2011. The results are drawn using a variety of applied econometric techniques, including Causality Test, Descriptive Statistics, and Ordinary Least Square. The study concluded that low levels of investment in human capital are caused by high levels of poverty, unemployment, illiteracy, and energy scarcity. The impact of skill development and vocational training on Pakistan's economic growth was explored by Khilji et al. (2012). The authors used the ADF test, the causality test, Johansen cointegration, and the error correction model to measure the relationship between the variables. They came to the conclusion that vocational training raises labor productivity levels and improves worker capacity. Asghar et al. (2012) looked into how human capital contributes to economic growth. They argued that there is a positive and direct relationship between economic growth and the human capital. They concluded that investments in health and education is necessary to achieve long-term economic prosperity. The growing worldwide shortage of skill-adjusted human capital was examined by Lutz et al. (2022). In particular, when considering the aggregate level, literacy and skills are closely connected with skill domain and also provide a good proxy for the population's total skill level. The measure is provided for people in 185 countries between the ages of 20 and 64 between 1970 and 2015. They came to the conclusion that a person's level of skill, or human capital, could be used to generate income in the labor market.

These empirical studies and Romer's (1990) economic growth theory illustrate key role of human capital in growth in gross national income per capita. Therefore, we can suggest first hypothesis:

H_1: Innovations (Patent applications of residents) positively correlates to gross national income per capita.

Al Masri et al. (2013) looked at how research publications in Asian nations were affected by factors such as GDP, R&D spending, university count, and scientific journal subscriptions. The years 1996–2011 serve as the basis for this research. The Ng-Perron test, ADF, and PP were employed to look at the stochastic characteristics of the variables. They came to the conclusion that Asian nations with higher R&D expenditures produced a sizable amount of research. Per capita income did not correlate with research findings. They suggest that more scientific journals should be published, R&D funding be increased, and universities be developed in order to achieve social and economic progress. An analysis of the role of

R&D in Pakistan's economic growth was conducted by Khan and Khattak (2013), sing time series data from 1971 to 2008 to identify the relationship between the variables by employing the Ordinary Least Square approach. The outcome demonstrates considerable influence of R&D on Pakistan's real GDP per capita. They came to the conclusion that, while research and economic growth are positively correlated, Pakistan invests less in R&D than other Asian nations. They suggested that research in the agricultural and industrial sectors is crucial to boost their productivity. Usmani et al. (2013) examined the GDP footprint, R&D investment, number of universities, and scientific journals on research landscape in the Middle East related to pharmaceutical science. The Johansen Cointegration test confirmed the long-term relationship between R&D and economic growth, as well as the long-term association between R&D. They concluded that increasing R&D spending, developing universities, and publishing journals would improve the quality of pharmaceutical science and scientific knowledge. Khan and Tariq (2014) conducted a study on the role of research and development in Pakistan's economy using time series data from 1971–2008 and employing the Johansen cointegration test, the Augmented Dickey Fuller test, and Ordinary Least Square to analyze data. They concluded that there is a positive correlation between R&D and economic growth. Saeed (2020) investigated how Pakistan's economic growth was impacted by technical advancement using time series data spanning from 1998 to 2018 and employing the ARDL Model and Bound Testing techniques to analyze data. They found that high-quality education and latest technical training are imperatives for development of human capital and without skilled work force and R&D investment national income and GDP growth could be increased.

These empirical findings and Endogenous growth theory of Romer (1990) highlight the positive role of Research and Development in productivity and growth in national income per capita. Thus, we proposed second hypothesis:

H_2: Government expenditures on R&D as % of GDP positively correlates to the growth in gross national income per capita.

Using annual time series data from 1995 to 2013, Yasmeen and Tufail (2015) examined the relationship between information technology and economic growth in South Asia, using time series data spanning from 1995 to 2013. They used panel unit root test and panel ARDL estimation techniques for analysis, and their findings indicated that the use of information technology particularly internet play a significant role in economic growth. Mangla et al. (2016) investigated economic growth, innovation, and public policy from a technological standpoint inside Pakistan's telecom sector. They came to the conclusion that Pakistan mainly relies on imported technology and that the country's tariff system penalizes telecom equipment manufacturers. It is projected that the telecommunications industry will provide significant benefits in the form of increased productivity, innovation, and technological advancements that will spur robust economic growth. Haq (2018) examined how innovation affected Pakistani, South Korean, and Canadian economies. This study's hypothesis was that innovation contributes to economic growth. The time series data covered the years 1991 through 2011. The investigation used the Hausman test for the Random effect VECM and

VAR models, as well as the causality test. They came to the conclusion that high rates of foreign direct investment, research and development, technology export, patent rights, and publishing of scientific journals will make a nation highly advanced and creative. Salam et al. (2019) investigated the dynamic relationship between technological innovation, technology adaptation, human capital, and economy. The panel data used in this study spans the years 2000–2016. For analysis, Filly Modified Ordinary Least Square, Error Correction Method, Unit Root Test, and descriptive statistics were used. Generally, to investigate the short- and long-term dynamics of under study variables, the method of moments is employed. They suggested that economic planning and policies, research and development, reforms in education and using technologies can boost economic growth.

These studies are aligned with Schumpeter's theory of innovation (1934), which illuminates the important role of technological advancement in accelerating growth in gross national income per capita. Therefore, we propose third hypothesis:

H_3: Technology progress in manufacturing sector positively correlates to the growth in gross national income per capita.

Saleem, et al. (2019) examined the impact of total factor productivity on economic growth, using annual time series data from 1972 to 2016. They concluded that a nation's capacity to make innovation, and maintain its position as a global leader is a key factor in long-term economic growth. They suggested that sustainable growth in the economy is pushed by the efficient use of resources. The dynamic relationship between advances in agricultural technology, agricultural insurance, and productivity of agriculture sector in China was examined by Tan et al. (2022). For this study, panel data covering the years from 2004 to 2019 was used. The study found that growth of agricultural technology and the implementation of agriculture insurance policies played a crucial role in China's productivity. Upgrading agricultural security policies is necessary, and allocating the maximum funds to agriculture sector could boost productivity and income in the rural areas of China.

These empirical findings also aligned with Solow's (1957) growth model, which stipulates the influence of technology on productivity and economic growth and growth as well as growth in gross national income per capita. Therefore, we can suggest fourth hypothesis:

H_4: Gross capital formation positively correlates to the growth in gross national income per capita.

The Endogenous growth model of Romer (1990) states that capital accumulation and human capital plays a significant role in the economic growth. The countries, which make significant investment in capital stock and human capital and accumulate them they grow rapidly compared to the countries which lag behind in their accumulation remain poor. This theory highlights the importance of human capital in boosting economic growth and growth in national income per capita. Therefore, we can suggest fifth hypothesis:

H_5: Human capital productivity positively correlates to the growth in gross national income per capita.

2.1 Novelty of study

The novelty of this study is that previous studies have mostly focused on traditional metric for innovation, ignoring modern metrics (like rates of digital transformation platforms, economy growth, or open-source contributions) could offer fresh perspectives. Moreover, previous studies used innovation, Research and Development, technological advancement, capital formation and productivity and their relationship separately but this study has combined these variables to measure their overall impact on growth in national income per capita. This unique approach will provide evidence-based fresh information to the researchers about the relationship of selected variables and provide an opportunity to them to conduct further research to strengthen this relationship through longitude data.

2.2 Hypothesized Model

The hypothesized model has been built on the basis of theoretical framework and review of empirical literature in order to highlight the hypothetical relationship between independent and dependent variables. The conceptual model of this study is shown in Figure 2:

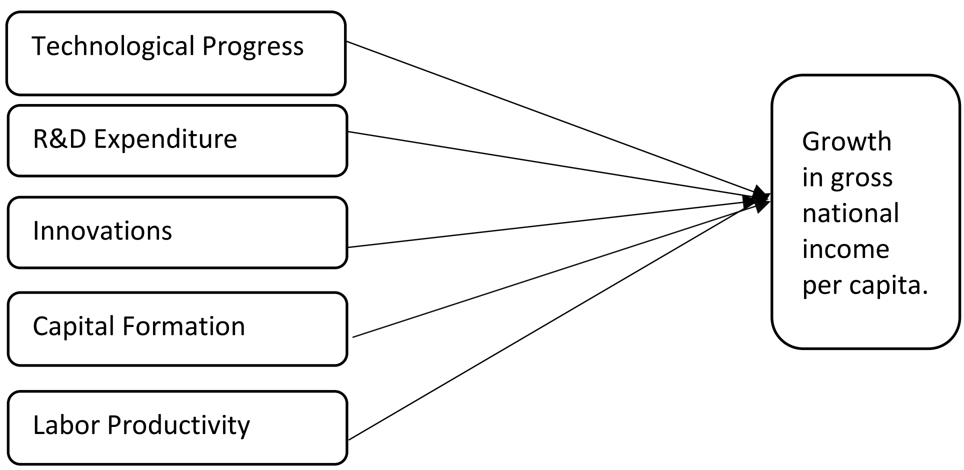

Fig 2: Conceptual Model

3. Data and Methodology

3.1 Selection of variable and data collection

The primary objective of this research is to understand the relationship between economic growth and various independent factors such as innovation, research & development (R&D), technological progress, gross capital formation and productivity. This study adopts a quantitative research design. This design was chosen because it allows for an objective assessment of the relationship between the dependent and independent variables. Through the quantitative analysis, we aim to derive statistical results that can inform policy decisions and future research directions. We used annual time series data spanning three decades, from 1991 to 2022 to observe patterns, trends, and potential causal relationships between variables over time. The data were sourced from World Bank databases, National Statistical Department, research journals, or international organizations such as the OECD, UNDP, etc. This metric provides a per person measure of national income and is often used as an indicator of economic health and living standards. The dependent variable is growth in national income per capita. This will serve as the primary outcome variable, indicating growth in national income per capita of a country. The independent variables include: innovation, R&D (Research and Development), Technological Progress, human capital, gross Capital formation and productivity. The sample of the study is manufacturing sector of Pakistan’s economy.

3.2 Specification of model

In the specified model, the economic growth, which is proxied for GNP, is dependent variable and Govt. Expenditure on Research and Development as % of GDP, Technology advancement, innovation which is proxied for Patent Applications (PATAPP), Gross Capital Formation and productivity are independent variables. The functional form of the model is given below:

$$LGNIPC = \beta 0 + \beta 1\ GOVTER\&D + \beta 2\ TECHA + \beta 3\ INNOV + \beta 4\ LGCAPF + \beta 5\ PROD + \varepsilon$$

Where LGNIP is the dependent variable, βo is intercept and β1 is the slope and ε is an error term (or residual term) in this model. We will use statistical techniques such as descriptive statistics, ADF test, correlation matrix, bound test, ARDL model and Granger causality test to determine statistical relationship and behavior of variables in the long run. The s variables selected for this study and their sources are exhibited in Table1

Table 1:

Selected variables, their definitions and sources

Variables and their abbreviations	Indicators	Units	Sources
Growth in gross national income per capita. (GNIPC)	Gross National income Per Capita.	Constant LCU	WDI
R&D Expenditure (GOVEON R&D)	Govt. Expenditure on Research & Development as % of GDP	%age of govt. expenditure	WDI
Technological Progress (TECHMNF)	Medium & High Technology Manufacturing	%age of manufacturing value added	WDI
Innovation/ (PATAPP)	Patent Applications of residents	Number of Application	WDI

Gross Capital Formation (GCAPFR)	Gross Capital Formation	Current LCU	WDI
Labor Productivity (LBFRPRO)	Labor Force Participation rate	%age of population	WDI

Analytical techniques are an integral part of Econometrics modeling and we will employe descriptive statistics, correlation matrix, ADF Test, ARDL Model, Bound Test, Causality, and diagnostic tests to determine long-term determine relationship between dependent and independent variables.

4. Results

4.1 Descriptive analysis:

Descriptive statistics is used to analyze the Mean, Mode, Standard Deviation, Minimum and Maximum variables, skewness and Kurtosis for measuring central tendency and central variability. Descriptive statistics is the summary of informational coefficients of available a data set of sampling population and is helpful to measure whether the data is normally distributed. The outcomes of descriptive statistics are given in Table 2.

Table 2

Descriptive analysis results

Statistic	**LGNIPC**	**LGCAPF**	**LGVEXOR& D**	**LLBFRPRO**	**TEHPRO**	**LPATAPP**
Mean	5.102458	12.22082	1.067792	1.703412	1.387859	1.958757

Statistic	LGNIPC	LGCAPF	LGVEXOR& D	LLBFRPRO	TEHPRO	LPATAPP
Median	5.109285	12.31028	1.061225	1.705265	1.380054	2.037426
Maximum	5.213760	12.84778	1.188803	1.716254	1.466790	2.528917
Minimum	5.006209	11.44329	0.892253	1.684486	1.357295	1.204120
Std. Dev.	0.070185	0.477474	0.078072	0.007967	0.039712	0.404568
Skewness	0.054642	-0.298805	-0.282593	-0.583599	1.266704	-0.455463
Kurtosis	1.765098	1.721949	2.736776	2.766352	3.114196	2.067724
Jarque-Bera	1.472887	1.907611	0.372525	1.357905	6.163232	1.628136
Probability	0.478814	0.385272	0.830056	0.507148	0.045885	0.443052
Sum	117.3565	281.0789	24.55922	39.17848	31.92076	45.05141
Sum Sq. Dev.	0.108370	5.015601	0.134096	0.001396	0.034695	3.600857

Statistic	**LGNI PC**	**LGCA PF**	**LGVEXO R& D**	**LLBFRP RO**	**TEHPR O**	**LPATA PP**
Observati ons	23	23	23	23	23	23

Descriptive statistics demonstrate the mean values, which reflect the average value of variables. The standard deviation of gross national income per capita is 0.070185, with the mean 5.102458. The average value of gross capital formation is 12.22082 with standard deviation 0.477474. The average value of government expenditure on R&D is 1.067792 with standard deviation 0.078072. The standard deviation of labor force participation is 0.007967 with mean 1.703421. The mean of technological advancement is 1.387859 with standard deviation 0.039712. The mean of innovations (patent application residents) is 1.958757 with standard deviation 0.404568. Skewness is a measure of lack of symmetry of probability distribution of random variable about its mean. Innovation (patent application residents), government expenditure on R&D and gross capital formation are approximately symmetric and medium and technology advancement is highly skewed compared to other variables. Kurtosis is an estimate of the combined weight of a distribution's tail respective to the center of distribution. Technology advancement is mesokurtic and all others variables are platykurtic. Jarque-Bera test is a measures of sample data showing either normal distribution or not. It is always a positive number and if it is beyond zero, it shows that sample data do not have normal distribution. The outcomes in Table 2 confirm that all variables are normally distributed.

4.2 ADF Unit Root Test:

This test is commonly used to check stationarity among the variable in order to decide which model can be used for further analysis. If the variables at stationers at the same level, then Ordinary Least Square method is used and if variables are stationers at different levels, then ARDL approach can be used. The results of unit root test are presented in Table 3.

Table 3

Results of ADF Test

Variables	Level		First Difference		Second Difference		Decision
	Intercept	Intercept & Trend	Intercept	Intercept & Trend	Intercept	Intercept & Trend	
LGDPG	t = 0.686707	P = 0.9898	t = - 2.812887	P = 0.2042	t = - 3.942624	P = 0.0053	I (1)
			t = - 4.202094	P = 0.0128	t = - 5.565845	P = 0.0001	
					t = - 5.340183	P = 0.0010	
LTECHA	t = 0.035282	P = 0.9480	t = 0.084808	P = 0.9932	t = - 5.991632	P = 0.0004	I (1)
					t = - 5.753357	P = 0.0000	

Variables	Level		First Difference		Second Difference		Decision
					t = - 3.532806	P = 0.0285	
					t = - 2.852724	P = 0.2131	
LINNO	t = - 1.952226	P = 0.3046	t = - 2.830218	P = 0.1986	t = - 3.506791	P = 0.0168	I (1)
			t = - 6.072635	P = 0.0003	t = - 3.328175	P = 0.0247	
					t = - 3.436420	P = 0.0700	
LINNO	t = - 0.480828	P = 0.8813	t = - 3.423575	P = 0.0671	t = - 6.066987	P = 0.0000	I (0)
(continued)					t = - 6.013458	P = 0.0002	
					t = - 9.370451	P = 0.0000	
					t = - 9.172971	P = 0.0000	
LGCAPF	t = - 1.029462	P = 0.7290	t = - 3.472898	P = 0.0614	t = - 5.160108	P = 0.0003	I (0)
					t = - 5.118326	P = 0.0017	
					t = - 6.695026	P = 0.0000	

Variables	Level		First Difference		Second Difference		Decision
					t = - 6.565093	P = 0.0001	
LGEXP R&D	t = - 2.498380	P = 0.1313	t = - 2.907494	P = 0.1946	t = - 3.135022	P = 0.0408	I (1)
					t = - 3.213403	P = 0.1113	
					t = - 3.992085	P = 0.0081	
					t = - 3.662612	P = 0.0543	

Table 3 show that the data of GDP Growth, government expenditure on R&D, technology advancement and innovations (patent application residents) are stationer at first difference. In contrast, Gross capital formation is stationer at level. Overall, the variables are stationary at I (0) and I (1) levels, it allows us to use ARDL dynamic approach for further analysis.

4.3 Bound Test:

The ARDL; s Bound test is employed to identify cointegration between variables with different order of integration in the long-term. The estimated results of Bound Test are shown in Table 4.

Table 4

Bound Test results

Null Hypothesis: No relationship between variables exists				
Test Statistic	**Value**	**Sign.**	**I(0)**	**I(1)**
Asymptotic: n = 1000				
F-statistic	4.515082	10%	2.08	3.00
		5%	2.39	3.38
		2.5%	2.70	3.73
		1%	3.06	4.15
Actual Sample Size: 19				
	10%		2.331	3.417
	5%		2.804	4.013
	1%		3.90	5.419
Finite Sample: n = 30				
	10%		2.407	3.517
	5%		2.91	4.193
	1%		4.134	5.761

The outcomes in Table 4 shows that the value of f-statistic does not lie between lower bound and upper bound. This value is greater than upper bound. So, we'll reject the null hypothesis. it's means that there is long run relationship between variables. Now, we can go for further long-run cointegration analysis through ARDL Model.

4.4. ARDL Model

The short run and long run results of ARDL model are presented in Table 5. Part fist depicts short-term relationship, while part second illustrates long-term association between dependent and independent variables.

Table 5

Short and long-term results

ARDL Long Run Form. Dependent variable: LGNIPC Selected Model: ARDL (3, 1, 1, 1, 0, 1) Case 2: Restricted constant and no trends Sample: 131 Observations: 19 Dated: 06/24 Time: 23:15 Case 1: Conditional Error Correction Model				
Error Correction Model: Short-term Coefficients				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	3.148086	1.150070	2.737299	0.0339
LGNIPC (-1)	-0.238041	0.340510	-0.699074	0.5107
LGCAPFR (-1)	0.120058	0.055905	2.147546	0.0754
LPATAPPRES (-1)	-0.049568	0.026752	-1.852840	0.1133
LMDHITECMNF (-1)	0.027146	0.249948	0.108606	0.9171
LLBFRCPA	-1.964040	0.487244	-4.030915	0.0069
LGVEXEDU (-1)	-0.006443	0.049598	-0.129895	0.9009
D(LGNIPC (-1))	1.219715	0.290143	4.203844	0.0057
D(LGNIPC (-2))	-0.761292	0.461577	-1.649327	0.1502
D(LGCAPFR)	0.210404	0.063477	3.314667	0.0161
D(LPATAPPRES)	-0.005491	0.018584	-0.295457	0.7776
D(LMDHITECMNF)	0.422164	0.193398	2.182877	0.0718
D(LGVEXEDU)	0.077326	0.044853	1.723971	0.1355

ARDL Model: Long Run results

Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
LGCAPFR	0.504357	0.512332	0.984433	0.3629
LPATAPPRES	-0.208231	0.385910	-0.539583	0.6089
TECHMNF	0.114038	0.901764	0.126461	0.9035
LLBFRP	-8.250829	11.58502	-0.712198	0.5031
LGEXPOR&D	-0.027065	0.180621	-0.149842	0.8858
C	13.22495	15.20695	0.869665	0.4179

EC = LGNIPC - (0.5044 * LGCAPFR - 0.2082 * LPATAPPRES + 0.1140 * TECHMNF - 8.2508 * LLBFRCP - 0.0271 * LGEXOR&D + 13.2249)

Part first of table 5 shows the short run outcomes and association between dependent and independent variables. The growth in gross national income per capita (LGNIPC) has negative sign and its value of t-statistic is greater than 2. The P-value is less than 0.05, its means that the level of significance is 5%. There is negative relationship between innovation (patent application residents), labor force participation (Human capital) and Government expenditures on R&D with growth in gross income per capita in short-term. Whereas Technology advancement in manufacturing sector and gross capital formation have positive relationship with growth in gross national income per capita in short-term.

The second part of table 5 depicts long-term cointegration between dependent and independent variables. The coefficients of all variables are statistically significant. Innovations (Patent applications of residents), and govt. expenditure on R&D are negatively related to GNI per capita in long-term. Technology advancement in manufacturing sector and gross capital formation are positively correlated to GNI per capita in the long-term. The coefficient of gross capital formation is 0.50, suggesting a one unit increases in gross capital formation is associated with 50% increase in GNI per capita, revealing statistically significant relationship between these two variables. The coefficient of Innovations (patent applications of residents) is -0.20, indicating a one unit increases in patent applications is associated with 20% decrease in GNI per capita. Patent applications have no significant impact on Pakistan's grows national income per capita because the level of innovations is very low. The coefficient of technology advancement in manufacturing sector is 0.11, suggesting a one unit increases in technological advancement is associated with an increase in GNI per capita by 11% in the long-term if all other factors remain constant. The coefficient of labor force productivity is -8.25, which suggest that a one unit increase in gross capital formation is associated with a decline in GNI per capita by 8.25% because mostly labor force in Pakistan is uneducated and unskilled, and this is the main cause of low growth in gross national income per capita. The coefficient of govt. expenditure on research and development is -0.027, indicating that a one unit increases in govt. expenditure on R&D is associated with a decrease in GNI per capita by 27% The possible explanation of this negative link is low quality of education, low R&D expenditures and lack of innovations in the manufacturing sector.

4.5 Granger Causality Test

In order to apply Granger causality test, we have used LGNIPC as dependent variable Innovation, Technology Advancement in Manufacturing Sector, Government Expenditure on R&D, and Gross

Capital Formation as independent variables. The results of Granger causality test are presented in Table 6.

Table 6:
Result of Granger Causality Test

Pairwise Granger Causality Tests

Date: 06/06/24

Time: 23:14

Sample: 1 31

Lags: 2

Null Hypothesis	**Obs**	**F-Statistic**	**Prob.**
LGCAPFR does not Granger Cause LGNIPC	28	6.68134	0.0052
LGNIPC does not Granger Cause LGCAPFR		3.73125	0.0395
LLBFRCPA does not Granger Cause LGNIPC	29	8.12752	0.0020
LGNIPC does not Granger Cause LLBFRCPA		3.34458	0.0523
LGVEXEDU does not Granger Cause LGNIPC	19	2.65357	0.1054
LGNIPC does not Granger Cause LGVEXEDU		1.65148	0.2270
LMDHITECMNF does not Granger Cause LGNIPC	28	0.58942	0.5628
LGNIPC does not Granger Cause LMDHITECMNF		2.46055	0.1076
LPATAPPRES does not Granger Cause LGNIPC	25	3.04183	0.0702

Null Hypothesis	Obs	F-Statistic	Prob.
LGNIPC does not Granger Cause LPATAPPRES		1.06702	0.3628
LLBFRCPA does not Granger Cause LGCAPFR	28	0.58816	0.5635
LGCAPFR does not Granger Cause LLBFRCPA		2.65228	0.0919
LGVEXEDU does not Granger Cause LGCAPFR	18	3.85706	0.0484
LGCAPFR does not Granger Cause LGVEXEDU		2.43279	0.1266
LMDHITECMNF does not Granger Cause LGCAPFR	28	4.94498	0.0164
LGCAPFR does not Granger Cause LMDHITECMNF		3.91600	0.0344
LPATAPPRES does not Granger Cause LGCAPFR	25	1.67987	0.2117
LGCAPFR does not Granger Cause LPATAPPRES		3.19324	0.0626
LGVEXEDU does not Granger Cause LLBFRCPA	19	4.94182	0.0238
LLBFRCPA does not Granger Cause LGVEXEDU		0.61778	0.5532

Null Hypothesis	Obs	F-Statistic	Prob.
LMDHITECMNF does not Granger Cause LLBFRCPA	28	1.95263	0.1647
LLBFRCPA does not Granger Cause LMDHITECMNF		6.90279	0.0045
LPATAPPRES does not Granger Cause LLBFRCPA	25	1.63640	0.2197
LLBFRCPA does not Granger Cause LPATAPPRES		2.01383	0.1597
LMDHITECMNF does not Granger Cause LGVEXEDU	18	0.35707	0.7064
LGVEXEDU does not Granger Cause LMDHITECMNF		2.10317	0.1617
LPATAPPRES does not Granger Cause LGVEXEDU	15	0.01812	0.9821
LGVEXEDU does not Granger Cause LPATAPPRES		2.91936	0.1003
LPATAPPRES does not Granger Cause LMDHITECMNF	25	4.68705	0.0214
LMDHITECMNF does not Granger Cause LPATAPPRES		2.25018	0.1314

The results in Table 6 reveal that Innovation (patent Applications of residents) at lag 1 has F-statistics :0304 and p-value 0.598, while at lag 2 it has F-statistics 0.345 and p-value 0.728. For both lag 1 and 2 the p-value is more than 0.5, and we can conclude that innovation does not Granger-cause Gross national income per capital (GNIPC). Technology Advancement in Manufacturing sector at lag 1 has F-statistics 3.849 and p-value 0.0091, and at lag 2 F-statistics is 3.271 and p-value 0.144. For both lag 1 and lag 2, the p-values are greater than 0.05 and we can conclude that Technology Advancement in Manufacturing Sector does not Granger-cause LGNIPC. As regards to Government Expenditures on R&D at lag 1 F-statistics are 20.91 and p-value 0.003 and at lag 2 F-statistics are 28.919 and p-value 0.004. We can see that for both lag 1 and lag 2, the p-values are less than 0.05 and therefore, the Government Expenditure on R&D Granger-causes LGNIPC. The Gross Capital Formation at lag 1 F-statistics are 19.874 and p-value 0.003 and at lag 2 F-statistics are 2.882 and p-value 0.147. It indicates that for lag 1, the p-value is less than 0.05, suggesting a significant relationship while for lag 2, the p-value is greater than 0.05, indicating insignificant relationship. Thus, we can conclude that Gross Capital Formation Granger-causes LGNIPC at lag 1 but not at lag 2.

These findings illuminated that government expenditure on R&D and gross capital formation have predictive power about changes in gross national income per capita, whereas innovation (patent applications) and technology advancement in manufacturing do not have any such predictive power about gross national per capita income.

5. Findings

The long run results of ARDL Model shown in Table 5 reveal that first hypothesis **(H_1),** which states that innovations (Patent applications of residents) have positive and significant relationship with gross national income per capita ((GNIPC), is not confirmed by the finding of the study. These findings are also confirmed by Granger casualty test which states that innovation does not Granger-cause Gross national income per capital (GNIPC). The possible explanation of this negative relationship is the low level of innovations and patent applications by scientists in Pakistan. These findings are opposite to economic theory but in line with the studies of Christensen, (1997) and Hussain, et al. (2024)

The second hypothesis **(H_2),** which posits that Government expenditures on R&D ((GEXPONR&D) has significant and positive relationship with gross national per capita income, is not confirmed by the finding of the study which shows negative association between two variables. The possible explanation of this negative association is that the ratio of Government expenditures on R&D is very low and is being spent on non-productive activities and as such R&D expenditures have negative impact on gross national income per capital. These findings are consistent with the study of Meo, et al., (2013), who found negative relationship between R&D expenditures in public sector in the developing countries like Pakistan and growth in gross national per capita due to nominal investment in the Research and Development.

However, third hypothesis **(H_3),** which states that technology progress in manufacturing sector (TECHPMNF), has significant and positive relationship with gross national income per capita, is confirmed by the finding of this study as the manufacturing sector in Pakistan is using cutting edge technology and it has positive impact on gross national income per capita. These finding also confirm Solow's (1957) growth model and empirical study of Kechagioglou, (2023).

The fourth hypothesis **(H_4),** which states that gross capital formation (GCAPF) has significant and positive association with gross national income per capita, has been confirmed by the empirical findings of this study, and these also align with the Solow's (1957) growth model and the Romer's (1990) Endogenous growth theory and empirical study of Haq, (2018). In contrast, the fifth hypothesis **(H_5),** which postulates that labor force productivity (LBFRPR) has significant and positive association with gross national income per capita, has not been confirmed by empirical results of this research. The possible explanation of this negative relationship is that mostly labor force in Pakistan is unskilled and they are hired on daily wages and manufacturing firms do not provide training facilities to it, and as such their productivity is low and has negative relationship with gross national income per capita. However, these findings confirm the study of Lutz, (2022), who found negative link between labor force productivity and GDP per capita in the developing countries due to unskilled labor force. This study proposes that further research is needed into negative relationship between labor productivity and per capita national income, between innovation and productivity and between R&D expenditure and innovation in Pakistan through a longitudinal data and employing latest econometric techniques.

5.1. Theoretical contribution

The findings of this study do not support Schumpeter's (1934) theory of innovation and Romer's (1990) Endogenous growth model because Pakistan's economic system and ways of doing business are different from the developed countries, where technology, innovation and investment in R&D are the major drivers of economic growth. The negative relationship between innovation and economic growth is that Pakistan's economy is still primitive economy which mainly depends upon agriculture sector that produces commodities for consumption. This sector is producing 30% less output compared to other regional countries because there is no innovation in this and other sectors such as industrial and services sector. The same situation is about investment in Research & Development and investment by private and public sector nominal, resulting in low innovation. Thus, there is no significant role of innovation and R&D in the economic growth in Pakistan. Moreover, the negative relationship between innovation, Research and Development and labor force productivity has open avenue for further research by new researchers in order to diagnosis of the causes of negative relationship between innovation and economic growth in Pakistan.

5.2 Policy implications

The policy implications of the study are illustrated below:

The finding of the study demonstrate that R&D and innovations have no significant impact on Pakistan's economic growth, suggesting that addressing internal challenges, such as low domestic investment, political instability, low literacy rates and training of labor are crucial. Policymakers should focus on creating a conducive environment for innovation, including improving political stability and promoting education. Moreover, the improving vocational training for upgrading the quality of education and labor force skills implies that investments in vocational training programs should be prioritized. Enhancing the workforce can lead to increased productivity and economic growth. Additionally, the neglect of R&D in Pakistan is a serious cause for concern.

The study underscores the need for increased investment in research and development activities. Policymakers should encourage public and private sectors investment in for R&D to foster innovation and technological progress. The negative impact of uneducated and unskilled labor on economic growth highlights the importance of improving the quality of education in Pakistan. Policies should focus on enhancing educational standards to produce a more skilled and capable workforce. Low capital investment in Pakistan, resulting in reduced demand for goods and services, needs immediate attention for intervention of policy makers. Encouraging higher levels of investment, particularly in machinery and infrastructure, can stimulate economic growth. The study suggests that long-run economic growth in Pakistan depends upon technology improvement. Therefore, Pakistan should prioritize the adoption of modern technology and efficient utilization of its physical and human resources to drive growth and productivity.

Data statement

The data that supports the findings of this study will be made available by corresponding authors on strong request.

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References

Adak, M. (2015) Technological Progress, Innovation and Economic Growth; the Case of Turkey, Procedi, *Social and Behavioral Science* 195, 776-782. http://dx.doi.org/10.1016/j.sbspro.2015.06.478 Google Scholar

Ahmad, M. (2021). Non-linear dynamics of innovation activities over the business cycles: Empirical evidence from OECD economies. *Technology in Society*, 67, 101721. https://doi.org/10.1016/j.techsoc.2021.101721 Google Scholar

Arrow, K. (1962) *Economic welfare and the allocation of resources for invention* The Rate and Direction of Inventive Activity (ed. R. Nelson), Princeton University Press, 609-625. Google Scholar

Awan, Anwar, Awan, Abdul Ghafoor (2015) Analysis of Pakistan and Indian Stock Markets: A Comparative study, *Science International Lahore* 27(6):6327-6333. Google Scholar

Awan, Abdul Ghafoor (2014). Brazil's Innovative Anti-Poverty & Inequality Model, *International Journal of Development and Economic Sustainability* 2 (5): 45-55 Google Scholar

Awan, Abdul Ghafoor (2012). Diverging Trends of Human Capital in BRIC countries, *International Journal of Asian Social Science*, 2 (12): 2195-2219. Google Scholar

---

Awan, Abdul Ghafoor; Rubina Yaqoob (2023) Economic value of introducing technology to improve productivity: An ARDL approach, *Innovation and Green Development*, 2 (3): 1-8 Google Scholar

---

Awan, Abdul Ghafoor (2012) Human Capital: Driving Force of Economic Growth in Selected Emerging Economies, *Global Disclosure of Economic and Business*, 1 (1): 09-30 Google Scholar

---

Awan, Abdul Ghafoor (2016). Wave of Anti-Globalization and capitalism and its impact on world Economy, *Global Journal of Management and Social Sciences*, 2 (4): 1-21. Google Scholar

---

Awan, Abdul Ghafoor (2015). Analysis of the impact of 2008 financial crisis on economic, political and health systems and societies of Advanced countries, *Global Journal of Management and Social Sciences* 1 (1): 1-16. Google Scholar

---

Awan, Abdul Ghafoor (2015). State Versus Free Market Capitalism: A comparative Analysis. *Journal of Economics and Sustainable Development*, 6 (1): 166-176 Google Scholar

---

Awan, Abdul Ghafoor (2015) Relationship between Environment and Sustainable Economic Development: A Theoretical approach to Environmental Problems, *International Journal of Asian Social Sciences* 3 (3): 741-761 Google Scholar

---

Awan, Abdul Ghafoor (2014). Shifting Global Economic Paradigm, *Asian Business Review*, 4 (3): 113-118 Google Scholar

---

Awan, Abdul Ghafoor (2011) Changing World Economic and Financial Scenario, *Asian Accounting and Auditing Advancement*, 1 (1): 146-175. Google Scholar

---

Awan, Abdul Ghafoor (2013). Environmental challenges to South Asian Countries. *Asian Accounting and Auditing Advancement*, 3 (1): 84-103. Google Scholar

---

Awan, Abdul Ghafoor (2013) China's Economic Growth-21st Century Puzzle *Global Disclosure of Economics and Business* 2 (2) 9-29. Google Scholar

---

Awan, Abdul Ghafoor. Kamran, Muhammad (2017). Impact of Human Capital development on Pakistan's Economic growth. *Global Journal of management, Social Sciences and Humanities*, 3 (3) Google Scholar

---

Bashir Ahmad Khilji, Zaheer Khan Kakar and Sabahat Subhan (2012) Impact of Vocational Training and Skill Development on Economic Growth in Pakistan: *World Applied Science Journal* 17(10): 1298-1302. Google Scholar

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. & Rickne, A. (2008) Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research Policy*, 37, 3, 407-429. https://doi.org/10.1016/j.respol.2007.12.003 Google Scholar

Cheung, C., Y. Guillemette and S. Mobasher-Fard (2012) Tertiary Education: Developing Skills for Innovation and Long-Term Growth in Canada, OECD Economics Department Working Paper No. 991, September. Google Scholar

Fichman, R. G., Dos Santos, B. L., & Zheng, Z. (2014). Digital innovation as a fundamental and powerful concept in the information systems curriculum. *MIS Quarterly,* 38(2), 329-A15. http://doi:10.25300/misq/2014/38.2.01. Google Scholar

Haq, Inayatul (2018) Impact of Innovation on Economic Development: Cross Nation Comparison of Canada, South Korea and Pakistan: *Journal of Economic Info* (JEI), 5 (3): 7-15, DOI: 10.31580/jei.v5i3.96. Google Scholar

Hussain, H., Jun, W. & Radulescu, M. (2024) Innovation Performance in the Digital Divide Context: Nexus of Digital Infrastructure, Digital Innovation, and E-knowledge. *Journal of Knowledge Economy*. https://doi.org/10.1007/s13132-024-02058-w Google Scholar

Kechagioglou, P. (2023). What We Know from Existing Theories of Innovation. In: Healthcare Innovation Success. Springer, Cham. https://doi.org/10.1007/978-3-031-28353-6_2. Google Scholar

Khan, Jungreis and Tariq, Muhammad (2014) The Significance of Research and Development for Economic Growth: The Case of Pakistan: MPRA Paper No. 565005. Google Scholar

Kostadinova, I. (2019). Digital models for transformation of corporate social responsibility education. In 2019 29th Annual Conference of the European Association for Education in Electrical and Information Engineering (EAEEIE) (pp. 1–5). Ruse, Bulgaria. https://doi.org/10.1109/EAEEIE46886.2019. 90004362014 13:11 UTC. Google Scholar

Javid, Muhammad (2019) Public and Private Investment and Economic Growth in Pakistan: An Aggregate and Disaggregate Analysis: *Sustainability*, 11, 3359; Doi:10.3390/su11123359 Google Scholar.

Li, J., Rim, GN. & An, CJ. (2023) Comparative Study of Knowledge-Based Economic Strength Between China and the USA. *Journal of*

Knowledge Economy 14, 4256–4292. https://doi.org/10.1007/s13132-022-01054-2. Google Scholar

Lutz, Wolfgang, Claudia Reiter, Caer Ozdemir, Delik Yildiz and Raquel Guimaraes (2022) Skill Adjusted Human Capital shows rising *Global Gap*.118 (7), e2015826118. https://doi.org/10.1073/pnas.2015826118 Google Scholar

Meysami, A.M., Naghizadeh, R., Heydari, J. et al. (2023) A Model of Effective Factors for Sustainable Growth of New Technology-Based Firms in Developing Countries. *Journal of Knowledge Economy* 14, 4630–4656 (2023). https://doi.org/10.1007/s13132-022-01050-6 Google Scholar

Nambisan, S., Wright, M., & Feldman, M. (2019). The digital transformation of innovation and entrepreneurship: Progress, challenges and key themes. *Research Policy*, 48(8), 103773. https://doi.org/10.1016/j.respol.2019.03.018. Google Scholar

Nambisan, S., Lyytinen, K., Majchrzak, A., & Song, M. (2017). Digital innovation management: Reinventing innovation management research in a digital world. *MIS Quarterly*, 41(1), 223–238. http://doi:10.25300/MISQ/2017/41:1.03 Google Scholar

OECD R&D Indicator (2019). *Gross Domestic Spending on R&D*. https://doi.org/10.1787/d8b068b4-en Google Scholar

Pradhan RP, Arvin MB, Hall JH, Nair M (2016) Innovation, financial development and economic growth in Eurozone countries. *Appl Econ Lett* 23 (16): 1144. http://doi.org/10.1080/13504851.2016.1139668 Google Scholar

Rehman, A., Ma, H., Khan, S.U. et al (2023). Do Exports of Communication Technology, Food, Manufacturing, and Foreign Investments Foster Economic Growth in Pakistan? an Exploration from Asymmetric Technique. *Journal of Knowledge of Economy*, 14, 4238–4255. https://doi.org/10.1007/s13132-022-01052-4 Google Scholar

Rizwan Yasmeen and Sadia Tufail (2015) Impact of Internet Technology on Economic Growth in South Asia with Special Reference to Pakistan: *Pakistan Journal of Social Sciences* (PJSS), 35, (2), 777-784. Google Scholar

Sajid Ali, Imran Sharief Chaudhry and Fatima Farooq (2012) Human Capital Formation and Economic Growth in Pakistan: *Pakistan Journal of Social Sciences* (PJSS) 32, (1):.229-240. Google Scholar

Schumpeter, J. A. (1934)) *The Theory of Economic Development*. Harvard University Press, Cambridge MA. Google Scholar

Scuotto, V., Santoro, G., Bresciani, S., & Del Giudice, M. (2017). Shifting intra-and inter-organizational innovation processes towards digital business: An empirical analysis of SMEs. *Creativity and Innovation Management*, 26 (3), 247–255. https://doi.org/10.1111/caim.12221. Google Scholar

Saleem, Hummer Malik Shahzad, Muhammad Bilal khan and Bashir Ahmad Khilji (2019) Innovation, total factor productivity and economic growth in Pakistan: a policy perspective: *Journal of Economic Structure*. https://doi.org/10.1186/s40008-091-0134-6. Google Scholar

Sener. S and Saridogan, E. (2011) The effect of Science-Technology-Innovation on Competitiveness and Economic Growth. Procedia—*Social and Behavioral Sciences* 24, 815-828, 2011, http://dx.doi.org/10.1016/j.sbspro.2011.09.127, Google Scholar

Shabbir, and Nusrat Yaqoob (2019) The impact of technological advancement on total factor productivity of cotton: a comparative analysis between Pakistan and Indian: *Journal of Economic Structure.* https://doi.org/10.1186/s400008-019-0160-4. Google Scholar

Sofka, W., & Grimpe, C. (2010). Specialized search and innovation performance–Evidence across Europe. *R&D Management*, 40(3), 310–323. https://doi.org/10.1111/j.1467-9310.2010.00592.x Google Scholar

Solow, R. (1957). Technical change and the aggregate production function". *Review of Economics and Statistics*, 39, 312-320.

Google Scholar

Tian, Y., & Hong, J. (2022). In the context of digital finance, can knowledge enable manufacturing companies to be more courageous and move towards sustainable innovation? *Sustainability*, 14(17), 10634. https://doi.org/10.3390/su141710634. Google Scholar

---

Träskman, T. I., & Skoog, M. (2022). Performing openness: how the interplay between knowledge sharing and digital infrastructure creates multiple accountabilities. *Journal of Strategy and Management*, 15(2), 194–219. http:// doi:10.1108/jsma-12-2020-0359. Google Scholar

---

Xu, Q. (2007) Total Innovation Management: a novel paradigm of innovation management in the 21st century. *Journal of Technology Transfer*, 32, (1); 9-25 https://doi.org/10.1007/s10961-006-9007-x

Google Scholar