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Demographic Dividend, Digital Transformation and Environmental Sustainability Nexus in South Asia

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ABSTRACT

The study explains the impact of digital transformation and environmental sustainability on the demographic dividend. Over the last few decades, remarkable demographic changes are founded in South Asian countries that provide a "window of opportunity" and cause sustainable development by promoting the working-age population. We have used Panel Autoregressive Distributed Lag Model (ARDL) to investigate the dynamic linkages between variables and estimate long-run and short-run results by applying different techniques. Data of all concerned variables are taken from 1972 to 2020 across all South Asian countries. The study employs two models to determine the relationship among variables. In the first model, long-run results show that mobile cellular subscriptions, internet users, urbanization growth, and trade are positively related to population ages (15-64) except for greenhouse gas emissions, governance index, and human capital index. In the second model, mobile cellular subscriptions, internet users, greenhouse gas emissions, urbanization growth, human capital index, and trade are positively related to secondary school enrolment except for the governance index. This study suggests that South Asian countries focus not only on the use of ICT but also promote other digitalization indicators for digital technology developments through investment. Further, policymakers may introduce policies to revamp the education system and create new opportunities to fulfil the labor market demand.

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1. Introduction

Demographic characteristics such as age, gender, size of family, income level, culture, background, and academic qualifications play a significant role in sustainable development. The demographic dividend provides abundant opportunities for fostering ICT, manufacturing, and service sectors in the South Asian region which leads to a rising growth rate. The working-age population has more tendency and capacity to adopt new technologies. The study explains the prospects of effective industrial policy that fosters the younger working population's productive capacities, produces employment and causes the South Asian demographic dividend (Hosan, Karmaker, Rahman, Chapman, & Saha, 2022). Over the next three to four decades, many developing nations are passing through rapid demographic changes which occur along with the age-structural transition. Many theories infer that the changes in age structure ultimately lead to higher development in their countries. Many researchers believe that the central part of human capital growth is one of the most important ways to get the most out of changes in the population. People think that the young, efficient work force is the main thing that helps the region's economy grow and stay strong. Many scholars have observed that the different infrastructural and institutional factors like roads, railways, bridges, transport, education, and healthcare help to facilitate the human development process (Zaman & Sarker, 2021).

The researchers point out that digital transformation and demographic changes cause to assisting the environmental policy and encouraging sustainable behavior. The techno-economic paradigm affects almost every sector of trade, business, and services sectors. The trend of advancement in technology and other networking tools triggers the growth rate of the country. Moreover, digital technology sometimes set off to diminish environmental sustainability and creates environmental damage and disturbances. The digital transformation across the nations starts with the improved energy efficiency of production and increasing electronic waste streams. So new climate-related programs and plans reduce the environmental impacts. All developing and low-income countries need to fulfill the gap in economic and social sectors and scientific technology that focuses on development. Sometimes demographic structure affects the consumption and production patterns of the nation, which are not always beneficial from a sustainability viewpoint.

The environmental extent of the digital economy deserves particular concentration on sustainability because the recent environmental-related issues are a result of production and consumption techniques. In small islands and developing countries, greater use of different technological innovations produces environmental sustainability. The demographic dividend helps in improving the various dimensions of digitalization. It strengthens the path to controlling environmental insufficiency and attaining Sustainable Development Goals. The researchers examine that variables of digital transformation and environmental sustainability are helping to boost the per capita growth rate of the region. To ensure the sustainable development of the economy, digitalization increases environmental indicators and economic growth (Sarker, Tandukar, & Dey, 2021).

The rest of the paper is organized as Section 2 is about the review of the literature. Section 3 explains the specification of models and the description, definition, and sources of data is given in Section 4 while methodology is described in Section 5. The results are discussed in section 6 and section 7 concludes the study along with policy implications.

2. Review of Literature

This section presents the analytical review of many studies that are based on demographic dividends, digital transformation, and environmental sustainability. Table 1 shows the summary of the studies.

Table 1: Summary of Studies

Reference(s)	Time	Country	Methodology	Main Results
Summary of Studies on Demographic Dividend and Digital Transformation				
Sarker et al. (2021)	1999-2019	Nepal	OLS Regression	GHG (+) , Governance (-), HDI (-), Trade(-), mobile phone cellular subscriptions(+), internet users(+),Urban population growth(+),
Hosan et al. (2022)	1995-2018	Emerging economies	CSD Test, CS-ARDL test, and D-H Panel Causality Test.	Digitalization (+), Energy intensity (-), Economic sustainability (-),Gross capital formation(+), Urbanization(+), Industrialization(+)
Zaman and Sarker (2021)	1990-2019	Bangladesh	Three-Stage Least Squares Model (3SLS)	Capital(+), labor productivity(+), internet users(+), mobile phone penetration(+), rural electricity(+), female participation rate (+), HDI(-), urban rate(-)
Popelo, Kychko, Tulchynska, Zhygalkevych, and Treitiak (2021)		Ukraine	The general scientific and specific method	Digital innovation activity(+), labor productivity(+), mobility(+), wages(+), competitiveness(+), unemployed labor(-), informal employment(-)
Barlybaev, Ishnazarova, and Sitnova (2021)		Russia	Specific methods, General scientific methods (analysis, synthesis, comparison), Methods of dialectical logic, statistics, and sociology	Health(+), Environment(+), Education(+), Infrastructure(+), Business(+), Agriculture(+), Information system(+), Finance(+), Economy(+)
Gautam, Bhimavarapu,	2018-2020	India	Panel data analytical technique	Kisan Credit Card (-), Digitalization (+) with farmer's income

and Rastogi (2021)				
Zaborovskaia, Nadezhina, and Avduevskaya (2020)	2014-2018	Russia	Multivariate regression, Ordinary Least Squares (OLS)	Internet users(-), social policies, broadband internet subscription(+), internet research and development cost(+),social and cultural activities(health)(+),(education)(+) ICT employment(+),educational technological Programme (-)
Wijayanti and Turgel (2021)	2012-2017	Indonesia	Badan Pusat Statistic (BPS)	Information communication technology (ICT) (-) Mean years of schooling (MYS) (+)
(Kozlova, Novak, & Karlova, 2020)		Russia	Multiple regression equations, Trend forecasting models	Investments in fixed capital(+), Cost of fixed capital(+), Number of companies and organizations(+), Number of employees(-), and Labor force aged 15-72 years(-)
(Ahmmed & Salim, 2019)		Bangladesh	The regression method, Pearson Chi-Square test,	The internet for studying(+), The internet for social networking(+), The internet for academy study(+), The internet for adult content(+), The internet for movies/music(-), other factors age(+), residence(+), class attendance(+), and marital status(-)
Summary of the Studies on Demographic Dividend and Economic Growth				
Sun, Tao, Su, and Umar (2021)	1992-2019	China	Low-frequency VAR and Mixed-frequency VAR models	GDP fluctuations(-), Center for disease control (CDC)(-)
Cutler, Huang, and Lleras-Muney (2016)		Developing countries	Regression analysis	GDP fluctuation (-) with adults mortality rate, GDP fluctuation (+) with an older mortality rate
Brueckner and Schwandt (2015)	19960-2007	Developing Countries	Regression analysis, least squares, and 2SLS method.	GDP per capita growth (+), Instrumental variable (oil price) (+-)
Erdoğan, Ener, and Arıca (2013)	1970-2007	Organization for Economic Development Countries (OECD)	Regression analysis and a Two-way fixed-effect model	Real GDP per capita (RGDP) (-)
Brennen and Kreiss (2016)	1901-2000	United State	Time series model	Real GDP per capita in purchasing power parity (-), the unemployment rate (-), and the interaction of GDP per capita, and the unemployment rate (+)
Ding (2002)	1990-1999	China	Regression Analysis	Relative per capita GDP(-), Per capita consumption-GDP growth ratio(-), and Gross allocation effect (GAE)(+)
Studies on Economic growth and Demographic Dividend				
Sari and Cahyadin (2021)	1986-2018	Indonesia	ARDL models	Long run, Health expenditure(-), infant mortality rate(+), and life expectancy(+), Short run Health expenditure(-), infant mortality rate(+), and life expectancy(+)
Mahdawi et al. (2021)	2009-2018	Indonesia	Linear Regression Model, LM Test method	Population growth (+)
Peter and Bakari (2018)	1980-2015	Africa	Difference GMM, Pooled OLS	Population growth rate(+), inflation rate(+), and crude death rate(+)
Joe, Kumar, and Rajpal (2018)	1980-2010	India	OLS, 2SLS, and ARDL	Working-age population(+), literacy rate(+), infant mortality rate(-)
Bhattacharya and Haldar (2015)	1971-2011	India	Regression analysis, two-stage least square method	Total size of working-age population(+), credit deposit ratio(+), mean growth(+), growth of working-age population(+),working-age population(15-29)(-), working-age population(30-44)(+), working-age population(45-59)(+), life expectancy at birth(+), working population(-), population growth rate(-), infant mortality rate(-), and total fertility rate(-)
Iqbal, Yasmin, and Yaseen (2015)	1974-2011	Pakistan	Co-integration, Autoregressive Distributed Lag (ARDL) model	Life expectancy(+), working-age population(+), gross domestic saving rate(-), rate of natural increase(-), and total literacy rate(+)
(Ismail, Rahman, & Hamid, 2015)	1970-2013	Malaysia	Autoregressive Distributed Lag Model (ARDL) and Co-integration method	Aging (for fertility rate(-), life expectancy(+), and old dependency ratio(+) (government expenditure(+), domestic saving(+), and primary education(+)
Shahid (2014)	1980-2012	Pakistan	Augmented Dicky Fuller, Phillip Perron tests, Johnson Co-integration test	Labor force participation (+), Gross Fixed Capital (-) in both short-run and long-run model

Yao et al. (2013)	1952-2007	China	Co-integration analysis and LM-test	Total population(+), working-age population(-), total factor productivity growth(-), non-agriculture labor force (-) and saving rate (-)
Summary of the Studies on Economic Growth and Digital Transformation				
Hussain, Batool, Akbar, and Nazir (2021)	1995-2016	South Asian	Co-integration methods like Pedroni Panel Cointegration test, Panel Fully Modified Ordinary Least Square model, and Panel VECM approaches	ICT indicators (+) (fixed-phone subscribers, mobile-phone subscribers, and internet users) financial development(+), real investment(+)
Ahmad, Majeed, Khan, Sohaib, and Shehzad (2021)	2011-2018	China	Fixed effect regression results, Granger causality test, Robust, and Driscoll & Kraay regression methods	Fixed effect regression results Digital financial inclusion (+), human capital, breadth of coverage (+), depth of usage (+), level of digitalization (+), government expenditure on science and technology (+), inflation rate (+), population growth rate (+), and trade openness (-)
Habibi and Zabardast (2020)	2000-2017	The Middle East and OECD countries	Ordinary Least Squares (OLS,) fixed-effect, and GMM methods	Middle East Countries, Internet subscription(-), broadband subscription(+), mobile subscription(+), education(+), inflation(-), investment(-), OECD Countries, Internet subscription(+), broadband subscription(-), mobile subscription(+), education(+), inflation(-), trade(+), investment(-)
Myovella, Karacuka, and Haucap (2020)	2006-2016	Sub-Sahara Africa and Organization for Economic Cooperation and Development (OECD) Countries	Ordinary Least Squares (OLS), fixed effect, and GMM method	Sub-Sahara Africa Trade openness (-) population growth rate (+), gross fixed capital formation (+), government consumption (+), mobile subscriptions (+), the percentage of people using the internet (+), and broadband subscription (+) OECD, population growth rate(+), gross fixed capital formation(+), the percentage of people using the internet(+),broadband subscriptions(-), government consumption(-), mobile subscriptions(-)
Lubis and Febrianty (2018)	2001-2016	Indonesia	VAR Granger Causality Test	Internet user (-), internet server (-), and broadband subscription (-), Co-integration test No long run relationship between variable Impulse Response Function, Internet user (+), internet server (+), and broadband subscription (+)
Yasmeen and Tufail (2015)	1993-2013	Asia (Pakistan)	ARDL	Capital (+), labor (+), internet (+) and financial development (-)
Taasim and Yusoff (2014)	1996-2014	Malaysia	Regression analysis	mobile cellular (+), fixed broadband((+), internet users(+), literacy rate(-), population growth(-)

We have subdivided the table into four sections. In the first section, the studies have been reviewed on the impact of digital transformation on the demographic dividend. In this section, fertility rate, labor productivity, population quality of life, and the young adult population are used as the dependent variable while internet users, broadband internet, digital marketing, information communication technology, mobile phone penetration, internet addiction, and digital innovation activity are used as the independent variables. The second section gives a review of various studies on demographic dividends and economic growth. In the third section, we analyzed the impact of demographic division on economic growth. This section used economic growth as the dependent variable while independent variables were population growth, working-age population, fertility rate, mortality rate, and dependency ratio. In the fourth section, we found the impact of digital transformation on economic growth. All studies used economic growth as the dependent variable and the proxies of digitalization like internet users, mobile phone subscriptions broadband internet were used as independent variables. We have found mixed results in all studies. In this paper, the demographic dividend in South Asian nations is analyzed in relation to environmental sustainability and digital transformation.

3. Model Specification

Two models have been specified. The first model is a demographic dividend based on Population (15-64), and the second is a demographic dividend based on Education.

Model 1: Demographic Dividend Model based on Population

The functional form of the demographic dividend model based on Population is:

$$POP_{15-64} = f(MOB, INT, GHGE, URBANG, GI, HCI, TRADE) \quad (1)$$

$$POP_{15-64it} = \delta_0 + \delta_1 MOB_{it} + \delta_2 INT_{it} + \delta_3 GHGE_{it} + \delta_4 URBANG_{it} + \delta_5 GI_{it} + \delta_6 HCI_{it} + \delta_7 TRADE_{it} + \varepsilon_{it} \quad (2)$$

Model 2: Demographic Dividend Model Based on Education
The functional form of the demographic dividend model based on education is:

$$SSE = f(MOB, INT, GHGE, URBANG, GI, HCI, TRADE) \quad (3)$$

$$SSE_{it} = \delta_0 + \delta_1 MOB_{it} + \delta_2 INT_{it} + \delta_3 GHGE_{it} + \delta_4 URBANG_{it} + \delta_5 GI_{it} + \delta_6 HCI_{it} + \delta_7 TRADE_{it} + \varepsilon_{it} \quad (4)$$

3.1. Description and Sources of Variables

The data of all variables are collected from different sources from 1972 to 2020. Table 2 exhibits the variables and their description and sources.

Table 2: Variables with Sources

Variable	Description of Variables	Source
Dependent Variables		
$POP_{15\text{-}64}$	Population ages 15-64 (% of total population)	WDI
SSE	Secondary School enrollment (% gross)	
Explanatory Variables		
MOB	Mobile cellular subscriptions (per 100 people)	WDI
INT	Internet Users as percentage of the population	
URBANG	Urban population as percentage of the total population	
TRADE	Trade as percentage of GDP	
GHGE	Total GHG emissions including LUCF (tones CO2)	Climate Watch
GI	Governance Indicators Index	The Worldwide Governance Indicators, 2021
HCI	Human capital index, based on years of schooling and returns to education	PWT9

4. Methodology: Panel ARDL

The ARDL specification of the demographic dividend model based on population is given below**:**

Model 1

$$\Delta(POP)_{it} = \alpha + \gamma_1 (POP)_{it-1} + \gamma_2 (MOB)_{it-1} + \gamma_3 (INT)_{it-1} + \gamma_4 (GHGE)_{it-1} + \gamma_5 (URBANG)_{it-1} + \gamma_6 (GI)_{it-1} + \gamma_7 (HCI)_{it-1} + \gamma_8 (TRADE)_{it-1} + \sum_{i=1}^{q_1} \varpi_{1i} \Delta(POP)_{it-i} + \sum_{i=0}^{q_2} \varpi_{2i} \Delta(MOB)_{it-i} + \sum_{i=0}^{q_3} \varpi_{3i} \Delta(INT)_{it-i} + \sum_{i=0}^{q_4} \varpi_{4i} \Delta(GHGE)_{it-i} + \sum_{i=0}^{q_5} \varpi_{5i} \Delta(URBANG)_{it-i} + \sum_{i=0}^{q_6} \varpi_{6i} \Delta(GI)_{it-i} + \sum_{i=0}^{q_7} \varpi_{7i} \Delta(HCI)_{it-i} + \sum_{i=0}^{q_8} \varpi_{8i} \Delta(TRADE)_{it-i} + \varepsilon_{it} \quad (5)$$

The parameters ϒ indicate the long-run coefficient multipliers, however, the symbol ϖ (for i=0) shows the short-run coefficient dynamics. The other symbols χ (for i=1, 2….. $q_{1,} q_{2,\ldots\ldots} q_8$) VAR factor of the ARDL models Δ is the first difference operator, and the ε is the disturbance term.

In case, the long-run association between variables exists, the long-run coefficients are estimated as:

$$POP_{it} = \alpha + \sum_{i=1}^{q_1} \sigma_{1i} (POP)_{it-i} + \sum_{i=0}^{q_2} \sigma_{2i} (MOB)_{it-i} + \sum_{i=0}^{q_3} \sigma_{3i} (INT)_{it-i} + \sum_{i=0}^{q_4} \sigma_{4i} (GHGE)_{it-i} + \sum_{i=0}^{q_5} \sigma_{5i} (URBANG)_{it-i} + \sum_{i=0}^{q_6} \sigma_{6i} (GI)_{it-i} + \sum_{i=0}^{q_7} \sigma_{7i} (HCI)_{it-i} + \sum_{i=0}^{q_8} \sigma_{8i} (TRADE)_{it-i} + \varepsilon_{it} \quad (6)$$

In the case of short-run dynamics, the parameters are estimated as in the given equation:

$$\Delta POP_{it} = \alpha + \sum_{i=1}^{q_1} \upsilon_{1i}(POP)_{it-i} + \sum_{i=0}^{q_2} \upsilon_{2i}(MOB)_{it-i} + \sum_{i=0}^{q_3} \upsilon_{3i}(INT)_{it-i} + \sum_{i=0}^{q_4} \upsilon_{4i}(GHGE)_{it-i} + \sum_{i=0}^{q_5} \upsilon_{5i}(URBANG)_{it-i} + \sum_{i=0}^{q_6} \upsilon_{6i}(GI)_{it-i} + \sum_{i=0}^{q_7} \upsilon_{7i}(HCI)_{it-i} + \sum_{i=0}^{q_8} \upsilon_{8i}(TRADE)_{it-i} + \mu ECM_{it-1} + \varepsilon_{it} \quad (7)$$

Equation (16) presents the short-run parameters and the coefficients of ECM in this equation (μ) indicate the speed of adjustments to restore equilibrium in the long run.

Model 2
The ARDL specification of demographic dividend based on education is:

$$\Delta(SSE)_{it} = \alpha + \eta_1(SSE)_{it-1} + \eta_2(MOB)_{it-1} + \eta_3(INT)_{it-1} + \eta_4(GHGE)_{it-1} + \eta_5(URBANG)_{it-1} + \eta_6(GI)_{it-1} + \eta_7(HCI)_{it-1} + \eta_8(TRADE)_{it-1} + \sum_{i=1}^{j_1} \varsigma_{1i}\Delta(SSE)_{it-i} + \sum_{i=0}^{j_2} \varsigma_{2i}\Delta(MOB)_{it-i} + \sum_{i=0}^{j_3} \varsigma_{3i}\Delta(INT)_{it-i} + \sum_{i=0}^{j_4} \varsigma_{4i}\Delta(GHGE)_{it-i} + \sum_{i=0}^{j_5} \varsigma_{5i}\Delta(URBANG)_{it-i} + \sum_{i=0}^{j_6} \varsigma_{6i}\Delta(GI)_{it-i} + \sum_{i=0}^{j_7} \varsigma_{7i}\Delta(HCI)_{it-i} + \sum_{i=0}^{j_8} \varsigma_{8i}\Delta(TRADE)_{it-i} + \varepsilon_{it} \quad (8)$$

The long-run coefficients of parameters are estimated by using the following equation:

$$SSE_{it} = \alpha + \sum_{i=1}^{j_1} \zeta_{1i}(SSE)_{it-i} + \sum_{i=0}^{j_2} \zeta_{2i}(MOB)_{it-i} + \sum_{i=0}^{j_3} \zeta_{3i}(INT)_{it-i} + \sum_{i=0}^{j_4} \zeta_{4i}(GHGE)_{it-i} + \sum_{i=0}^{j_5} \zeta_{5i}(URBANG)_{it-i} + \sum_{i=0}^{j_6} \zeta_{6i}(GI)_{it-i} + \sum_{i=0}^{j_7} \zeta_{7i}(HCI)_{it-i} + \sum_{i=0}^{j_8} \zeta_{8i}(TRADE)_{it-i} + \varepsilon_{it} \quad (9)$$

To measure short-run parameters, the coefficients can be estimated by the given equation:

$$\Delta SSE_{it} = \alpha + \sum_{i=1}^{j_1} \kappa_{1i}\Delta(SSE)_{it-i} + \sum_{i=0}^{j_2} \kappa_{2i}\Delta(MOB)_{it-i} + \sum_{i=0}^{j_3} \kappa_{3i}\Delta(INT)_{it-i} + \sum_{i=0}^{j_4} \kappa_{4i}\Delta(GHGE)_{it-i} + \sum_{i=0}^{j_5} \kappa_{5i}\Delta(URBANG)_{it-i} + \sum_{i=0}^{j_6} \kappa_{6i}\Delta(GI)_{it-i} + \sum_{i=0}^{j_7} \kappa_{7i}\Delta(HCI)_{it-i} + \sum_{i=0}^{j_8} \kappa_{8i}\Delta(TRADE)_{it-i} + \nu ECM_{it-1} + \varepsilon_{it} \quad (10)$$

5. Results and Discussions

5.1. Unit Root Analysis

Table 3 depicts various unit root tests. The decision of a stationary value or a non-stationary value has based on the probability value of the test. The results show that population ages (15-64), secondary school enrollment, mobile cellular subscriptions, internet users, greenhouse gas emissions, governance index, and trade are non-stationary except for urbanization growth and human capital index.

Table 3: Results of Panel Unit Root Tests

	Intercept				**Intercept and Trend**				
Variable	**LLC Test**	**IPS Test**	**ADF-Fisher Chi-Square**	**PP-Fisher Chi-Square**	**LLC Test**	**IPS Test**	**ADF-Fisher Chi-Square**	**PP-Fisher Chi-Square**	**Conclusion**
POP	-1.606 (0.0541)	1.06522 (0.9805)	0.0713 (0.8929)	62.6271 (0.0000)	-1.25423 (0.1049)	1.89814 (0.9712)	1.0425 (0.6696)	2.80742 (0.9999)	**I(1)**
SSE	-1.06994 (0.1423)	0.86999 (0.8078)	1.65946 (0.7317)	1.20152 (0.9056)	-1.68727 (0.0458)	-0.12919 (0.4486)	1.3906 (0.4958)	1.89413 (0.6252)	**I(1)**
MOB	-4.49464 (0.0000)	-1.49549 (0.0674)	22.2420 (0.1355)	16.8442 (0.3958)	1.58481 (0.9435)	2.97253 (0.9985)	4.81376 (0.9966)	1.81067 (1.0000)	**I(1)**
INT	3.53269 (0.9998)	7.05836 (1.0000)	1.37906 (1.0000)	0.40587 (1.0000)	2.21674 (0.9867)	3.92333 (1.0000)	2.72861 (0.9999)	2.24845 (1.0000)	**I(1)**
GHGE	-0.27558 (0.3914)	3.14849 (0.9992)	3.42603 (0.9996)	2.24973 (1.0000)	2.19406 (0.9859)	1.35018 (0.9115)	7.21705 (0.9688)	17.2141 (0.3719)	**I(1)**

URBANG	-4.85753 (0.0000)	-4.91223 (0.0000)	63.7408 (0.0000)	88.7969 (0.0253)	-11.5030 (0.0000)	-7.27250 (0.0000)	63.9228 (0.0000)	8.21340 (0.9423)	**I(0)**
GI	0.98235 (0.8370)	1.03250 (0.8491)	8.41829 (0.9354)	13.2831 (0.6520)	-0.64331 (0.2600)	1.21438 (0.8877)	8.33960 (0.9381)	18.7369 (0.2825)	**I(1)**
HCI	0.40603 (0.6576)	1.37944 (0.9161)	23.5380 (0.1001)	63.0124 (0.0000)	-268.166 (0.0000)	-253.813 (0.0000)	57.2164 (0.0000)	65.0403 (0.0000)	**I(0)**
TRADE	-0.94343 (0.1727)	-0.12240 (0.3913)	17.2576 (0.2427)	12.3846 (0.5754)	-3.22812 (0.0006)	-1.44284 (0.0745)	19.1636 (0.0847)	28.9327 (0.0107)	**I(1)**

5.2. Long Run Analysis

Table 4 discusses the panel ARDL estimates of demographic dividends based on Population. In this table, the dependent variable is population ages (15-64) with independent variables of mobile cellular subscriptions, internet users, greenhouse gas emissions, urbanization growth, governance index, human capital index, and trade.

Table 4: Panel ARDL Estimates of Demographic Dividend Model based on Population

Dependent Variable: d(POP $_{15-64}$)				
Selected Model: ARDL (1, 1, 1, 1, 1, 1, 1)				
Variable	**Coefficient**	**SE**	**t-Statistic**	**Prob.**
MOB	0.1908	0.0178	10.7387	0.0000
INT	0.1713	0.0809	2.1171	0.0379
GHGE	-1.7625	0.6371	-2.7666	0.0073
URBANG	0.1088	0.0244	4.4503	0.0000
GI	0.1376	0.0945	1.4567	0.1488
HCI	1.7125	1.0616	1.6132	0.1095
TRADE	0.1175	0.0284	4.1342	0.0001
Constant	0.0090	0.0264	0.3393	0.7352

The demographic dividend is significantly influenced by digitalization. When a nation's population of working age is greater than its population of non-working age, economic development might result. This phenomenon is known as the demographic dividend. When the population changes from having a high birth rate and a high death rate to having a low birth rate and a low death rate, this happens. Digitalization has led to increased access to education, job opportunities, and improved healthcare, which have resulted in a larger and more productive workforce. The use of digital technologies has also improved productivity, efficiency, and innovation in various sectors, leading to economic growth and higher wages. Additionally, digitalization has facilitated the growth of the gig economy, enabling individuals to work flexibly and create their businesses, further boosting economic activity. Overall, the impact of digitalization is positive on the demographic dividend, contributing to a more educated, productive, and innovative working-age population, which is essential for sustained economic growth. Our results aligned with the studies by (Alam, 2009; Gautam et al., 2021; Hosan et al., 2022; Popelo et al., 2021; Sarker et al., 2021).

Greenhouse gas (GHG) emissions have a negative impact on the demographic dividend. The negative effects of climate change resulting from GHG emissions can include rising temperatures, more frequent natural disasters, reduced agricultural productivity, and increased health risks. These impacts can disproportionately affect younger generations, who will bear the long-term consequences of climate change. Additionally, the economic costs of climate change can lead to reduced economic growth, increased healthcare costs, and reduced job opportunities, which can negatively affect the demographic dividend. Therefore, reducing GHG emissions and mitigating the impacts of climate change is essential to ensure the demographic dividend is sustained in the long term. This can be achieved through the adoption of sustainable development policies and the transition to a low-carbon economy. Fan, Zhou, Zhang, Shao, and Ma (2021); Sarker et al. (2021) argue there is a significant negative relationship between greenhouse gas emissions and population aging (15-64).

The demographic dividend is significantly influenced by urbanization's expansive reach. There is a change in the age distribution of the population as a direct result of the migration of individuals from rural to urban areas. Urban areas tend to have a higher proportion of working-age individuals, which can lead to increased economic growth and productivity. Additionally, urbanization can lead to increased access to education, healthcare, and job opportunities, which can further boost the demographic dividend[1]. Managing urbanization effectively through the provision of necessary infrastructure and social services is essential to ensure that the

[1] However, rapid urbanization can also lead to challenges such as overcrowding, increased pollution, and inadequate infrastructure, which can negatively impact the demographic dividend.

demographic dividend is sustained in the long term. Our results are consistent with (Sarker et al., 2021; Zaman & Sarker, 2021).

Governance indicators have a significant impact on the demographic dividend. Good governance, characterized by transparency, accountability, and the rule of law, can promote economic growth, social development, and stability, which are essential for realizing the demographic dividend. Effective governance can ensure that public resources are used efficiently and effectively, leading to improved education, healthcare, and infrastructure, which can enhance the quality of life and well-being of the population. Additionally, good governance can help to create an enabling environment for business and investment, leading to increased job opportunities and economic growth. On the other hand, poor governance, characterized by corruption, lack of accountability, and weak institutions, can hinder the realization of the demographic dividend by reducing trust in government, undermining social cohesion, and limiting economic opportunities. Therefore, improving governance indicators is crucial for realizing the demographic dividend and ensuring sustainable economic growth and development. Chambers and Munemo (2019); Hotz and Xiao (2011) also confirm the positive relationship.

Human capital refers to the knowledge, skills, and abilities of a population, which are essential for economic growth and development. Investment in human capital through education, training, and healthcare can enhance the productivity and potential of the working-age population, leading to a larger and more productive workforce. This, in turn, can lead to increased economic growth and higher wages, contributing to the realization of the demographic dividend. Additionally, a population with higher levels of human capital is better equipped to adapt to technological changes and innovation, which can further drive economic growth and development. Therefore, investment in human capital is crucial for realizing the demographic dividend and ensuring sustained economic growth and development. Huang, Orazem, and Wohlgemuth (2002) concluded that the Human Capital Index (based on years of schooling and returns education) and Population aging (15-64) are directly related to each other.

Trade can contribute to economic growth and job creation, leading to a larger and more productive workforce, which is essential for realizing the demographic dividend. Increased trade can also provide access to new technologies and ideas, facilitating innovation and technological progress, which can further enhance productivity and drive economic growth. Additionally, trade can lead to increased competition and specialization, which can lead to increased efficiency and reduced prices, benefiting consumers and improving standards of living. On the other hand, trade can also lead to challenges, such as job displacement and inequality, which can negatively impact the demographic dividend if not effectively addressed through policies and investments. Therefore, managing the impact of international trade is crucial for realizing the demographic dividend and ensuring sustainable economic growth and development. Feng, Xie, and Zhang (2021); Lopez and Schiff (1998) conclude that trade expansion also causes a rise in the population growth rate and income per capita. Table 5 shows ARDL estimates of demographic dividends based on education.

Table 5: Panel ARDL Estimates of Demographic Dividend Model based on Education

Dependent Variable: d(SSE)
Selected Model: ARDL(1, 1, 1, 1, 1, 1,1)

Variable	Coefficient	SE	t-Statistic	Prob.
MOB	0.1259	0.0187	6.7316	0.0000
INT	1.6802	0.2373	7.0794	0.0000
GHGE	-0.6846	0.2342	-2.9228	0.0044
URBANG	0.0544	0.0175	3.1074	0.0027
GI	1.2848	0.3993	3.2175	0.0019
HCI	0.0404	0.0165	2.4454	0.0168
TRADE	0.0722	0.0176	4.0988	0.0001
C	0.0432	0.0655	0.6596	0.5115

Digitalization can have a significant impact on the demographic dividend based on secondary school enrollment. Digital technologies can enhance access to education, particularly in underserved areas, leading to increased enrollment and a larger pool of educated and skilled workers, which is essential for realizing the demographic dividend. Additionally, digital tools can enhance the quality of education, leading to better learning outcomes and improved human capital. However, the impact of digitalization on secondary school enrollment and the demographic dividend depends on the extent to which digital technologies are accessible and effectively integrated into the education system. Ensuring equitable access to digital technologies and investing in digital infrastructure and education is crucial for realizing the demographic dividend and ensuring sustained economic growth and development. The findings match with the studies i.e., (Dneprovskaya, Bayaskalanova, Ruposov, & Shevtsova, 2018; Sarker et al., 2021). Greenhouse gas emissions can have a negative impact on the demographic dividend based on secondary school enrollment. Climate change resulting from greenhouse gas emissions can lead to increased frequency and intensity of natural disasters, which can disrupt education systems and limit access to education, particularly in vulnerable and underserved areas. Additionally, climate change can lead to health impacts such as malnutrition, which can negatively affect cognitive development and school enrollment. Furthermore, climate change can lead to economic disruption and job loss, reducing the potential for realizing the demographic dividend. Therefore, reducing greenhouse gas emissions through sustainable and climate-resilient development is crucial for ensuring access to education, improving human capital, and realizing the demographic dividend.

Urbanization can have both positive impacts on the demographic dividend based on secondary school enrollment. Urban areas tend to have better access to educational resources, such as schools and libraries, leading to increased enrollment and a larger pool of educated and skilled workers, which is essential for realizing the demographic dividend. Additionally, urban areas tend to provide more job opportunities and higher wages, which can incentivize parents to invest in their children's education[2]. Arouri, Youssef, Nguyen-Viet, and Soucat (2014); Bertinelli and Zou (2008); Sarker et al. (2021) also confirm the results that urban growth is a significant determinant of secondary school enrollment.

Governance can have a significant impact on the demographic dividend based on secondary school enrollment. Good governance characterized by transparency, accountability, and effective policy implementation can lead to increased investment in education, improved access to educational resources, and better educational outcomes, leading to a larger and more skilled workforce, which is essential for realizing the demographic dividend. Additionally, good governance can foster an enabling environment for entrepreneurship and innovation, leading to job creation and sustained economic growth and development. However, poor governance characterized by corruption, political instability, and ineffective policy implementation can hinder investment in education and limit access to educational resources, leading to decreased enrollment and a less skilled workforce, negatively impacting the demographic dividend. Therefore, promoting good governance through transparent and accountable policymaking is crucial for realizing the demographic dividend and ensuring sustained economic growth. Alam (2009); Sarker et al. (2021) concluded an indirect relationship between governance indicators and secondary school enrollments.

Human capital can have a significant impact on the demographic dividend based on secondary school enrollment. Investing in education and skill development can lead to a larger and more skilled workforce, which is essential for realizing the demographic dividend. Education not only enhances employability but also promotes entrepreneurship and innovation, leading to job creation and sustained economic growth and development. Additionally, education can lead to improved health and well-being, leading to increased productivity and economic participation. However, the impact of human capital on the demographic dividend depends on the quality of education and its relevance to the job market. Wößmann (2003) also confirms the direct relationship between human capital and schooling.

Foreign trade can have a significant impact on the demographic dividend based on secondary school enrollment. Trade can provide access to new markets, increasing demand for goods and services and creating new job opportunities, leading to sustained economic growth and development, which is essential for realizing the demographic dividend. Additionally, trade can facilitate technology transfer and knowledge-sharing, leading to increased productivity and improved access to educational resources, which can lead to increased enrollment and a more skilled workforce. However, the impact of foreign trade on the demographic dividend depends on the nature of trade policies and their impact on education and the labor market. Afzal, Farooq,

[2] However, urbanization can also bring challenges such as overcrowding, inadequate infrastructure, and pollution, which can negatively affect health, education, and economic opportunities, particularly for marginalized groups.

Ahmad, Begum, and Quddus (2010); Gumus and Kayhan (2012) also confirm the positive and significant relationship between Trade and secondary school enrollment.

5.3. Error Correction Analysis

This section demonstrates the need to identify the short-run fluctuations incorporated into the model after studying the long-run relationships between variables. The Error Correction Model (ECM) is the most crucial technique used to gauge short-run dynamics. Table 6 presents the findings of the demographic dividend model's error correction estimates based on population.

Table 6: Error Correction Estimates of Demographic Dividend Model based on Population

Dependent Variable: D(POP)				
Selected Model: ARDL(1, 1, 1, 1, 1, 1,1)				
Variable	**Coefficient**	**SE**	**t-Statistic**	**Prob.**
ECT	-0.0157	0.0076	-2.0676	0.0424
d (MOB)	0.0012	0.0109	0.1100	0.9127
d (INT)	0.0509	0.0189	2.6931	0.0089
d (GHGE)	0.1424	0.2344	0.6077	0.5454
d (URBANG)	0.1874	0.3063	0.6120	0.5426
d (GI)	-0.5869	0.5521	-1.0630	0.2915
d (HCI)	5.4257	0.5000	10.8506	0.0000
d (TRADE)	0.6056	1.1285	0.5367	0.5928
Constant	4.3220	0.7755	5.5734	0.0000

The error correction term in Table 6 denotes the model's rate of adjustment and convergence to equilibrium. With a negative sign, the phrase is statistically significant. The error correction term's statistically significant coefficient is -0.0157. Error correction estimates for the demographic dividend model based on education are shown in Table 7.

Table 7: Error Correction Estimates of Demographic Dividend Model based on Education

Dependent Variable: D(SSE)				
Selected Model: ARDL(1, 1, 1, 1, 1, 1,1)				
Variable	**Coefficient**	**SE**	**t-Statistic**	**Prob.**
ECT	-0.0334	0.0178	-1.8730	0.0650
d(MOB)	4.5736	0.4798	9.5322	0.0000
d(INT)	0.0764	0.0626	1.2211	0.2259
d (GHGE)	0.0415	0.0145	2.8649	0.0054
d (URBANG)	-0.8069	0.7345	-1.0984	0.2755
d (GI)	4.9028	0.4639	10.5698	0.0000
d (HCI)	0.0091	0.0142	0.6452	0.5208
d (TRADE)	0.1222	0.0385	3.1737	0.0022
Constant	0.4607	0.0809	5.6929	0.0000

The coefficient value is -0.0334, with a significant probability value showing how much deviation from their long run-equilibrium in the model.

6. Conclusions and Policy Implications

In this study, the effects of digital transformation, technological innovation, and environmental sustainability on the demographic dividend are investigated. To determine the demographic dividend in South Asian nations for the period of 1972-2020, the models employ mobile cellular subscriptions, internet users, greenhouse gas emissions, urbanization, human capital index, governance index, and trade as their explanatory variables.

In model one, the positive impact of mobile cellular subscriptions, internet users, urbanization, and trade on demographic dividend based on population (15-64) have been observed while the negative influence of the human capital index, governance index, or greenhouse gas emissions on demographic dividend based on population (15-64) have been found. In model two, the results show the positive and significant impact of mobile cellular subscriptions, internet users, urbanization, greenhouse gas emissions, human capital index, and trade on demographic dividend based on education except for the governance index. The study concludes that all the variables show a distinct effect on the demographic dividend based on the working-age population and education in South Asian countries.

These are the policy implications for a demographic dividend, taking into account the factors of mobile cellular subscriptions, internet users, urbanization, greenhouse gas emissions, human capital index, and trade and governance:

- Promote the adoption and affordability of mobile cellular subscriptions and internet services to increase access to educational resources, promote digital literacy and enhance enrollment rates.
- Invest in infrastructure and social services, particularly in urban areas, to improve the quality of life and educational outcomes for all individuals.
- Encourage sustainable development practices and the use of clean energy to mitigate the negative impact of greenhouse gas emissions on health and education.
- Invest in education and skill development programs to increase the pool of skilled workers and promote sustained economic growth and development.
- Promote good governance and transparent policymaking to ensure that policies support education and skill development.
- Encourage trade policies that support education and training and ensure that benefits from trade are distributed equitably.

Overall, these policies can help to promote access to education and improve the quality of education for all individuals, which is essential for realizing the demographic dividend and ensuring sustained economic growth.

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