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Climate Change and Crop Productivity: Implications for Food Security in Global North and South

ABSTRACT

A special predicament in global climate-agriculture nexus is the existence of asymmetricity in empirical relationships, which the existing literature fails to capture these threshold effects. The present study addresses this gap by investigating the non-linear relationship between climate variability and crop productivity with a particular focus on global disparities between the Global South and Global North. Using panel data from 1980 to 2022, the analysis employs a panel quantile regression framework to understand the relationship across different levels of global crop productivity. The results reveal significant non-linear responses of crop production to climate variables, where moderate increases in temperature and precipitation enhance yields up to a threshold, beyond which productivity declines. Global South demonstrates higher vulnerability to rising temperatures due to limited adaptive capacity and dependence on rain-fed agriculture, while Global North exhibits greater sensitivity to excessive rainfall, although its advanced technologies and management practices help mitigate losses. These findings emphasize that climate impacts are context-specific, shaped by regional agronomic practices, technological adoption, and resource availability.

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Author's contribution in the article: 1- Conceived and designed the analysis, 2- Reviewed and compiled the literature, 3-Collected the data, 4- Contributed data or analysis tools, 5- Performed the analysis, 6- Wrote the paper, 7- Financial support for the conduct of the study, 8-Other

1. INTRODUCTION

Agriculture remains a cornerstone of global economic stability and food security, contributing about 4% to global GDP and employing over 26% of the world's workforce (World Bank, 2023). Beyond its economic role, agricultural productivity underpins rural livelihoods, trade balances, and the capacity to feed a global population projected to reach 9.7 billion by 2050 (United Nations, 2022; World Bank, 2025). Within this framework, crop production systems form interdependent components of a complex network that supplies food, fiber, and raw materials essential for human survival and economic growth.

Food insecurity is a crucial global challenge and despite advances in technology and trade, nearly 733 million people or 1 in 11 globally goes hungry every day, with the majority concentrated in climate-vulnerable regions. Moreover, over 2.8 billion inhabitants, 34% of the world population, could not afford a healthy diet, with the problem concentrated in the Global South that is around 71.5%. According to FAO (2023), about 82% of people lacked affordability in Sub-Saharan Africa, and around 70% in Southern Asia as compared to only 14% in high-income countries. Under these circumstances, climatic variability exacerbates the crisis by reducing crop yields, destabilizing food supplies, and driving up food prices, disproportionately affecting low-income and agrarian economies (IPCC, 2022) and directly widening the gap between food supply and demand (Wheeler & Von Braun, 2013).

Owing to the rise in global temperatures and volatility in precipitation patterns, the climate-agriculture nexus has gained unprecedented attention (Vermeulen et al., 2012). The literature advocates that favorable weather conditions lead to surpluses whereas the opposite conditions lead to shortfalls of food supply (Tanveer & Kalim, 2025; Tanveer et al., 2025). This alarming condition is very crucial for global agriculture system, where nearly 80% of the area is rain-fed (FAO, 2021), leaving it highly sensitive and vulnerable to erratic climatic variations.

In this regard, the existing research demonstrates that agriculture production is not directly proportional to climate change such as temperature and rainfall and its variation depends on level of climatic conditions (Lobell et al., 2011; Schlenker & Roberts, 2009; Zhao et al., 2017). Several researchers identified polynomial inverted U-shaped relationships, where initially rising temperature and precipitation boost agriculture productivity until a threshold is reached, after which further rise become harmful (Lobell et al., 2011; Schlenker & Roberts, 2009; Tanveer & Kalim, 2025; Zhao et al., 2017; Zambrano-Medina et al., 2024). This non-linearity has multiple implications for smart agricultural, climate adaptation and mitigation policies, and global food security (Seneviratne et al., 2021).

Despite growing recognition of the impacts of climate change on crop production, significant gaps remain in understanding optimal climate conditions for crop productivity on a global scale, particularly for global north and south, where the Global South refers to developing countries, mostly in the southern half of the world, that generally have lower incomes and face various economic challenges. The Global North, by contrast, are the developed, wealthier countries, often found in the northern hemisphere that are characterized by high incomes, advanced technology, and stable economies (Kowalski, 2020). The study tries to estimate the impacts of climatic variables, average annual temperature and annual precipitation, on crop production index globally as well as on global south and north regions.

The current study contributes to literature in multiple ways. First, existing research is region specific and crop specific studies which have estimated the complex relationship in climate change and crop production and comprehensive global analyses remain limited. Second, to identify how global warming is differently affecting poor and rich regions, the current study separates the analysis for global south and north for the whole crop system. Third, while much of the prevailing literature relies on projections and forecasts of the potential impacts of global warming on the food system, the present study employs actual observed data to provide empirical estimates of climate effects. Finally, by applying a panel quantile regression framework, the study is able to capture the distributional impacts of climate variability on crop productivity specifically across productivity quantiles like how climatic variations influence both low-productivity and high-productivity regions in the Global South and Global North. Besides, the key novelty of the study is the estimation of global threshold levels for temperature and precipitation across quantiles of global crop productivity and compares them with global south and north.

2. LITERATURE REVIEW

The relationship between climate change and crop productivity has been extensively investigated over the past decades, with empirical evidence showing that temperature and precipitation shifts play crucial roles in shaping agricultural performance. At the global level, crop productivity responds non-linearly to climate variables, with moderate changes sometimes enhancing yields, but extremes often exert adverse effects. The direction and magnitude of these impacts vary significantly between regions, largely due to differences in agro-ecological conditions, adaptation capacities, and resource endowments.

Temperature has been identified one of the most important climatic determinants of crop productivity. Lobell and Field (2007) found that global warming trends since 1981 have had a negative effect on major cereal crops, with wheat and maize particularly sensitive to higher growing-season temperatures. Similarly, Schlenker and Roberts (2009), using county-level data for the United States, reported that crop yields exhibit strong yield declines beyond certain temperature thresholds, suggesting limited adaptation capacity within existing agricultural systems. In the context of developing countries, Zhang et al. (2017) observed that tropical and subtropical crops are more tolerant of higher average temperatures than temperate crops but are more vulnerable to extreme heat events.

In addition to temperature, precipitation patterns also play a crucial role and have important implications for crop production. It also has non-linear impacts on crop production as Tao et al. (2008) estimated that moderate increases in precipitation boosted yields, but excessive rainfall caused waterlogging, nutrient leaching, and pest outbreaks. On the other hand, shortage in rainfall limited soil moisture availability, reduced photosynthesis, and hindered plant growth (Rosenzweig et al., 2014). Moreover, Tanveer and Kalim (2025) identified quantile-wise threshold levels for both temperature and precipitation for global agricultural system.

Taking together, the simultaneous effects of them are more challenging because of the influence on evapotranspiration, soil moisture balance, and plant physiology. Warming-induced yield losses are often amplified under drought conditions, particularly in water-limited areas (Lobell et al., 2011). Similarly, Zhao et al. (2017) used a global meta-analysis to show that simultaneous increases in temperature and precipitation variability can lead to substantial reductions in yields of staple crops, especially in low-income countries with limited adaptive technologies.

Beyond crop-level impacts, regional disparities further complicate the phenomenon. Climate change has different impacts on different regions (FAO, 2021; Tanveer & Kalim, 2025) and several cross-country analyses strengthen this proposition like Nelson et al. (2014) estimated that climate change could reduce global agricultural productivity by up to 17% by 2050, with losses disproportionately larger in developing countries. Similarly, Moore and Lobell (2015) reported that although the North has a relatively high potential for adaptation owing to availability of sources, it is still not enough to fully offset the impacts of global warming. Nevertheless, adaptation in the South is limited due to low financial resources, weak extension services, and poor access to modern farming technologies.

The literature has portrayed significant evidence that how crop production responses to the climatic variations worldwide. Nevertheless, a key dilemma in global climate-agriculture nexus is the existence of asymmetricity in empirical relationships, which the existing literature fails to capture these threshold effects. The present study has estimated temperature and rainfall threshold levels for global south and north which is the key novelty of the analysis. Moreover, authors have contributed to the literature in multiple ways such as providing global analysis based on observed data beyond region- and crop-specific research, comparing Global South and North difference and employing median based model to estimate distributional effects of climate variability across different levels of crop productivity.

3. DATA AND METHODOLOGY

The basic economic theory illustrates that agricultural production is determined by land, labor, capital, and ecological factors (Zambrano-Medina et al., 2024) where climate variables like temperature and precipitation affect productivity through multiple channels. Therefore, the basic functional form of the model is given as:

$$Crop\ productivity = f(input\ variables, climatic\ variables, technology) \tag{1}$$

Where input variables include land, labour and capital, climate variables contain temperature and precipitation whereas technology is presented as patents. These variables have multiple effects on crop yield. These effects include volatility in photosynthesis and respiration of plants (Lobell & Gourdji, 2012) as well as variation in insects' infestations, weedicides, pesticides, herbicides, moisture Stress and soil erosion (Malhi et al., 2021; Rosenzweig et al., 2014; Tao et al., 2008). Their influences generate the possibility of non-linear relationships where crops perform best within an optimal range. Below this range, growth of the plants slows; at the optimum, photosynthesis and growth peak; above it, heat stress damages plant cells and disrupts metabolism, reducing yields. These thresholds vary by crop, region, and management practice, and adaptation can extend tolerance but often with trade-offs (Hatfield & Prueger, 2015; Schlenker & Roberts, 2009). Consequently, the quadratic term for the climatic variables has been incorporated to estimate the potential polynomial relationships.

Moreover, water stress theory describes precipitation effects in a similar inverted U-shaped manner (Vandana et al., 2024) where shortage of water leads to drought stress, reduced photosynthesis, and smaller yields (Akhtar & Nazir 2013; Wu et al. 2022), while excessive rainfall causes waterlogging, nutrient leaching, and disease (Akhtar & Nazir 2013; Vandana et al., 2024). However, the optimal rainfall level varies in different types of crops, soil, and growth stage, and rainfall variability can disrupt planting and harvesting schedules (Lobell et al., 2011). Collectively, both theories elaborate that impacts of climate change crop productivity are mainly not linear; nevertheless, climatic thresholds differ across regions. This rate of change is also critical to allow adaptation, but rapid one's risk overwhelming capacity (Porter et al., 2014). In this regard, the following quadratic functional form has been developed:

$$Crop\ productivity = f(input\ variables, climatic\ variables^2,\ technology) \tag{2}$$

Equation (2) thus provides the theoretical basis for our empirical model, which is operationalized in Equation (3). For empirical analysis, the study has used a balanced panel dataset comprising 169 countries[1] over the period 1980 to 2022, ensuring broad global coverage and consistent temporal observations for all cross-sectional units. Given the macro-panel structure, where cross-country linkages and common shocks are likely, the analysis first examines cross-sectional dependence using the Breusch–

[1] List of countries used for the analysis is given in Appendix-A.

Pagan LM test, Pesaran scaled LM test, bias-corrected scaled LM test, and Pesaran CD test. The outcomes of this cross-sectional dependence test indicate the application of second-generation panel unit root tests, which explicitly account for such interdependence (Baltagi, 2021). Resultantly, the study has employed Pesaran's (2007) Cross-sectionally Augmented Dickey–Fuller (CADF) test to determine the stationarity properties of the series.

Based on the results of the panel unit test, Panel Quantile Regression (PQR) is found to be the most suitable econometric model for empirical analysis. PQR models provide heterogeneous relationships across the median based conditional distribution of the dependent variable and do not need normal distribution assumption (Baltagi, 2021). By Using PQR the present study has estimated the distributional effects of the climatic variables, temperature and rainfall, on crop productivity across all quantiles. Econometrically, Koenker (2004) and Canay (2011) provided the foundational frameworks for implementing PQR in panel settings with fixed effects.

A number of researchers used PQR to examine environmental effects of economic growth in sub-Saharan Africa (Twerefou et al., 2017) and to assess the heterogeneous impacts of growth, environmental policy, and innovation on energy consumption (Nguyen et al., 2020). Similarly, Ibrahim and Law (2014) applied PQR to investigate the relationship between social capital and CO_2 emissions. Therefore, PQR is a robust and flexible tool for capturing distributional heterogeneity, making it well-suited for analyzing the global and regional impacts of climatic variables on crop productivity in the present study. The present study has used the following models for the estimation:

$$\mathrm{CRPI}\tau_{it} = \alpha_{\tau 1} TEMP_{it} + \alpha_{\tau 2} TEMP_{it}^2 + \alpha_{\tau 3} PREC_{it} + \alpha_{\tau 4} PREC_{it}^2 + \beta_{\tau 1} CLPC_{it} + \beta_{\tau 2} CLR_{it} + \beta_{\tau 3} PTNT_{it} + \varepsilon_{\tau it} \quad (3)$$

Where in equation (3), $\mathrm{CRPI}\tau_{it}$ is the quantile-specific crop productivity index for country i at time t and $\alpha_{\tau i}$ and $\beta\tau_j$ are the quantile-specific coefficients for the explanatory variables and $\varepsilon_{\tau it}$ is the quantile-specific error term. The estimated values of $\alpha_{\tau i}$ present the existence of non-linear impacts of climatic variables on CRPI whereas estimates of $\beta\tau_j$ show how input and technology variables influence crop production. To examine regional heterogeneity, the analysis is further stratified into two subsamples: the Global South and the Global North. Separate PQR estimations are conducted for each subsample, and results are presented for the global sample, the Global South, and the Global North to facilitate comparative interpretation.

4. DATA DESCRIPTION

Table 1 summarizes the variables used in the analysis, their definitions, sources, and time coverage. The dependent variable, Crop Production Index (CRPI), from the *World Development Indicators (WDI)*, measures agricultural output relative to the 2014–2016 base period. Key climatic variables—average temperature (TEMP) in °C and precipitation (PREC) in millimeters—are obtained from the *Climate Change Knowledge Portal*. Permanent cropland (CLPC), expressed as a percentage of total land area, also comes from *WDI*, while the capital–labor ratio (CLR), an indicator of mechanization and input intensity, is sourced from the *United States Department of Agriculture (USDA)*. Patent applications (PTNT), serving as a proxy for technological innovation, are drawn from *WDI*. All variables cover the period 1980–2022, ensuring consistent cross-country and temporal comparisons.

Table 2 reports the descriptive statistics for the variables used in the study. The mean value of the Crop Production Index (CRPI) is 82.92, with a median of 86.86, suggesting a slightly left-skewed distribution. Climatic variables show substantial variation: average temperature (TEMP) ranges from –13.71°C to 34.90°C, while precipitation (PREC) spans from zero to over 4,700 mm. The dispersion is similarly pronounced for structural variables—permanent cropland (CLPC) ranges from 0% to over 50%, and capital–labor ratio (CLR) from 0.03 to 9.93—while patent applications (PTNT) exhibit extreme heterogeneity, from zero to more than 1.5 million. High skewness and kurtosis values across most variables, combined with statistically significant Jarque–Bera test results ($p < 0.01$), indicate strong departures from normality and the presence of outliers. These distributional characteristics imply that mean-based estimators, such as pooled OLS or fixed effects, may mask important heterogeneity and be sensitive to extreme values. Panel Quantile Regression (PQR), by contrast, allows the estimation of covariate effects across the entire conditional distribution of CRPI, providing a more robust and nuanced understanding of how climatic and structural factors influence crop productivity at different performance levels.

Table 1: Details and Description of the Variables used for the Analysis

Variable	Description	Source	Time
CRPI	Crop production index (2014-2016 = 100)	World Development Indicator (WDI)	1980-2022
TEMP	Average mean temperature over the aggregation period (Unit °C)	Climate Change Knowledge Portal	1980-2022
PREC	Aggregated accumulated precipitation. (Unit mm)	Climate Change Knowledge Portal	1980-2022
CLPC	Permanent cropland (% of land area)	World Development Indicator (WDI)	1980-2022
CLR	Ratio of capital input to labor input index	United Stated Department of Agriculture	1980-2022
PTNT	Residents and nonresidents patent applications (Proxy for Technological Innovations)	World Development Indicator (WDI)	1980-2022

Source: Authors' own work.

Table 2: Descriptive Statistics of the Study Variables

Statistics	CRPI	TEMP	PREC	CLPC	CLR	PTNT
Mean	82.92	18.58	906.75	3.13	0.85	9136.30
Median	86.86	22.07	686.70	1.03	0.80	53.00
Maximum	355.97	34.90	4761.13	50.51	9.93	1585663.00
Minimum	5.62	-13.71	0.00	0.00	0.03	0.00
Std. Dev.	30.81	8.58	846.92	4.85	0.56	65825.19
Skewness	0.54	-0.82	1.10	2.66	5.52	14.71
Kurtosis	5.63	2.73	3.86	12.46	61.57	281.18
Jarque-Bera	2451	834	1699	35661	10757	236939
Probability	0.00	0.00	0.00	0.00	0.00	0.00

Source: Authors' own work.

5. ANALYSIS AND RESULTS

5.1 Results of cross-sectional dependency test

Table 3 presents the results of cross-sectional dependence (CSD) tests, including the Breusch–Pagan LM, Pesaran scaled LM, bias-corrected scaled LM, and Pesaran CD statistics, for all variables used in the study. The test statistics are all highly significant ($p < 0.01$) for most variables, indicating the presence of strong cross-sectional dependence across countries in the panel dataset. This suggests that shocks or changes in one country's agricultural productivity, climate indicators, or economic factors are likely to be correlated with those in other countries, reflecting interconnected global patterns. The only exception is the Pesaran CD statistic for patents (PTNT), which is insignificant, implying weaker contemporaneous correlations for this variable.

Table 3: Results of Cross-Sectional Dependent Tests

Variables	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
CRPI	236754.28 (0.00)	1320.83 (0.00)	1318.81 (0.00)	255.18 (0.00)
TEMP	137683.46 (0.00)	732.87 (0.00)	730.85 (0.00)	250.60 (0.00)
PREC	30428.45 (0.00)	96.34 (0.00)	94.32 (0.00)	19.91 (0.00)
$TEMP^2$	135537.20 (0.00)	720.13 (0.00)	718.12 (0.00)	238.46 (0.00)
$PREC^2$	27801.86 (0.00)	80.75 (0.00)	78.74 (0.00)	19.47 (0.00)
CLR	276967.98 (0.00)	1559.48 (0.00)	1557.47 (0.00)	221.47 (0.00)
CLPC	26998.37 (0.00)	100.79 (0.00)	97.31 (0.00)	11.98 (0.00)
PTNT	25620.24 (0.00)	198.71 (0.00)	196.37 (0.00)	-1.88 (0.06)

Source: Author's own work, Note: Probability values are given in parenthesis.

5.2 Results of panel unit root test

Table 4 reports the outcomes of Pesaran's CADF panel unit root test for the study variables, indicating their stationarity properties. The results show that all variables—crop production index (CRPI), temperature, temperature square, precipitation, precipitation square, capital–labor ratio (CLR), permanent cropland (CLPC), and patents (PTNT)—are stationary at level, as evidenced by their statistically significant p-values ($p < 0.05$). The negative t-statistics and large negative Z-statistics confirm rejection of the null hypothesis of non-stationarity for each variable. This implies that the series do not require differencing and can be used directly in the model without transformation, supporting the validity of further econometric analysis.

Table 4: Outcomes of Pesaran's CADF Panel Unit Root Test for the Study Variables

Variable	T-Statistic	Z Statistic	P-value	Conclusion
CRPI	-2.33	-7.63	0.000	Stationary at Level
TEMP	-3.19	-19.46	0.000	Stationary at Level
PREC	-3.28	-20.8	0.000	Stationary at Level
$TEMP^2$	-4.06	-31.47	0.000	Stationary at Level
$PREC^2$	-4.02	-30.94	0.000	Stationary at Level
CLR	-2.46	-1.82	0.035	Stationary at Level
CLPC	-3.61	-25.24	0.000	Stationary at Level
PTNT	-2.16	-5.3	0.000	Stationary at Level

Source: Author's own work

5.3 Results of panel quantile regression model

The panel quantile regression results, given in Table 5, for the global analysis reveal a consistent and statistically significant inverted-U relationship between temperature and crop productivity across all quantiles. At lower productivity quantiles, a 1°C increase in mean temperature is associated with a 1.58-point rise in the crop production index, while at higher quantiles the effect increases to 2.49 points. This shows that temperature has stronger marginal positive effects in relatively high-productivity regions. However, this effect is non-linear and inverted U-shaped confirming by the negative and significant coefficients of the temperature-squared term across all quantiles.

Temperature thresholds, reported in Table 6, range from 12.91°C for lowest productive quantile to 24.36°C for the highest productive quantile. This implies that moderate warming boosts yields, but beyond these points, additional heat reduces productivity. High-productivity regions are more than twice as resilient to temperature increases compared to lower-productivity regions, likely due to climate-resilient technologies and heat-tolerant crop varieties.

Table 5: Results of Panel Quantile Regression Model for Overall World and Global South and North Regions

Outcomes of Econometric Model for the Whole Globe/World

Variables	**Q20**	**Q40**	**Q50**	**Q60**	**Q80**
TEMP	1.580***	1.901***	1.836***	1.975***	2.487***
	(0.208)	(0.193)	(0.180)	(0.148)	(0.190)
$TEMP^2$	-0.061***	-0.058***	-0.051***	-0.048***	-0.051***
	(0.008)	(0.007)	(0.006)	(0.005)	(0.007)
PREC	0.019***	0.024***	0.026***	0.027***	0.022***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)
$PREC^2$	$(-6.8x6^{-10})$***	$(-9.3x6^{-10})$***	$(-9.6x6^{-10})$***	$(-9.6x6^{-10})$***	$(-7.9\ x6^{-10})$***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CLR	16.251***	29.044***	34.554***	37.52***	42.487***
	(2.300)	(2.386)	(2.713)	(2.664)	(2.245)
CLPC	1.595***	1.236***	0.966***	0.643***	0.167
	(0.165)	(0.115)	(0.128)	(0.127)	(0.157)
PTNT	4.884***	4.710***	4.778***	4.971***	6.008***
	(0.153)	(0.183)	(0.169)	(0.176)	(0.176)

Outcomes of Econometric Model for Global South Region

Variables	**Q20**	**Q40**	**Q50**	**Q60**	**Q80**
TEMP	0.182	0.452	1.060***	1.751***	2.575***
	(0.282)	(0.313)	(0.272)	(0.335)	(0.377)
$TEMP^2$	0.017	0.013	0.001	-0.020	-0.040***
	(0.010)	(0.010)	(0.008)	(0.009)	(0.012)
PREC	-0.004	0.003	0.006**	0.004**	0.006***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
$PREC^2$	$(7.9\ x7^{-10})$	$(-1.7\ x6^{-10})$**	$-2.6\ x6^{-10})$***	$(-2\ x6^{-10})$***	$(-2.5\ x6^{-10})$***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CLR	28.565***	45.159***	50.701***	55.872***	56.820***
	(1.461)	(2.317)	(2.385)	(2.581)	(2.877)
CLPC	0.843***	0.553***	0.421***	0.295***	0.017
	(0.186)	(0.138)	(0.137)	(0.110)	(0.128)
PTNT	3.349***	2.948***	2.033***	1.676***	2.408***
	(0.288)	(0.259)	(0.255)	(0.218)	(0.195)

Outcomes of Econometric Model for Global North Region

Variables	**Q20**	**Q40**	**Q50**	**Q60**	**Q80**
TEMP	2.167***	2.205***	2.286***	2.147***	0.331
	(0.242)	(0.244)	(0.245)	(0.235)	(0.510)
$TEMP^2$	-0.070***	-0.075***	-0.077***	-0.069***	0.044
	(0.012)	(0.013)	(0.014)	(0.015)	(0.033)
PREC	0.057***	0.059***	0.058***	0.052***	0.063
	(0.003)	(0.003)	(0.005)	(0.004)	(0.004)
$PREC^2$	$(-2.8\ x5^{-10})$***	$(-3.2\ x5^{-10})$***	$(-3.2\ x6^{-10})$***	$(-2.8\ x5^{-10})$***	$(-3.4\ x6^{-10})$***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
CLR	2.842***	11.692***	17.791***	24.402***	32.867***
	(0.386)	(2.474)	(4.497)	(3.679)	(3.613)
CLPC	1.787***	1.469***	1.613***	1.496***	1.912***
	(0.197)	(0.197)	(0.251)	(0.247)	(0.380)
PTNT	4.651***	5.385***	5.449***	5.786***	6.787***
	(0.203)	(0.230)	(0.290)	(0.252)	(0.315)

*Source: Author's own work. Note: Standard errors are given in parentheses and ***, **, and * represent 1%, 5%, and 10% level of significance, respectively*

Precipitation, the second climatic variable, also exhibits an inverted-U polynomial pattern. Positive precipitation coefficients and negative, significant square terms indicate yield benefits up to 1,313–1,400 mm annually, after which excess rainfall becomes harmful. Agronomically, crops require adequate heat and water for growth, but extreme heat can cause heat stress, reduce photosynthesis, and increase water loss, while excessive rainfall can cause flooding, waterlogging, and soil erosion. These results align with Lobell et al. (2011), who found global yields peaking with moderate warming; Schlenker and Roberts (2009), who reported U-shaped temperature effects in U.S. crops; and Zhang et al. (2017), who emphasized mechanization's role in resilience. Moreover, these results are also well matched with Tanveer and Kalim (2025) where researchers estimated similar outcomes for agricultural total factor productivity.

Among control variables, the capital–labour ratio has a strong, increasing positive effect, from 16.25 at the lower quantile to 42.48 at upper quantile, suggesting that investments in human and physical capital significantly boost productivity. Additionally, high-productivity regions demonstrate deeper and larger marginal returns on such investments. By contrast, cropland expansion has stronger positive effects at lower productivity quantiles (1.59 at Q20) than at higher quantiles, reflecting lower-productivity regions' reliance on land and labour, while high-productivity regions achieve greater output from existing land. Technological innovation, measured by patents, has robust positive effects across all quantiles, increasing from 4.88 at lower quantile to 6.01 at upper quantile, showing that innovation is most effective where complementary factors already exist.

In the Global South, temperature effects are weaker and statistically insignificant at lower quantiles, becoming positive and significant only from middle quantile onward (1.06 at Q50 and 2.58 at Q80). The estimated coefficients of temperature-squared term are insignificant except for the upper quantile, denoting that heat damage emerges only at the highest productivity levels. The lack of significant impacts in lower quantiles suggests that many countries with subsistence or low yield crops already operate in challenging climates, where small changes in temperature or precipitation have little marginal effect. Moreover, it would be possible that Global South regions' economies may not yet be at the point where average temperatures consistently reduce yields, though vulnerability rises in high-performing areas.

Mixed effects of precipitation are found in the South regions with insignificant coefficients for lower quantiles and positive but small from mid-quantiles onward and with negative and significant estimated coefficients for precipitation-squared terms at these higher levels which indicate an inverted U-shape. Thresholds appear only in mid- to high-quantiles, at 1,085–1,114 mm relatively lower than of global precipitation thresholds and higher than global north, suggesting that moderate rainfall is beneficial but excess water is harmful in more developed cropping areas.

The capital–labour ratio has large positive effects across all quantiles, underlining the productivity gains from mechanization in capital-scarce contexts. Cropland's impact drops sharply from 0.84 at lower quantiles to near zero at higher ones, showing that land expansion matters more in early productivity stages. Technological innovation has positive but smaller coefficients than in the North, possibly due to slower adoption or weaker institutional support for technological diffusion.

These patterns reflect the South's greater tolerance for higher temperatures, owing to crop adaptation and agronomic practices, but also its reliance on capital deepening rather than land expansion for yield growth. Similar patterns were reported by Seo and Mendelsohn (2008) for African farms adapting to warming, Gollin et al. (2014) on mechanization in developing countries, and Fuglie and Toole (2014) on technology adoption gaps.

For the Global North, the temperature–productivity relationship is strong and positive up to the upper-middle quantiles (about 2.15–2.29 points per °C), showing that lower- to upper-middle-productivity regions benefit from warming. Yet this relationship is non-linear, with negative, significant temperature-squared coefficients confirming the inverted-U. Thresholds are lower than the global average, at 14–15°C, and do not significantly vary across quantiles, highlighting temperate agriculture's greater warming sensitivity. At the highest quantile, temperature effects become insignificant, suggesting that top-performing regions may be near or beyond their optimal thermal range.

Table 6: Quantile-Wise Threshold Levels of Temperature and Precipitation[2]

Quantile	Temperature's Thresholds			Precipitation's Thresholds		
	World	Global South	Global North	World	Global South	Global North
Q20	12.91	Not Significant	15.43	1374.03	Not Significant	1011.05
Q40	16.38	Not Significant	14.69	1313.12	Not Significant	930.92
Q50	17.85	Not Significant	14.84	1366.67	1094.88	921.26
Q60	20.38	Not Significant	15.45	1379.76	1085.17	924.56
Q80	24.36	Not Significant	Not Significant	1399.84	1113.97	912.35

Source: Authors' work based on empirical analysis. Note: (only statistically significant values are included)

Precipitation effects are consistently positive and larger than in the South (0.052–0.059), but thresholds are also lower (912–1,011 mm), implying that excess rainfall causes harm sooner, possibly due to soil saturation and higher disease pressure in cooler climates. Given efficient irrigation systems, additional rainfall beyond the norm may reduce yields in these developed regions. The capital–labour ratio has a positive effect that rises with productivity, though magnitudes are smaller than in the South due to already high mechanization levels.

Cropland consistently has a strong positive impact, suggesting stable land productivity and intensive management. Moreover, technological innovation effects are large and rise with quantiles, reinforcing that advanced solutions like precision agriculture and genetic improvements are especially valuable in high-yield contexts. Overall, the North's lower climate thresholds reflect narrower crop temperature ranges and less historical heat exposure, while precipitation sensitivity is linked to cooler soils' reduced drainage capacity. These findings are consistent with Schlenker et al. (2011) on Northern agriculture's climate sensitivity, Tack et al., (2015) on precipitation extremes in U.S. wheat, and Fuglie and Toole (2014) on innovation's central role in sustaining productivity.

It can be concluded that both the Global South and Global North show that temperature, precipitation, and technological innovations significantly influence crop productivity, but the direction and magnitude of these effects differ (Farah et al., 2025; Fuglie et al., 2024; Gray, 2021). In the South, moderate increases in temperature are less harmful due to crop adaptation and heat-resilient farming practices (Ruane and Rosenzweig, 2019), while in the North, even slight warming tends to reduce yields because crops are more suited to cooler climates (Gray, 2021). Similarly, precipitation benefits productivity in both regions (He et al., 2025), but the South shows greater sensitivity to rainfall variability, reflecting its higher dependence on rain-fed agriculture (Tefera et al., 2025). Technological innovation boosts productivity across both regions (Fuglie et al., 2024), yet in the South it complements capital-intensive farming to offset climate pressures (Daum, 2023), whereas in the North it primarily enhances efficiency within stable climatic conditions (Coninck et al., 2022). These patterns highlight that while the two regions share

[2] Figure Appendix-B1 and Appendix-B2 give graphs of quantile-wise threshold levels of temperature and precipitation, respectively.

common drivers of productivity, their responses are shaped by distinct climatic, structural, and technological contexts (Raitzer & Drouard, 2024).

6. CONCLUSION AND POLICY IMPLICATIONS

Food insecurity is a crucial global problem where more than 2 billion people lack access to a healthy diet. Climatic conditions are further exacerbating this challenge by affecting crop productivity worldwide, with unfavorable weather disproportionately harming the already poor and vulnerable segments of the population. A special predicament in the global climate–agriculture nexus is the existence of asymmetric and non-linear empirical relationships, which much of the existing literature fails to capture.

The present study addresses this gap by investigating the non-linear relationship between climate variability and crop productivity, with particular attention to disparities between the Global South and the Global North. The findings reveal that moderate temperature increases can enhance productivity in certain regions, especially in the Global South, where crops and farming practices are better adapted to warmer conditions. However, excessive heat beyond a threshold exerts significant negative impacts across the globe, and these thresholds are relatively narrow in the Global North, where temperature variability disrupts traditional growing cycles.

Rainfall patterns similarly show a non-linear relationship with crop productivity across the globe, where moderate increases support growth, while heavy rainfall led to declines crop production index. In this regard, it can be concluded that the Global South is more vulnerable to rising temperatures, reflecting lower adaptive capacity and dependence on rain-fed agriculture owing to limited resources, whereas the Global North shows higher sensitivity to excessive rainfall, where productivity declines sharply beyond critical thresholds yet their higher mechanization, innovation, and advanced crop management allow them to mitigate adverse effects more effectively. These results emphasize that climate impacts are context-specific, shaped by regional agronomic practices, technological adoption, and resource availability.

Therefore, policymakers should prioritize investment in climate-resilient crop varieties, improved irrigation systems, and water conservation technologies in global south regions. This can be done by strengthening adaptive capacity through farmer training, crop diversification, and affordable access to climate-smart practices is crucial. On the other hand, in global north, it is recommended to focus on enhancing drainage infrastructure, soil management practices, and flood-resilient cropping systems. To achieve this, advanced climate monitoring and early-warning systems can help farmers adjust planting and harvesting decisions to rainfall extremes.

The study has certain limitations due to the use of aggregate data for crop production and climatic variables. Future research can be extended by incorporating seasonal temperature data aligned with specific crops, as well as additional climatic indicators such as droughts and extreme weather events. Furthermore, including factors like soil quality, pest outbreaks, and input use would provide a deeper understanding of climate–productivity dynamics. Longitudinal analyses tracking changes in farming practices over time could also offer valuable insights into how adaptation evolves, and which strategies are most effective in mitigating climate-induced productivity losses.

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REFERENCES

Akhtar, I., & Nazir, N. (2013). Effect of waterlogging and drought stress in plants. *International Journal of Water Resources and Environmental Sciences*, 2(2), 34–40.

Baltagi, B. H. (2021). *Econometric Analysis of Panel Data*, 6th edition. Springer.

Canay, I. A. (2011). A simple approach to quantile regression for panel data. *The Econometrics Journal*, 14(3), 368–386.

Coninck, H., Sagar, A., Blanco, G. & Agbemabiese, L. (2022). Chapter 16: Innovation, technology development and transfer. In Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the *Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1653–1720). Cambridge University Press.

Daum, T. (2023). Mechanization and sustainable agri-food system transformation in the global south. *Agronomy for Sustainable Development*, 43(16).

FAO (2021). Food and Agriculture Organization of the United Nations. *Land and Water: Facts and figures – SOLAW 2021*. Retrieved August 16, 2025, from https://www.fao.org/land-water/solaw2021/facts/en

FAO (2023). *In brief to The State of Food Security and Nutrition in the World 2023: Urbanization, Agrifood Systems Transformation and Healthy Diets Across the Rural–Urban Continuum.* FAO, IFAD, UNICEF, WFP, and WHO. https://doi.org/10.4060/cc6550en

Farah, A., Shah, W., & Chen, J. (2025). Machine learning assessment of CMIP6 projected maximum temperature and precipitation impacts on crop yields and rangeland productivity in Pakistan. *Geo Journal*, 90(4), 1-6.

Fuglie, K. O., & Toole, A. A. (2014). The evolving institutional structure of public and private agricultural research. *American Journal of Agricultural Economics*, 96(3), 862–883.

Fuglie, K., Morgan, S., & Jelliffe, J. (2024). Global changes in agricultural production, productivity, and resource use over six decades. *Amber Waves, USDA Economic Research Service*.

Gollin, D., Lagakos, D., & Waugh, M. E. (2014). The agricultural productivity gap. *Quarterly Journal of Economics*, 129(2), 939–993.

Gray, E. (2021, November 2). Global climate change impact on crops expected within 10 years, NASA study finds. NASA Climate Change: Vital Signs of the Planet. https://climate.nasa.gov/news/3124/global-climate-change-impact-on-crops-expected-within-10-years-nasa-study-finds/

Hatfield, J. L., & Prueger, J. H. (2015). Temperature extremes: Effect on plant growth and development. *Weather and Climate Extremes*, 10, 4–10.

He, L., Wang, J., Peltier, D. M., Ritter, F., Ciais, P., Peñuelas, J., & Li, Z. L. (2025). Lagged precipitation effects on plant production across terrestrial biomes. *Nature Ecology and Evolution*, 1-12.

Ibrahim, M., & Law, S. H. (2014). Social capital and CO_2 emissions—A panel quantile regression analysis. *Renewable and Sustainable Energy Reviews*, 29, 528–534.

IPCC (2022). Climate Change 2022: Impacts, *Adaptation and Vulnerability*. *Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Koenker, R. (2004). Quantile regression for longitudinal data. *Journal of Multivariate Analysis*, 91(1), 74–89.

Kowalski, A.M. (2020). *Global South-Global North Differences*. In: Leal Filho, W., Azul, A., Brandli, L., Lange Salvia, A., Özuyar, P., Wall, T. (eds) *No Poverty. Encyclopedia of the UN Sustainable Development Goals*. Springer, Cham.

Lobell, D. B., & Field, C. B. (2007). Global scale climate–crop yield relationships and the impacts of recent warming. *Environmental Research Letters*, 2(1), 014002.

Lobell, D. B., & Gourdji, S. M. (2012). The influence of climate change on global crop productivity. *Plant Physiology*, 160(4), 1686–1697.

Lobell, D. B., Schlenker, W., & Costa-Roberts, J. (2011). Climate trends and global crop production since 1980. *Science*, 333(6042), 616–620.

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of climate change on agriculture and its mitigation strategies: A review. *Sustainability* (Switzerland), 13(3), 1–21.

Moore, F. C., & Lobell, D. B. (2015). The fingerprint of climate trends on European crop yields. *Proceedings of the National Academy of Sciences*, 112(9), 2670–2675.

Nelson, G. C., Valin, H., Sands, R. D., Havlík, P., Ahammad, H., Deryng, D., ... & Willenbockel, D. (2014). Climate change effects on agriculture: Economic responses to biophysical shocks. *Proceedings of the National Academy of sciences 111*, no. 9: 3274-3279.

Nguyen, T. T., Pham, T. P., & Huynh, T. L. D. (2020). The impacts of economic growth, environmental policy, and technological innovation on energy consumption: Evidence from G7 and BRICS countries. *Energy Policy*, 139, 111356.

Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, 22(2), 265–312.

Porter, J. R., Xie, L., Challinor, A. J., Lobell, D. B., & Travasso, M. I. (2014). Food security and food production systems. In C. B. Field, V. R. Barros,… L. L. White (Eds.), Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 485–533). Cambridge University Press.

Raitzer, D. A., & Drouard, J. (2024). Empirically estimated impacts of climate change on global crop production via increasing precipitation–evapotranspiration extremes (ADB Economics Working Paper Series No. 759). Asian Development Bank. https://www.adb.org/sites/default/files/publication/1017806/ewp-759-impacts-climate-crop-production.pdf

Rosenzweig, C., Elliott, J., Deryng, D., Ruane, A. C., Müller, C., Arneth, A., ... & Jones, J. W. (2014). Assessing agricultural risks of climate change in the 21st century in a global gridded crop model inter comparison. *Proceedings of the National Academy of sciences*, 111(9), 3268-3273.

Ruane, A. C., & Rosenzweig, C. (2019). Climate change impacts on agriculture: Challenges, opportunities, and AgMIP frameworks for foresight. In *Handbook of Climate Change and Agroecosystems: The Agricultural Model Intercomparison and Improvement Project (AgMIP)* 45–78. NASA Technical Reports Server. https://ntrs.nasa.gov/api/citations/20190025372/downloads/20190025372.pdf

Schlenker, W., & Roberts, M. J. (2009). Nonlinear temperature effects indicate severe damages to U.S. crop yields under climate change. *Proceedings of the National Academy of Sciences*, 106(37), 15594–15598.

Schlenker, W., Roberts, M. J., & Lobell, D. B. (2011). Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, 6(1), 014010.

Seneviratne, S. I., Zhang, X., Adnan, M., Badi, W., & Zhou, B. (2021). *Weather and Climate Extreme Events in a Changing Climate*. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, O. Yelekçi, R. Yu, and B. Zhou (Eds.), Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1513–1766). Cambridge University Press.

Seo, N., & Mendelsohn, R. (2008). Measuring impacts and adaptations to climate change: A structural Ricardian model of African livestock management. *Agricultural Economics*, 38(2), 151–165.

Tack, J., Barkley, A., & Nalley, L. L. (2015). Effect of warming temperatures on US wheat yields. *Proceedings of the National Academy of Sciences*, 112(22), 6931–6936.

Tanveer, Z., & Kalim, R. (2025). An empirical analysis of climate transition: A global outlook of agriculture productivity. *Journal of Economic Studies*, 52(6), 1025–1042.

Tanveer, Z., Kalim, R., & Arshad, N. (2025). Role of climate change in altering global agricultural trade dynamics: An empirical analysis. *Journal of Economic Studies*. https://doi.org/10.1108/JES-12-2024-0829

Tao, F., Yokozawa, M., Liu, J., & Zhang, Z. (2008). Climate–crop yield relationships at provincial scales in China and the impacts of recent climate trends. *Climate Research*, 28(1), 83–94.

Tefera, M. L., Seddaiu, G., Carletti, A., & Awada, H. (2025). Rainfall variability and drought in West Africa: Challenges and implications for rainfed agriculture. *Theoretical and Applied Climatology*, 156(41).

Twerefou, D. K., Danso-Mensah, K., & Bokpin, G. A. (2017). The environmental effects of economic growth and globalization in sub-Saharan Africa: A panel quantile regression approach. *Research in International Business and Finance*, 42, 939–949.

United Nations (2022). World population prospects 2022: *Summary of results. United Nations, Department of Economic and Social Affairs*, Population Division. https://www.un.org/development/desa/pd/content/World-Population-Prospects-2022

Vandana, P., Gupta, A., & Kumar, M. (2024). Drought and waterlogging stress responses in crops. In *Plant-Microbe Interaction and Stress Management* (pp. 51–78). Springer.

Vermeulen, S. J., Campbell, B. M., & Ingram, J. S. I. (2012). Climate change and food systems. *Annual Review of Environment and Resources*, 37, 195–222.

Wheeler, T., & Von Braun, J. (2013). Climate change impacts on global food security. *Science*, 341(6145), 508–513.

World Ban (k2023). *Employment in Agriculture (% of Total Employment) (Modeled ILO Estimate)*. World Bank Open Data. https://data.worldbank.org/indicator/SL.AGR.EMPL.ZS

World Bank (2025). Agriculture and food: *Development News, Research, Data*. World Bank Topics. https://www.worldbank.org/en/topic/agriculture

Wu, J., Wang, J., Hui, W., Zhao, F., Wang, P., Su, C., & Gong, W. (2022). Physiology of plant responses to water stress and related genes: A review. *Forests*, 13(2), 324.

Zambrano-Medina, Y. G., Avila-Aceves, E., Perez-Aguilar, L. Y., Monjardín-Armenta, S. A., Plata-Rocha, W., Franco-Ochoa, C., & Chávez-Martínez, O. (2024). The impact of climate change on crop productivity and adaptation and mitigation strategies in agriculture. In *Transforming Agricultural Management for a Sustainable Future*, 1–20. Springer Nature.

Zhang, P., Zhang, J., & Chen, M. (2017). Economic impacts of climate change on agriculture: The importance of additional climatic variables. *Journal of Environmental Economics and Management*, 83, 8–31.

Zhao, C., Liu, B., Piao, S., Wang, X., Lobell, D. B., Huang, Y., ... & Asseng, S. (2017). Temperature increase reduces global yields of major crops in four independent estimates. *Proceedings of the National Academy of Sciences*, 114(35), 9326–9331.

Appendix-A: List of Countries Used for the Analysis

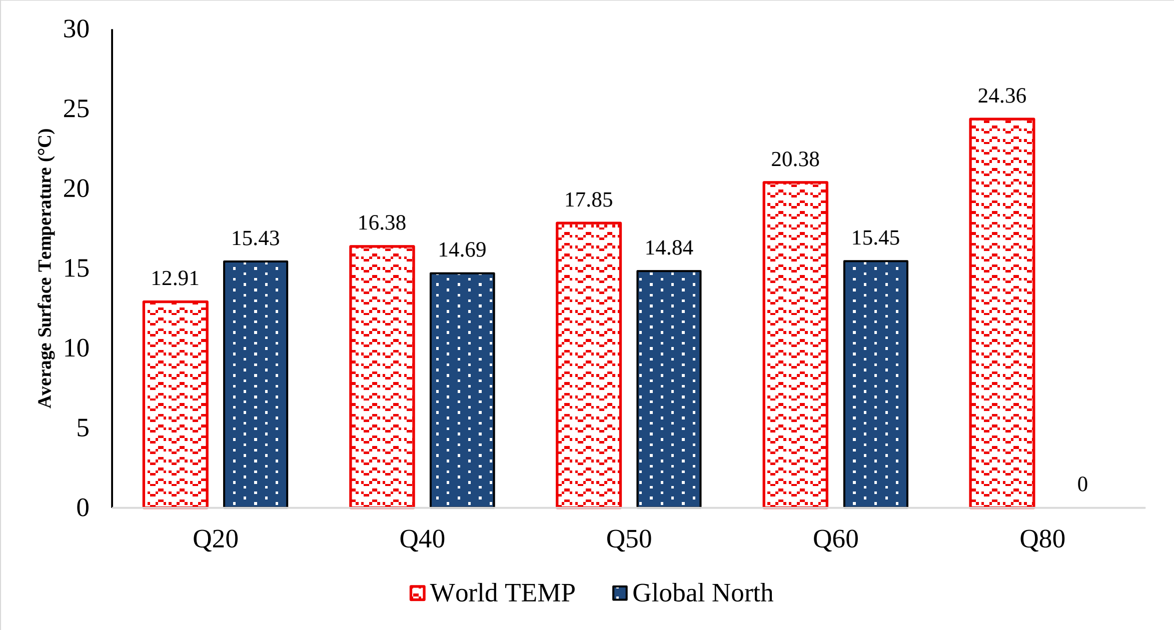
Sr. No.	Country
1	Afghanistan
2	Albania
3	Algeria
4	Angola
5	Argentina
6	Armenia
7	Australia
8	Austria
9	Azerbaijan
10	Bahrain
11	Bangladesh
12	Belarus
13	Belgium
14	Belize
15	Benin
16	Bhutan
17	Bolivia
18	Botswana
19	Brazil
20	Brunei Darussalam
21	Bulgaria
22	Burkina Faso
23	Burundi
24	Cabo Verde
25	Cambodia
26	Cameroon
27	Canada
28	Central African Republic
29	Chad
30	Chile
31	China
32	Colombia
33	Comoros
34	Congo DR
35	Congo Republic
36	Costa Rica
37	Croatia
38	Cuba
39	Cyprus
40	Czechia
41	Denmark
42	Djibouti
43	Dominican Republic
44	Ecuador
45	Egypt
46	El Salvador
47	Equatorial Guinea
48	Eritrea

Sr. No.	Country
49	Estonia
50	Eswatini
51	Ethiopia
52	Fiji
53	Finland
54	France
55	Gabon
56	Gambia
57	Georgia
58	Germany
59	Ghana
60	Greece
61	Guatemala
62	Guinea
63	Guinea-Bissau
64	Guyana
65	Haiti
66	Honduras
67	Hungary
68	Iceland
69	India
70	Indonesia
71	Iran
72	Iraq
73	Ireland
74	Israel
75	Italy
76	Jamaica
77	Japan
78	Jordan
79	Kazakhstan
80	Kenya
81	Korea DPR
82	Korea Republic
83	Kuwait
84	Kyrgyzstan
85	Laos
86	Latvia
87	Lebanon
88	Lesotho
89	Liberia
90	Libya
91	Lithuania
92	Luxembourg
93	Madagascar
94	Malawi
95	Malaysia
96	Mali
97	Malta
98	Mauritania
99	Mauritius

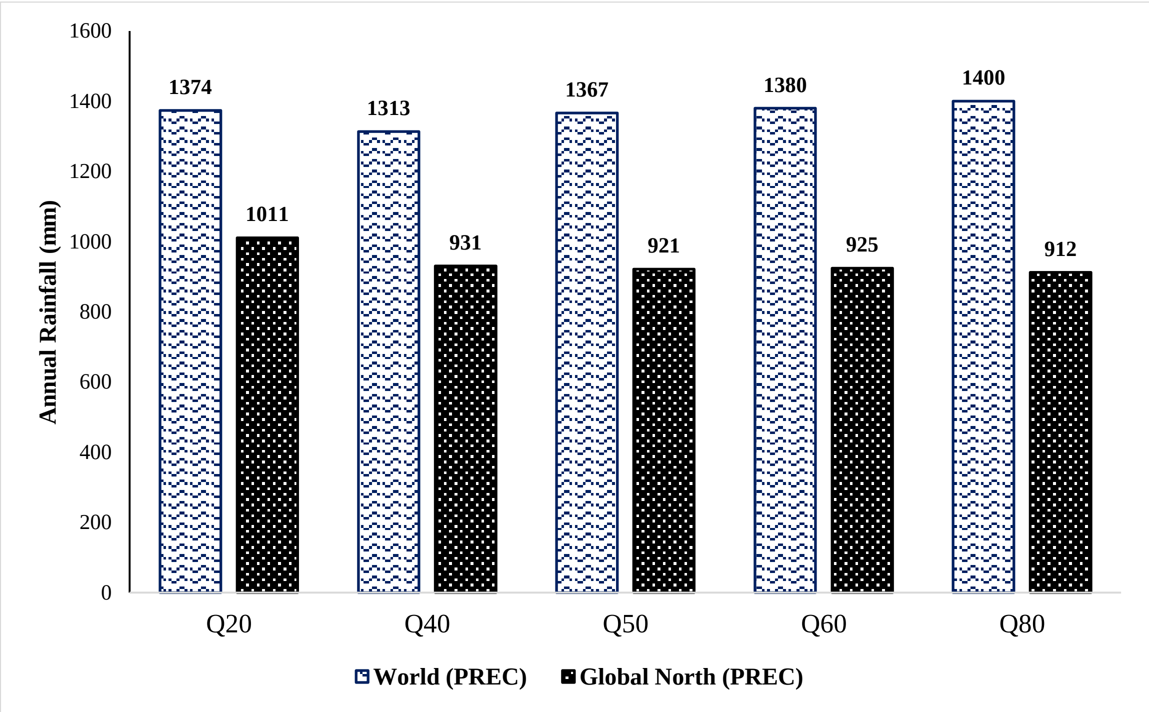
Sr. No.	Country
100	Mexico
101	Micronesia
102	Moldova
103	Mongolia
104	Montenegro
105	Morocco
106	Mozambique
107	Myanmar
108	Namibia
109	Nepal
110	Netherlands
111	New Caledonia
112	New Zealand
113	Nicaragua
114	Niger
115	Nigeria
116	North Macedonia
117	Norway
118	Oman
119	Pakistan
120	Panama
121	Papua New Guinea
122	Paraguay
123	Peru
124	Philippines
125	Poland
126	Portugal
127	Qatar
128	Romania
129	Russian Federation
130	Rwanda
131	Saudi Arabia
132	Senegal
133	Serbia
134	Sierra Leone
135	Slovakia
136	Slovenia
137	Solomon Islands
138	Somalia
139	South Africa
140	Spain
141	Sri Lanka
142	Sudan
143	Suriname
144	Sweden
145	Switzerland
146	Syria
147	Tajikistan
148	Tanzania

Sr. No.	Country
149	Thailand
150	Timor-Leste
151	Togo
152	Trinidad and Tobago
153	Tunisia
154	Turkiye
155	Turkmenistan
156	Uganda
157	Ukraine
158	United Arab Emirates
159	United Kingdom
160	United States
161	Uruguay
162	Uzbekistan
163	Vanuatu
164	Venezuela
165	Vietnam
166	West Bank and Gaza
167	Yemen
168	Zambia
169	Zimbabwe

Appendix B1: Quantile-Wise Comparison of Threshold Levels of Temperature



Appendix B2: Quantile-Wise Comparison of Threshold Levels of Precipitation



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Investigating Pakistan's Debt Sustainability and Debt Management: An Econometric Analysis

ABSTRACT

As an indebted country, Pakistan has observed the substantial and persistent increase in its debt burden over the years. This study aims to empirically investigate the impact of public and external debt on the primary balance, while emphasizing the need to break the cycle of reliance on the foreign aid and external borrowing. Using annual data from 1973 to 2022, the study employs breakeven unit root test to identify the potential structural shocks and applies the Two-Stage Least Squares (2SLS) estimation technique to ensure robust empirical findings. Regression results reveal that public debt negatively and significantly affects the primary balance, whereas external debt has an insignificant impact. Debt sustainability analysis suggests that Pakistan has experienced the unsustainable debt management throughout. However, decades 1973–1982 and 1993–2002 demonstrate partial fulfillment of debt stabilization conditions, with the primary balances remaining non-negative, though necessary condition was not consistently met. Graphical analysis further reveals the lack of persistent debt sustainability in the presence of primary deficits. This study recommends that to achieve the sustainable debt levels, policymakers must focus on the economic diversification, export promotion, fiscal responsibility, and transparent governance. Complementary strategies, including risk management, targeted subsidies, and the international cooperation, are essential for fostering the long-term financial independence.

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Keywords

Debt sustainability, primary balance, public debt, external debt, and structural break

JEL Classification

F0; F4; H3; H6

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Author's contribution in the article: 1- Conceived and designed the analysis, 2- Reviewed and compiled the literature, 3- Collected the data, 4- Contributed data or analysis tools, 5- Performed the analysis, 6- Wrote the paper, 7- Financial support for the conduct of the study, 8-Other

1. INTRODUCTION

Debt sustainability refers to a country's ability to meet its current and future debt obligations without resorting to exceptional financing or compromising long-term economic stability (Lesage et al., 2013). In the Pakistan's case, this issue has grown critical over the past five decades due to the persistent fiscal imbalances, weak public financial management, and heavy dependence on the external borrowing (Mahmood et al., 2009; Hussain & Idrees, 2019; Bandiera & Tsiropoulos, 2020). These vulnerabilities have led to recurring the debt cycles and macroeconomic instability, undermining investor confidence and limiting the policy space.

Since 1970s, successive Pakistani governments have struggled to maintain a sustainable debt profile. Political transitions, structural inefficiencies, and the external shocks such as oil crises, geopolitical tensions, and natural disasters have compounded country's fiscal burden (Bird, 2007; Ejaz & Hyder, 2019). Pakistan's public debt reached 87% of the GDP well above 60% threshold defined in the Fiscal Responsibility and Debt Limitation (FRDL) Act, 2005 indicating the persistent solvency concerns (Ampofo et al., 2021; Roubini, 2001).

Debt Sustainability Analysis (DSA) framework, employed by the International Monetary Fund (IMF), provides a systematic approach to assess whether the fiscal and macroeconomic conditions can support existing debt levels. This study adopts that framework to evaluate the debt sustainability over the period 1973–2022 as an extension of the macro-econometric model by Fatemah and Haq (2024), with a specific focus on influence of the public and external debt on Pakistan's primary balance. It integrates structural break analysis and accounting approach (using the conditions $r < g$ and primary balance ≥ 0) to assess whether the debt dynamics have been sustainable over the time (Mendoza & Ostry, 2008; Mahmood et al., 2009).

Unlike previous literature that isolates debt indicators, this study offers a multidimensional assessment by combining empirical estimation using Two-Stage Least Squares (2SLS), structural break tests, and historical regime analysis. The novelty lies in analyzing how different political regimes, macroeconomic shocks, and policy inconsistencies have shaped debt sustainability trends over five decades (Ghosh et al., 2011). The main objectives of this study are to empirically evaluate the effect of public and external debt on the primary fiscal balance and to identify key structural shocks and fiscal discontinuities (Forgha et al., 2014). The paper will also assess Pakistan's debt sustainability through both econometric and accounting-based approaches. By doing so, the paper provides evidence-based insights for policymakers on the conditions necessary to achieve long-term fiscal discipline and reduce dependency on external financing.

The rest of the paper is organized as follows: Section 2 reviews the existing literature on debt sustainability and fiscal policy. Section 3 describes theoretical and empirical models, including data sources and estimation techniques. Section 4 presents and interprets results, including structural breaks and the sustainability assessments. Finally, Section 5 concludes with the key policy recommendations and suggestions for the future research.

2. LITERATURE REVIEW

Debt sustainability has long been a central concern for the developing economies, where fiscal imbalances, structural inefficiencies, and the political instability often lead to unsustainable debt paths (Ormaechea & Martinez, 2021). Early theoretical models, including those by Modigliani (1961) and the Barro (1979), emphasized long-term implications of the public borrowing and inter-generational debt burden. These ideas were further developed by the Bohn (1998, 2008), who introduced fiscal reaction functions to empirically test whether the governments adjust their primary balances in response to the rising debt (Cecchetti et al., 2010). Mahmood et al. (2009) applied these concepts to

Pakistan and found recurring periods of the unsustainable debt due to weak fiscal performance and heavy reliance on short-term borrowing.

Several empirical studies have examined the role of the external debt and donor dependency in weakening fiscal resilience (Hussain & Idrees, 2015**)**. For instance, (Anwer, 2000; Bond, 2020; Bresser-Pereira, 2022) argued that the structural adjustment programs by institutions like IMF and World Bank often reinforce the fiscal rigidity, limiting domestic policy autonomy. Similar concerns were echoed by the (Conway, 2006; Chuku et al., 2023), who noted that aid conditions increase long-term debt exposure and reduce effectiveness of the domestic fiscal planning.

Political and institutional factors have also been found to play a key role in the debt sustainability. Campos et al. (2020) and Nizami et al. (2020) adopted the dynamic forecasting techniques such as fan charts to analyze the fiscal risks under uncertainty (Sokol, 2021). Their findings suggest that the macroeconomic volatility, inflation, and weak governance significantly impair a country's ability to manage debt (Campos et al., 2020). These conclusions are consistent with observations by the (Bowlsby et al., 2020; Husain, 2018), who highlighted how political instability and policy inconsistency deter the investment and disrupt long-term planning.

Literature further emphasizes importance of the revenue generation and expenditure efficiency in maintaining fiscal balance. Fuest and Riedel (2010) and Mascagni et al. (2014) stressed that the low tax compliance, narrow tax bases, and institutional weaknesses contribute to the chronic deficits in developing countries like Pakistan. (Safiullah et al., 2024; Mehrotra & Sergeyev, 2021) expanded this discussion by linking the unsustainable debt to broader the economic and social outcomes, such as environmental degradation and reduced developmental spending.

Lastly, recent studies such as Shah et al. (2024) and Ejaz and Hyder (2019) have tested the debt sustainability across different developing regions using panel data and structural models. Their findings reveal that while the fiscal consolidation and low interest rates may help in short term, long-run sustainability requires the deep institutional reforms, stable governance, and the effective public finance management (Agnello et al., 2013; Alvarado et al., 2004).

In summary, literature indicates that debt sustainability is a multidimensional issue shaped by the fiscal behavior, external dependency, institutional capacity, and macroeconomic conditions Okunola (2022). This study builds on these foundations by using a more integrated framework to examine how the public and external debt influence Pakistan's primary balance over a 50-year period, while also accounting for the structural breaks and political transitions.

3. METHODOLOGY

3.1. Theoretical Framework

Debt sustainability is commonly evaluated through the deterministic and stochastic frameworks. While deterministic models (e.g., bound testing) assess the long-term relationships between macroeconomic variables, they often fail to capture the policy-driven volatility. In contrast, stochastic and simulation-based models, such as those by (Abiad & Ostry, 2005; Afonso, 2005), allow for the endogenous fiscal responses under uncertainty. This study adopts a hybrid framework informed by Mahmood et al. (2009), combining the intertemporal budget constraints with accounting-based conditions and empirical estimation (Wilcox, 1989). The two key accounting conditions used in this study are:

1. **Necessary Condition:**

$$r^* < g \tag{1}$$

Where r represents real interest rate on debt, g represents real GDP per capita growth rate. If $r < g$, the debt-to-GDP ratio is expected to decline over the time, indicating sustainability.

2. **Sufficient Condition:**

$$S \geq 0 \tag{2}$$

Where S represents primary fiscal balance as a percentage of GDP. These indicators form the basis of debt sustainability tests applied across decades in Pakistan.

This study employs Two-Stage Least Squares (2SLS) estimation method to address the endogeneity in the relationship between debt indicators and primary balance (Mogstad et al., 2021). Endogeneity may arise from reverse causality or omitted variables, especially in the macroeconomic time series. The 2SLS approach ensures consistent estimation of coefficients by using lagged values of the external debt and the GDP deflator as instruments. This framework can also be interpreted as under in Table 1:

Table 1: DSA framework of Study on Public Debt, Annual Time series Data: 1973-2022

Component	Approach/Details
Objective	Assess debt sustainability using empirical (2SLS) and accounting-based approaches
Estimation Methods	Traditional indicators, Accounting conditions ($r < g$, $PB \geq 0$), 2SLS econometric model
Key Variables	Public debt, external debt, primary balance, real interest rate, GDP deflator
Data Sources	WDI, IFS, Economic Survey of Pakistan, Cross-Country Fiscal Database
Instrumental Variables (IVs)	Lag of external debt, Lag of GDP deflator
Period Covered	1973–2022 (annual time series)

3.2. Data Description and Sources

Annual data from 1973 to 2022 was sourced from the World Development Indicators (WDI), IMF's International Financial Statistics (IFS), Economic Survey of Pakistan, and the Cross-Country Database of Fiscal Space. The key outcome variable is the primary balance, while public debt and external debt serve as main regressors. Control variables include real interest rates and GDP deflator. Data details are given in table 2.

Table 2: Summary of Variables

Variable	Abbreviation	Unit	Description
Primary Balance	PB	% of GDP	Fiscal revenue minus non-interest expenditure
External Debt	ED	% of GDP	Total debt owed to non-residents
Public Debt	PD	Index (constructed)	Sum of domestic and external debt (exchange rate adjusted)
Real Interest Rate	RIR	Percentage	Inflation-adjusted interest rate
GDP Deflator	GDPD	Index	Measures price level changes in GDP

Note: Public debt is constructed using Barro's (1979) approach, combining external debt (adjusted by exchange rate) and domestic debt. Data gaps from 1973 to 1990 were interpolated where necessary using cross-country series.

Descriptive statistics in table 3 reveal that Pakistan's primary balance averaged -4.23% of GDP, indicating persistent deficits. External debt remained around 32.5% of GDP on average, while public debt was more volatile, averaging 61.2%. The real interest rate fluctuated from -3.2% to 6%, reflecting mixed monetary policy regimes.

Table 3: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max
Primary Balance	–4.23	3.12	–10.87	1.56
External Debt	32.45	7.34	18.23	45.87
Public Debt	61.22	14.52	34.89	87.43
GDP Deflator	92.43	23.11	45	142.01
Real Int. Rate	2.15	1.74	–3.21	5.98

Note: Data sources include WDI, IFS, Handbook of Statistics, and author's calculations.

3.3. Empirical Strategy and Econometric Model

The paper uses the following model to investigate the hypothesis for debt sustainability. As shown below,

$$PB = f\,(ED, PD, GDPD, RIR) \tag{3}$$

Where, *PB* represents primary balance (% of GDP), *ED* represents external debt (% of GDP), *PD* represents public debt (constructed index), *GDPD* represents GDP deflator (index), and *RIR* represents real interest rate (%). This study uses a Two-Stage Least Squares (2SLS) approach shown in equation 4 and 5 to address potential endogeneity in the relationship between debt variables and the primary balance. Endogeneity may arise due to reverse causality or omitted variable bias, especially in time series settings where debt accumulation and macro indicators co-move (Koutsoyiannis, 1977).

Thus, we have the following expressions:

$$PB_t = \alpha_0 + \alpha_1 PD_t(\ln) + \alpha_2 ED_t + \alpha_3 RIR_t + \alpha_4 GDPD_t + \varepsilon_t \tag{4}$$

Where ED_t and $GDPD_t$ are endogenous variables.

This paper uses the lags of the endogenous variables plugged into a normal fitted model. These lag variables are instrumented variables, used in the study. Thus, the final model will be:

$$PB_t = \alpha_0 + \alpha_1 PD_t(\ln) + \alpha_2 Z_{1t} + \alpha_3 RIR_t + \alpha_4 Z_{2t} + \varepsilon_t \tag{5}$$

Where $Z_{1t} = ED_{t-1}$ and $Z_{2t} = GDPD_{t-1}$

Instrumental Variables (for 2SLS) are Z_{1t} representing lag of external debt and Z_{2t} represents lag of GDP deflator. To address endogeneity, lagged value of ED_t and $GDPD_t$ are used as instrument (Zahid et al., 2020).

3.4. Justification for Model Selection

The Durbin Wu Hausan test has been done to confirm the presence of endogeneity. As shown below:

Table 4: Durbin-Wu-Hausman Test

Variable	OLS Coeff.	2SLS Coeff.	Diff.
External Debt	-0.0006	-0.0002	-0.00033
Public Debt	-1.032	-2.055	1.023
Real Interest Rate	-0.0216	0.032	-0.053
GDP Deflator	0.0373	0.034	0.003
Test Statistic	χ^2= 73.80	Prob. > χ^2	0.0000

The Durbin-Wu-Hausman test in table 4 confirmed the presence of endogeneity, validating the use of 2SLS over OLS (Sheikhi et al., 2022). This approach is preferred over Ordinary Least Squares (OLS) due to its consistency and efficiency in the presence of endogenous regressors. A correlation matrix further supported the presence of multicollinearity and potential bias in simple regressions.

The correlation matrix (see Table 5) shows strong multicollinearity among the regressors and residuals, further supporting instrument-based estimation. To assess multicollinearity and the degree of association among variables, we present the correlation matrix below.

Table 5: Correlation Matrix

Variable	PB	ED	PD	RIR	GDPD
Primary Balance (PB)	1				
External Debt (ED)	–0.4746	1			
Public Debt (PD)	–0.6807	0.8086	1		
Real Interest Rate (RIR)	–0.6882	0.62	0.9604	1	
GDP Deflator (GDPD)	–0.5487	0.9492	0.9232	0.7925	1

The matrix in table 5 depicts, that external debt and GDP deflator are highly correlated with residuals listed in the last column causing the issue of endogeneity. Moreover, primary balance moderately correlated with external debt, public debt, GDP deflator and real interest rate while we can see that external debt is highly correlated with GDP deflator. In brief there are more chances for occurrence of endogeneity caused by these endogenous variables.

4. ANALYSIS AND RESULTS

For unit root testing the Augmented Dickey Fuller (ADF) test has been employed. All variables appear stationary (Results are given in Appendix A). This section presents the regression output using the Two-Stage Least Squares (2SLS) estimation technique (Table 6), selected to address endogeneity concerns between debt variables and Pakistan's primary balance. Lagged values of external debt and the GDP deflator were used as instruments.

Table 6: 2SLS Regression Estimates

Variables	Coefficient	Std. Error	z	P > t	[95% Confidence Interval]
External Debt	-0.0006	0.0007	-0.83	0.408	-0.0019 to 0.0008
Public Debt (ln)	-1.0320	2.1986	-0.47	0.639	-5.3412 to 3.2772
Real Interest Rate	-0.0216	0.1186	-0.18	0.856	-0.2540 to 0.2109
GDP Deflator	0.0374*	0.0200	1.87	0.062	-0.0019 to 0.0764
Constant	7.7493	25.3997	0.31	0.76	-42.033 to 57.532
Number of Obs.	49		Prob > χ^2		0.0000
Wald χ^2 (4)	44.00		R-squared		0.4704

4.1. 2SLS Results Discussion

Table 6 displays the 2SLS results. Public debt has a negative but statistically insignificant impact on the primary balance, with a coefficient of –1.03 ($p = 0.639$), while external debt's effect is similarly insignificant ($p = 0.408$). Among the control variables, only the GDP deflator approaches significance ($p = 0.062$), suggesting that inflation may affect fiscal performance. The real interest rate shows no significant impact. The model explains approximately 47% of the variation in the dependent variable ($R^2 = 0.4704$), indicating a moderate fit.

These findings support the previous literature (e.g., Awan et al., 2011; Mahmood et al., 2014), which also reported the weak or inconsistent fiscal responses to rising debt levels in the Pakistan. Results underscore the limited explanatory power of debt variables alone and highlight need to account for the broader structural and institutional factors.

Regression results suggest that neither public nor external debt significantly predicts the Pakistan's primary balance in long run. This may be due to country's historically weak fiscal institutions, inconsistent tax policies, and the politically driven expenditure patterns (Fuest & Riedel, 2010; Mascagni et al., 2014). Moderate explanatory power of the model reinforces that debt sustainability is not solely a function of the debt stock variables but is shaped by the structural governance challenges and macroeconomic instability (Chandia et al,, 2013). In light of these findings, achieving debt sustainability will require more than managing the debt levels. It demands improving public financial management, enhancing the institutional efficiency, and building fiscal buffers against the external shocks (Willems & Zettelmeyer, 2022).

4.2. Structural Break Analysis and Historical Context

To contextualize regression outcomes, the study incorporates structural break tests that identify the significant fiscal disruptions over the sample period (Ydstie, 2011). Breakpoints were detected in primary balance (2005), public debt (1985), external debt (2010), GDP deflator (2009), and the real interest rate (2007). These shifts correspond to the critical events such as increased defense spending, energy subsidies, major floods, global financial crises, and the policy tightening (Colander et al., 2009).

For instance, the 2005 break in the primary balance aligns with rising subsidies and stagnant revenue mobilization. Similarly, the 2010 surge in external debt reflects trade deficits and post-disaster borrowing, while the 2009 shift in price levels corresponds to the inflationary aftermath of the global crisis. These episodes emphasize how macroeconomic volatility and policy shocks affect debt sustainability beyond linear regression outcomes (Hetzel, 2024).

4.3. Addressing Research Questions

Central research question guiding this study is: To what extent do public and external debt influence the Pakistan's primary fiscal balance, and what do these relationships imply about sustainability of the country's debt from 1973 to 2022? This question aims to evaluate both the *short-run fiscal responsiveness* to the debt accumulation and *long-run sustainability* of the fiscal policies using empirical econometric tools and theoretical benchmarks. Through a Two-Stage Least Squares (2SLS) regression framework and debt sustainability conditions (i.e., $r < g$ and primary surplus ≥ 0). The study further explored, whether debt management has been aligned with the responsible fiscal behavior (Khan, 2016). The results suggest that neither public nor external debt significantly determines primary balance in Pakistan. Instead, fiscal position appears to be shaped by the structural inefficiencies (like weak tax systems and poor public finance management), macroeconomic shocks (such as inflation, natural disasters, and security costs), and the policy inconsistency (due to political instability). Moderate R-squared value of 0.4704 confirms that these debt-related variables explain almost half of the variation in Pakistan's primary balance, highlighting that while debt matters, broader systemic reforms are crucial for achieving the long-term debt sustainability.

4.4. Debt Sustainability Issues

Although the regression results show no significant direct impact of public and external debt on Pakistan's primary balance, they uncover deeper structural issues affecting debt sustainability. Persistent fiscal deficits, weak tax administration, and inefficient public spending exacerbated by political instability and policy inconsistency have eroded fiscal discipline. External shocks such as oil price volatility and natural disasters have further increased borrowing needs, exposing the economy to financial risks. Structural weaknesses like a stagnant tax-to-GDP ratio and widespread tax evasion limit the government's fiscal capacity. Applying the accounting-based criteria ($r^* < g$ and primary balance ≥ 0), only the periods 1973–82 and 1993–2002 are found to be sustainable, underscoring that Pakistan's debt challenges stem from long-standing governance failures, institutional weaknesses, and vulnerability to both domestic and external shocks.

4.5. Debt Sustainability Trend Analysis

Figure 1 illustrates trajectory of the real interest rate and the GDP growth rate over the time. Periods when real interest rates exceeded the growth rates are marked as fiscally unsustainable. For instance, during the 1984–91 and 2006 onwards, $r > g$, indicating debt accumulation without the growth support. This violates necessary condition for the sustainability (Mahmood et al., 2009).

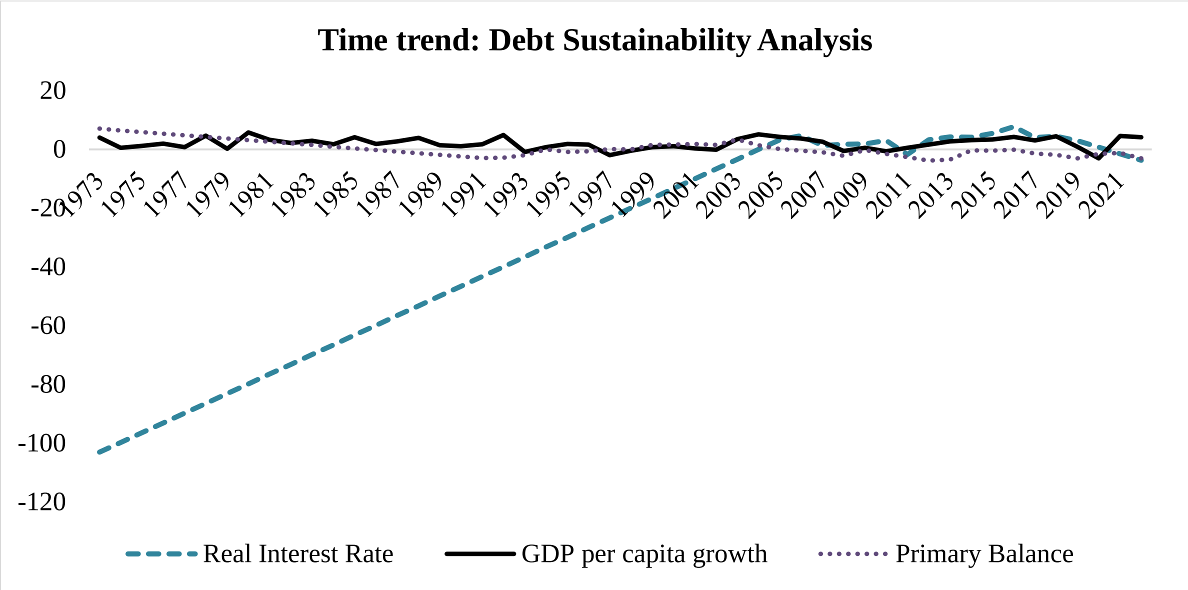

Figure 1: Real Interest Rate vs. GDP Growth Rate (1973–2022)

4.6. Debt Sustainability Test Using Accounting Approach

Pakistan's debt sustainability from table 7 has remained largely elusive over past five decades, with the only two decades 1973–82 and 1993–2002 meeting both necessary ($r < g$) and sufficient (primary balance ≥ 0) conditions. This persistent failure reflects the deep-rooted structural weaknesses in the fiscal management, including poor revenue mobilization, excessive reliance on the external borrowing, and policy instability (Bandiera & Tsiropoulos, 2020; Khan et al., 2020). Historical factors such as nationalization, political transitions, and the external shocks further compounded problem, while repeated IMF programs in 1980s and 2000s yielded the limited long-term gains. Despite occasional reforms, ongoing challenges like low tax-to-GDP ratios, corruption, and the inefficient spending continue to undermine fiscal resilience. Sustainable debt management in Pakistan will require the consistent fiscal discipline, institutional strengthening, and the reduced external dependency. Historically, Pakistan's debt burden stems from its early dependence on external borrowing post-independence to fund development, which was not accompanied by effective debt oversight (Voeten, 2013).

Table 7: Decade-wise Debt Sustainability Assessment

Years	**r^***	**g**	**PB**	**$r^* < g$**	**PB ≥ 0**	**Conclusion**
1973-82	-88.10	2.49	4.56	Yes	Yes	Unsustainable
1983-92	-54.85	2.65	-0.92	Yes	No	Unsustainable
1993-02	-21.60	0.35	0.36	Yes	Yes	Sustainable
2003-12	1.45	2.09	-0.65	Yes	No	Unsustainable
2013-22	2.88	2.79	-1.61	No	No	Unsustainable

Structural break analysis highlighted how major economic disruptions influenced the Pakistan's fiscal indicators: primary balance broke in 2005 due to the rising defense expenditures, energy subsidies, and a weak tax mobilization; public debt spiked in 1985 amid large fiscal deficits and the exchange rate depreciation; external debt surged in 2010 due to the trade imbalances, floods, and instability; GDP deflator shifted in 2009 following the global financial crisis and domestic inflation (Javed et al., 2021) and real interest rates adjusted in the 2007 due to inflationary pressure and policy changes. These breaks underscore the Pakistan's fiscal fragility. Summarizing the section by integrating both the econometric and accounting approaches, it affirms only partial empirical support for debt sustainability, with sustainability observed in the isolated decades but an overall trend of the persistent fiscal vulnerability.

5. CONCLUSION AND POLICY IMPLICATIONS

This study examined Pakistan's debt sustainability by assessing the impact of public and external debt on the primary fiscal balance from 1973 to 2022, using a break-adjusted 2SLS estimation approach and accounting-based debt sustainability tests. The results indicate that neither public nor external debt significantly affects the primary balance, suggesting that debt sustainability in Pakistan is influenced less by debt stock variables and more by structural weaknesses such as fiscal mismanagement, limited tax capacity, and political instability.

The structural break analysis confirmed that external shocks, such as the 2008 financial crisis and 2010 floods, alongside policy inconsistencies, have contributed to persistent fiscal vulnerability. Accounting-based conditions (i.e., $r < g$ and primary balance ≥ 0) were met only in two decades 1973–82 and 1993–2002 highlighting that sustainable debt management in Pakistan has been the exception, not the norm.

To enhance debt sustainability, policymakers should implement broad-based fiscal reforms by expanding the tax base, improving compliance, and rationalizing subsidies. Strengthening institutions through greater transparency, fiscal discipline, and improved public finance management is equally vital. A prudent debt strategy that minimizes reliance on short-term and foreign-currency borrowing can reduce exposure to external risks, while building fiscal buffers and adopting counter-cyclical spending policies will improve the country's resilience to economic shocks. While the study captures long-term trends, it does not model potential future debt trajectories under different macroeconomic scenarios (e.g., fan charts or probabilistic simulations). Also, some historical data (pre-1990) were interpolated, which may affect precision. Future studies should integrate political economy variables, can simulate policy shocks, and explore regional comparisons across similar developing economies. Incorporating dynamic panel models or machine learning-based fiscal risk assessments may also enrich the analysis.

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REFERENCES

Abiad, M.A., Ostry, M.J.D., 2005. *Primary Surpluses and Sustainable Debt Levels in Emerging Market Countries*. International Monetary Fund.

Afonso, A. (2005). Fiscal sustainability: The unpleasant European case. *FinanzArchiv/Public Finance Analysis*, 19-44.

Agnello, L., & Sousa, R. M. J. B. o. E. R. (2013). Fiscal policy and asset prices. *Bulletin of Economic Research* 65(2), 154-177.

Alvarado, C. D., Izquierdo, A., & Panizza, U. (2004). *Fiscal Sustainability in Emerging Market Countries with an Application to Ecuador*, Working Paper No. 511, Inter-American Development Bank (IDB).

Ampofo, G. M. K., Jinhua, C., Bosah, P. C., Ayimadu, E. T., & Senadzo, P. J. R. P. (2021). Nexus between total natural resource rents and public debt in resource-rich countries: A panel data analysis. *Resources Policy*, *74*, 102276.

Anwer, T. (2000). *Unsustainable Debt Burden and Poverty in Pakistan:* A Case for Enhanced HIPC Debt Relief *(No. 2002/53).* WIDER Discussion Paper. Helsinki: United Nations University.

Awan, A., Asghar, N., & Rehman, H. U. (2011). The impact of exchange rate, fiscal deficit and terms of trade on external debt of Pakistan. *Australian Journal of Business and Management Research*, 1(3), 10.

Bandiera, L., & Tsiropoulos, V. (2020). A framework to assess debt sustainability under the Belt and Road Initiative. *Journal of Development Economics*, 146, 102495.

Barro, R. J. (1979). On the determination of the public debt. *Journal of Political Economy*, 87(5), 940-971.

Bird, G. (2007). The IMF: A bird's eye view of its role and operations. *Journal of Economic Surveys*, 21(4), 683-745.

Bohn, H. (2008). The sustainability of fiscal policy in the United States. *Sustainability of Public Debt*, 15, 15-50.

Bohn, H. (1998). The behavior of US public debt and deficits. *Quarterly Journal of Economics*, 113(3), 949-963.

Bond, P. (2020). BRICS banking and the demise of alternatives to the IMF and World Bank. *International Development Assistance and the BRICS*, 189-218.

Bowlsby, D., Chenoweth, E., Hendrix, C., & Moyer, J. D. (2020). The future is a moving target: predicting political instability. *British Journal of Political Science*, 50(4), 1405-1417.

Bresser-Pereira, L. C. (2022). A turning point in the debt crisis: Brazil, the US Treasury and the World Bank. *Brazilian Journal of Political Economy*, 19, 350-380.

Campos, V. L., Marín, K. L., & Badilla, C. M. (2020). *Primary Balance: Sustainability Analysis Under Uncertainty*. IDB Working Paper Series, No. IDB-WP-1151, Inter-American Development Bank (IDB), Washington, DC,

Cecchetti, S. G., Mohanty, M. S., & Zampolli, F. (2010). *The Future of Public Debt: Prospects and Implications*. BIS Working Paper (No. 300), Bank for International Settlements.

Chandia, K. E., Javid, A. Y. J. P. E., & Finance. (2013). An analysis of debt sustainability in the economy of Pakistan. *Journal of Public Economics and Finance*, 5(1), 133-142.

Chuku, C., Samal, P., Saito, J., Hakura, D., Hakura, M. D. S., Chamon, M., ... & Zettelmeyer, M. J. (2023). Are we heading for another debt crisis in low-income countries? Debt vulnerabilities: Today vs the pre-HIPC era. International Monetary Fund.

Colander, D., Goldberg, M., Haas, A., Juselius, K., Kirman, A., Lux, T., & Sloth, B. J. C. R. (2009). The financial crisis and the systemic failure of the economics profession. *Critical Review* 21(2-3), 249-267.

Conway, P. J. (2006). The International Monetary Fund in a time of crisis: A review of Stanley Fischer's IMF essays from a time of crisis: The international financial system, stabilization, and development. *Journal of Economic Literature*, 44(1), 115-144.

Ejaz, M., & Hyder, K. (2019). A fan chart approach to debt sustainability in Pakistan. *Lahore Journal of Economics*, 24(2), 1-23.

Fatemah, A., & Haq, A. ul. (2024). Targeting debt in Pakistan: A structural macro-econometric model. *IRASD Journal of Economics*, 6(2), 285–312.

Forgha, N. G., Mbella, M. E., & Ngangnchi, F. H. (2014). External debt, domestic investment and economic growth in Cameroon: A system estimation approach. *Journal of Economics Bibliography*, 1(1), 3-16.

Fuest, C., & Riedel, N. (2010). *Tax Evasion and Tax Avoidance in Developing Countries: The Role of International Profit Shifting*, Working Papers 1012, Oxford University Centre for Business Taxation.

Ghosh, A. R., Kim, J. I., Mendoza, E. G., Ostry, J. D., & Qureshi, M. S. (2011). Fiscal Fatigue, Fiscal Space and Debt Sustainability in Advanced Economies. Working Paper 16782, National Bureau of Economic Research, Cambridge.

Hetzel, R. (2024). What the Fed needs to do to control inflation and stabilize the economy. *Annals of Computational Economics*.

Husain, I. (2018). Pakistan's economy and regional challenges. *International Studies*, 55(3), 253-270.

Hussain, A., & Idrees, A. S. (2019). Fiscal performance and external public debt sustainability: A case study of Pakistan. *Review of Economics and Development Studies*, 5(4), 142-149.

Hussain, A., Idrees, A. S. J. J. o. E., & Development, S. (2015). Fiscal Performance and External Public Debt Sustainability: A Case Study of Pakistan. *Journal of Economics and Sustainable Development*, 6(7), 1-9.

Javed, S. A., Shaukat, B., & Ahmad, I. (2021). How the Global and Gulf Financial Crises Affected Pakistan: Ten-year Review. *International Migration*, 59(5), 19-37.

Khan, H. R. (2016). *Public Debt Management: Reflections on Strategy and Structure*, Springer.

Khan, Z., Changgang, G., Afzaal, M., Ahmad, R., & Aron Issack, S. (2020). Debunking criticism on the China-Pakistan economic corridor. *The Chinese Economy*, 53(6), 477-487.

Koutsoyiannis, A. (1977). *Theory of Econometrics*, 2nd edition, Macmillan. In: London.

Lesage, D., Debaere, P., Dierckx, S., Vermeiren, M.J.I.P. (2013). IMF Reform After the Crisis. *International Politics*, 50(4), 553-578.

Mahmood, T., Arby, M. F., & Sherazi, H. (2014). Debt sustainability: A comparative analysis of SAARC countries. *Pakistan Economic and Social Review*, 15-34.

Mahmood, T., Rauf, S.A., & Ahmad, H.K.J.P.E. (2009). Public and external debt sustainability in Pakistan (1970s—2000s). *Pakistan Economic and Social Review*, 47(2), 243-267.

Mascagni, G., Moore, M., & McCluskey, R. (2014). *Tax Revenue Mobilisation in Developing Countries: Issues and Challenges*. European Union (Belgium).

Mehrotra, N. R., & Sergeyev, D. (2021). Debt sustainability in a low interest rate world. *Journal of Monetary Economics*, 124, 1-18.

Mendoza, E. G., & Ostry, J. D. (2008). International evidence on fiscal solvency: Is fiscal policy responsible? *Journal of Monetary Economics*, 55(6), 1081-1093.

Modigliani, F. (1961). Long-run implications of alternative fiscal policies and the burden of the national debt. *The Economic Journal*, 71(284), 730-755.

Mogstad, M., Torgovitsky, A., & Walters, C. R. (2021). The causal interpretation of two-stage least squares with multiple instrumental variables. *American Economic Review*, 111(11), 3663-3698.

Nizami, M. I., Ihsan, H., & Hasan, H. (2020). Debt Sustainability Analysis in Pakistan: A Fan Chart Approach. *Pakistan Economic Review*, 3(1), 1-23.

Okunola, B. P. (2022). *Determinants of Sectoral Capital Inflows in Nigeria*. MSc thesis, Department of Economics and Development Studies, Faculty of Management and Social Sciences. Lead City University. Ibadan, Oyo State, Nigeria.

Ormaechea, M. S. A., & Martinez, M. L. (2021). *A Guide and Tool for Projecting Public Debt and Fiscal Adjustment Paths with Local-and Foreign-Currency Debt*, International Monetary Fund.

Roubini, N. (2001). *Debt Sustainability: How to Assess Whether a Country is Insolvent*. Stern School of Business, New York University.

Safiullah, M., Houqe, M. N., Ali, M. J., & Azam, M. S. (2024). Debt overhang and carbon emissions. *International Journal of Managerial Finance*, 20(4), 1069-1093.

Shah, S. S. A., Rafique, R., & Afridi, M. A. (2024). Empirical examination of public debt sustainability in African economies: A panel data analysis. *Journal of Public Affairs*, 24(1), e2896.

Sheikhi, A., Bahador, F., & Arashi, M. (2022). On a generalization of the test of endogeneity in a two stage least squares estimation. *Journal of Applied Statistics*, 49(3), 709-721.

Sokol, A. (2021). *Fan Charts 2.0: Flexible Forecast Distributions with Expert Judgement*. ECB Working Paper No. 2624, European Central Bank.

Voeten, E. (2013). *Data and Analyses of Voting in the UN General Assembly*. Routledge handbook of international organization, 54-66.

Wilcox, D. W. (1989). The sustainability of government deficits: Implications of the present-value borrowing constraint. *Journal of Money, Credit and Banking*, 21(3), 291-306.

Willems, T., & Zettelmeyer, J. (2022). Sovereign debt sustainability and central bank credibility. *Annual Review of Financial Economics*, 14(1), 75-93.

Ydstie, J. J. N. P. R. (2011). Does The Economy Need A Little Inflation? *American Economic Association, Papers and Proceedings*, 101(3), 307-310.

Zahid, M., Rahman, H. U., Khan, M., Ali, W., & Shad, F. (2020). Addressing endogeneity by proposing novel instrumental variables in the nexus of sustainability reporting and firm financial performance: A step-by-step procedure for non-experts. *Business Strategy and the Environment*, 29(8), 3086-3103.

Appendix A: Results of the Unit Root Test (Augmented Dickey-Fuller test)

Variables	**Test Statistic Z(t)**	**p-value for Z(t)**	**Number of obs**
Primary balance	-2.207	0.2038	45
Real interest rate	-1.988	0.2920	45
External debt	3.601	1.0000	45
GDP deflator	3.653	1.0000	45
Public debt	4.647	1.0000	45

All the indicators show that the series is stationary throughout the given time range. P value is greater than 0.05 indicating rejection of null hypothesis i.e., series has a unit root.

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Measuring the Affordability of Key Food and Energy Commodities in Pakistan: An Application of Simon Abundance Framework

ABSTRACT

This study applies the Simon Abundance Framework (SAF) to assess food and energy resource affordability in Pakistan from 2007 to 2021. Developed by Tupy and Pooley (2022), the SAF uses the concept of time price, which shows the number of working hours required to purchase a good or service. It serves as an alternative measure of resource affordability, incorporating both prices and the efforts required by labour. By evaluating changes in time prices across 22 essential food and energy items for male and female workers of low and high-skilled categories, the study finds a broad-based improvement in affordability of these items in terms of time price. The findings support the argument made by Julian Simon that human efforts to innovate and find new alternatives can counteract resource scarcity despite population pressure.

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Author's contribution in the article: 1- Conceived and designed the analysis, 2- Reviewed and compiled the literature, 3- Collected the data, 4- Contributed data or analysis tools, 5- Performed the analysis, 6- Wrote the paper, 7- Financial support for the conduct of the study, 8-Other

1. INTRODUCTION

Concerns about resource scarcity have historically dominated economic and environmental debates. The earliest and most influential argument was presented by Malthus (1798), warning that population growth would outpace food production, leading to mass starvation. This pessimistic view was reinforced in the 20th century by Ehrlich (1968) book "*The Population Bomb*" predicted global famines due to overpopulation. The 1972 "Limits to Growth" report by the Club of Rome extended this narrative, suggesting that exponential growth in population and resource consumption would lead to ecological and economic collapse.

However, in a counter argument, Simon (1981) argued that human ingenuity, not natural resources, is the ultimate limiting factor. Simon emphasized that population growth could spur innovation and efficiency, ultimately increasing the availability of resources. Their famous wager with Ehrlich in 1980, involving the prices of selected metals, provided empirical support for this argument. Over ten years, real prices for all five chosen resources declined, indicating increased abundance despite global population growth.

This study contributes to the ongoing debate between scarcity and abundance theorists by applying the Simon Abundance Framework (SAF) developed by Tupy and Pooley (2022) to the context of Pakistan. The SAF replaces traditional money price measures with time price, reflecting the number of hours a person must work to purchase a good. Time price, and its derivatives such as personal resource abundance multiplier (pRAM) and compound annual growth rate (CAGR), offer an alternative and more comprehensive metric to evaluate affordability and abundance.

By analyzing 22 key food and energy resources, we examine how their affordability has evolved across different worker categories (low and high-skilled, male and female) in Pakistan between 2007 and 2021. This period includes significant economic, demographic, and energy market changes, making it a rich ground for analysis.

1.1 Problem Statement

As the global population continues to grow, concerns about the scarcity of essential resources, such as food and energy, have sparked scholarly debate. While many researchers have studied long-term trends in the real prices of resources to assess scarcity, no consensus exists on whether these prices are increasing or decreasing over time (Slade, 1982; Haque, 1994; Erdem & Ünalmış, 2016; Baffes & Kabundi, 2023). This study aims to fill this gap by analyzing the relationship between population growth and resource scarcity using newly developed concepts of the time price of essential food and energy resources and the SAF.

1.2 Objectives of the Study

The main objective of this study is to assess the affordability of food and energy resources in Pakistan using time prices and its derivatives. Specifically, the study aims to calculate the time price and personal resource abundance multiplier (PRAM) for selected food and energy items across male and female workers, disaggregated by skill level (low and high-skilled).

1.3 Organization of the Study

The study is organized as follows: Section 2 covers the literature review. Methodology and data are explained in Section 3. Analysis and results are presented in Section 4, and finally, Section 5 contains the conclusion of the study.

2. LITERATURE REVIEW

The scarcity of resources has been debated in economic literature since its inception. The debate revived in economics when the British Economist Thomas Robert Malthus published the book titled "*An Essay on the Principle of Population*" in 1798. His argument was based on an economic reality of diminishing returns that presented the concept of absolute scarcity. He assumed that the agricultural land is limited and population increase would put pressure on the fixed amount of available land for more output, thus the diminishing returns of land decrease the availability of food.

Ricardo (1817) and Mill (1848) were also convinced that limited availability of land was a limit to growth, as already expressed by the concern of diminishing of returns of fixed availability of land and further most importantly due to the decline in quality of land in the context of profit maximization and presented the concept of relative scarcity. An influential work by Jevons (1866) on the consumption of coal in the production process of Great Britain, in which he expressed his concern that with the fixed resources of coal, it would not be possible for Britain to maintain its industrial output at a high level indefinitely.

Paul Ehrlich in his book *The Population Bomb* (1968), predicted mass starvation and ecological collapse due to rapid population growth and limited resource availability. He argued that natural systems have strict biological and ecological limits that cannot sustain population pressure.

Similarly, Meadows et al. (1972) projected that the world will come to the physical limits in terms of non-renewable resources, agricultural production, and excessive pollution. The study predicted a new model to make projections about five global variables that include population, food, non-renewable resources, pollution, and industrialization. It concludes that eleven resources will vanish by the end of this century, while Copper, Mercury, Gold, Gas, and Oil are part of those eleven resources. We are still having all the minerals that were projected to disappear by the end of the last century, raising objections about study's accuracy.

Contrary to Paul Ehrlich's arguments, Simon (1981) argued that population growth is not a threat but a catalyst for innovation and abundance. He believed that human intellectual capacity is the ultimate resource; resources may be physically limited, but economically unlimited. Simon's famous bet with Ehrlich in 1980 (Simon wagered that real prices of selected metals would fall over the decade) provided empirical evidence supporting their thesis. Boserup (1965) also presented an argument that labour, not the land, was the limiting factor in agricultural output. Boserup further found a positive impact of population density on poor agrarian societies.

Krautkraemer (2005) concluded that the prices of many commodities, such as corn and wheat, showed relatively constant behaviour from 1800 to 1950. However, an increase in agricultural productivity due to technological innovations led to an increase in food availability and a decrease in prices. Harvey et al. (2010) used data from 1900 to 2003 for a set of twenty-five primary commodity prices, applying time series techniques to estimate the trend function and the existence of possible structural breaks. The results showed that thirteen commodities (Aluminum, Banana, Cotton, Hide, Jute, Lead, Rice, Silver, Sugar, Tea, Wheat, Wool, and Zinc) present a declining trend over the 1900-2003 period, and found that there is no statistical evidence that relative commodity prices have ever trended upwards.

Based on Simon's work, Tupy and Pooley (2022) developed the Simon Abundance Framework, which uses time price as a metric of resource scarcity. Time price reflects the number of working hours required to purchase a good, integrating both wage and price changes. Their framework offers a comprehensive tool to evaluate long-term trends in affordability and human welfare, shifting the scarcity debate from physical limits to economic affordability.

Recently, Janicki (2024) analyzed different human fears like overpopulation, scarcity of resources, climate change, nuclear power, etc., with the help of historical data, and claimed that all these fears are baseless. The primary reason for living a fearless life is that humans have consistently proven to be problem solvers throughout history, rather than problem creators, on average. The ability of the human mind to innovate and solve the problem of resource scarcity has been empirically estimated by using Simon Abundance Index and the results show that the value between 1980 and 2023 has reached 609.4, which shows that the time price of 50 basic commodities has decreased by 70.4 percent (Tupy, 2022; 2024).

Similarly, Pooley (2025) estimates the time price of gasoline for U.S. blue-collar workers and finds that it has decreased by 35 percent since 1950. The decline in the time price is a result of discoveries and substitutes for gasoline, which confirm human progress through knowledge creation.

3. METHODOLOGY

This study is based on Julian Simon's theory of resource abundance (1981). Contrary to the Malthusian approach, Simon argued that human knowledge, innovation, and the discovery of alternatives—often driven by population growth—are the ultimate resources that lead to long-term welfare improvements. Based on Simon's perspective, Tupy and Pooley (2022) developed Simon Abundance Framework and introduce the concept of time price, a labour-based measure of affordability that better reflects changes in welfare than nominal prices.

Within this framework, a decline in time prices indicates an increase in abundance, and vice versa. This change is quantified through various indicators, including the personal resource abundance multiplier (pRAM), the compound annual growth rate (CAGR), and the doubling time of resources. Collectively, these measures constitute the Simon Abundance Framework (SAF).

Applying the SAF, this study measures the affordability and resource abundance of Pakistan's essential food and energy commodities between 2007 and 2021. These items are selected based on their data availability and relatively higher weights in the current basket of CPI in Pakistan. The framework requires data on nominal prices and nominal hourly wages. Wage data for different worker categories were obtained from ILOSTAT (International Labour Organization Statistics), while prices data were sourced from the Pakistan Bureau of Statistics. To achieve our objectives, we have measured the following indicators.

3.1 Time Price

Time price (TP) denotes the amount of time that a buyer needs to work to earn enough money to be able to buy something. The time price of a good or service is measured in hours and minutes.

$$Time\ Price = Nominal\ Money\ Price\ \div Nominal\ Hourly\ Incom \qquad (1)$$

3.2 Percentage Change in Time price

Equation 2 below shows the formula to calculate percentage change in time price over the period:

$$PCTP = (Time\ Price_{end\ year} - Time\ Price_{start\ year}) \div Time\ Price_{Start\ year} \qquad (2)$$

3.3 Personal resource abundance multiplier (pRAM)

It is the ratio between the start year time price to end year time price, and it tells us how much more or less of an item we can buy with the same amount of labour. The relevant calculation here is as follows in equation 3:

$$pRAM = Time\ Price_{start\ year} \div Time\ Price_{end\ year} \qquad (3)$$

3.4 Compound annual growth rate (CAGR) of pRAM

This measure helps to measure the speed at which the personal resource abundance multiplier is growing.

$$CAGR = (pRAM^{1/years} - 1) \qquad (4)$$

3.5 Doubling Time

This indicator shows how much time is required for a resource to double in its affordability. for this purpose, the Simon Abundance framework used the following formula

$$Doubling\ Time = 70 \div CAGR \quad (5)$$

4. ANALYSIS AND RESULTS

The results summarized in Table 1 reveal a consistent trend of declining time prices (TP) and increasing personal resource abundance (pRAM) for both male and female workers, across both low and high-skilled categories, over the period 2007–2021. This is despite the fact that key global economic shocks like oil price surge and Covid-19 pandemic happened during the study period. On average, time prices declined by 28.1% for low-skilled females, 24.8% for high-skilled females, 26.4% for low-skilled males, and 23.2% for high-skilled males. These reductions imply that fewer work hours are needed in 2021 to purchase the same essential items compared to 2007, indicating improved affordability and economic efficiency. Similarly, pRAM increased by 47.2% for low-skilled females and 40.6% for high-skilled females, with similar trends among males (45.6% and 38.6%, respectively). The compound annual growth rate (CAGR) of pRAM ranged from 2.04% to 2.43%, while the years to double pRAM ranged from 37 to 44 years, with faster doubling among low-skilled workers.

Table 1: Summary of Results

Indicator	Female Low-Skilled	Female High-Skilled	Male Low-Skilled	Male High-Skilled
Average % Change in Time Price (TP)	-28.1%	-24.8%	-26.4%	-23.2%
Average pRAM (2021)	1.49	1.41	1.47	1.39
Average % Change in pRAM (2007–2021)	+47.2%	+40.6%	+45.6%	+38.6%
Average Compound Annual Growth Rate (CAGR)	2.43%	2.12%	2.36%	2.04%
Average Years to Double pRAM	37 years	43 years	37 years	44 years

Source: Authors' own calculations

Overall trends in Appendix A and Appendix B, given in the annexure, show that time prices of selected food and energy items are higher for female workers than for their male counterparts. These differences primarily stem in gender wise wage differences in Pakistan, where female workers on average earn less than that of male workers both in low and high skilled categories. Consequently, when the nominal prices of goods are same for both male and female workers, lower wages lead to higher time prices for female workers in Pakistan. However, further insights show that a higher decline has been observed in the time prices of food and energy items for female low-skilled workers between 2007 and 2021. This trend shows that the food and energy resources are becoming more affordable for low-skilled workers, particularly female workers. The doubling period is also relatively shorter for low-skilled female workers compared to their male counterparts.

4.1 Male Low-Skilled Workers

The time price of all food and energy resources, given in Appendix A, has decreased for low-skilled workers between 2007 and 2021. However, the time price of Moong pulse has increased from 2007 to 2021. This increase may be due to its climate vulnerability and high import dependency in Pakistan. One of the most important food items, cooking oil, has shown a decline of the time price from 15.77 hours to 7.74 hours, that is around a 51% decline between 2007 and 2021. In the case of energy resources, the most essential resource is petrol, which has shown a decline of about 52% from 2.55 hours in 2007 to 1.23 hours in 2021. The personal resource abundance calculations for low-skilled workers show that almost all the food and energy resources have become more abundant between 2007 and 2021. The values reveal the fact that the low-skilled worker can afford more food and energy resources with the same amount of labour between the two time periods. The more abundant food item is cooking oil, which has become about 104% more affordable with the same labour effort.

The low-skilled workers can have 107% more affordability of petrol resources during the same period. The speed at which these two food and energy items are becoming more affordable annually is 4.86 and 4.96, respectively. By looking at the speed of affordability of food and energy items, cooking oil and petrol are projected to double in affordability within around 14 years for low-skilled workers.

4.2 Male High-Skilled Workers

Appendix A in the annexure shows that the high-skilled workers have also experienced a decline in time prices during 2007 and 2021, however, food items like Moong pulse and Gur have shown an increase in their time prices. This may be due to the reasons that Gur is often produced in small and traditional setups with limited economies of scale. The personal resource abundance estimation shows that cooking oil and petrol seem to have the highest increase in resource abundance of about 94% and 96% respectively. The speed at which these items are becoming more available can be observed with the estimated value of compound annual growth rate, which is 4.5% and 4.6%. The estimated doubling time period of cooking oil is 16 years, and for petrol is 15 years showing greater affordability in future.

4.3 Female Low-Skilled Workers

Appendix B, in the annexure, reveals that the low-skilled workers have experienced a decline in the time prices of all food and energy items from 2007 and 2021. The highest decline of 67% can be seen in the time price of cooking oil from 28.26 hours in 2007 to 10.77 hours in 2021. In the category of energy, the time price of petrol has shown a substantial decline in the time price 62% from 4.56 hours to 1.71 hours from 2007 to 2021. The affordability of cooking oil and petrol with the same labour work between 2007 and 2021 is 162% and 166% respectively. Further, both goods are becoming cheaper compared to early basis with the same rate of about 7%, which will lead to double the resources within 10 years.

4.4 Female High-Skilled Workers

The time prices of almost all food and energy resources, given in Appendix B, have declined for high-skilled female workers between 2007 and 2021. Cooking oil and petrol have shown a substantial decline in its time prices among different food and energy items. Both resources are becoming cheaper at the same rate of around 6%, which may lead them to become double available within 12 years.

These findings resonate strongly with the empirical results of Tupy and Pooley (2022), which shows that as societies grow more productive, time prices for essential goods tend to fall. The current study also shows that despite differences in income levels, low-skilled workers experienced greater relative gains in affordability, reflecting more equitable improvements in purchasing power. This indicates a form of inclusive productivity growth, where even the least skilled are gaining better access to necessities due to either rising real wages or stable goods prices.

5. CONCLUSION AND POLICY IMPLICATIONS

This study uses the Simon Abundance Framework to assess changes in the affordability of food and energy resources in Pakistan between 2007 and 2021. The findings consistently show that time prices have declined for most essential items, particularly for low-skilled and female workers, indicating growing resource abundance. The most notable improvements are seen in cooking oil and petrol, which have become significantly more affordable across all demographic groups. The application of time price as a metric reveals important insights not captured by traditional monetary prices. It underscores that the standard of living, especially for economically vulnerable groups, has improved in terms of resource affordability. The results support the view that human capital, productivity growth, and technological advancement can overcome resource scarcity. This suggests that policy efforts should continue focusing on increasing income, skill development, and innovation to sustain and accelerate this trend. The study also opens new areas of research to measure the cost of living, inequality in terms of time price and time inequality in Pakistan. In future, studies can be conducted to analyze the determinants of time prices through econometric techniques.

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REFERENCES

Baffes, J., & Kabundi, A. (2023). Commodity price shocks: Order within chaos? *Resources Policy*, 83, 103640. https://doi.org/10.1016/j.resourpol.2023.103640
Boserup, E. (1965). *The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure*. Aldine Publishing.
Ehrlich, P. R. (1968). *The Population Bomb*. Ballantine Books.
Erdem, F. P., & Ünalmış, İ. (2016). Revisiting super-cycles in commodity prices. *Central Bank Review*, 16(4), 137–142. https://doi.org/10.1016/j.cbrev.2016.10.001
Haque, M. (1994). Measuring the trends of natural resource commodity prices: An empirical analysis. *Hitotsubashi Journal of Economics*, 35(1), 59–71.
Harvey, D. I., Madsen, J. B., & Wohar, M. E. (2010). The Prebisch-Singer hypothesis: Four centuries of evidence. *The Review of Economics and Statistics*, 92(2), 367–377.
Janicki, W. (2024). *Fear/Less: Why Your Lifelong Fears are Probably Groundless*. Armin Lear Press.
Jevons, W. S. (1866). *The Coal Question: An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of our Coal-Mines*. Macmillan.
Krautkraemer, J. (2005). Economics of natural resource scarcity: The state of debate. *RFF Discussion Paper*, 05–14. https://doi.org/10.2139/ssrn.760927
Malthus, T. R. (1798). *An Essay on the Principle of Population*. J. Johnson.
Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*. Universe Books.
Mill, J. S. (1848). *Principles of Political Economy*. John W. Parker.
Pooley, G. L. (2025). *Gasoline Abundance Increases with Population Growth. Human Progress*. https://humanprogress.org/gasoline-abundance-increases-with-population-growth/
Ricardo, D. (1817). *On the Principles of Political Economy and Taxation*. John Murray.
Simon, J. L. (1981). *The Ultimate Resource*. Princeton University Press.
Slade, M. E. (1982). Trends in natural-resource commodity prices: An analysis of the time domain. *Journal of Environmental Economics and Management*, 9(2), 122–137.
Tupy, M. L. (2024). *Post-Pandemic Pesource Abundance is Rebounding*. Cato Institute. https://www.cato.org/commentary/post-pandemic-resource-abundance-rebounding
Tupy, M. L., & Pooley, G. L. (2022). *Superabundance: The story of Population Growth, Innovation, and Human Flourishing on an Infinitely Bountiful Planet*. Cato Institute.

Appendix A: Time Price and Personal Resource Abundance for Male Workers

Sr. No.	Items	Low Skilled			High Skilled			Personal Resource Abundance Multiplier (pRAM)				Compound Annual Growth Rate (pRAM)		Years to double (pRAM)	
		Time Price 2007	Time Price 2021	% Δ in Time Price	Time Price 2007	Time Price 2021	% Δ in Time Price	Low Skilled	High Skilled	% Δ Low Skilled	% Δ High Skilled	Low Skilled	High Skilled	Low Skilled	High Skilled
1	**Wheat Flour**	8.57	5.38	-37.27	3.04	2.01	-33.99	1.59	1.51	59.41	51.5	3.16	2.81	22	25
2	**Rice**	1.81	1.01	-44.08	0.64	0.38	-41.16	1.79	1.7	78.83	69.95	3.95	3.6	18	19
3	**Chicken**	3.98	2.55	-35.89	1.41	0.95	-32.54	1.56	1.48	55.97	48.23	3.01	2.66	23	26
4	**Milk**	1.37	1.19	-12.66	0.48	0.45	-8.1	1.14	1.09	14.5	8.82	0.91	0.56	77	124
5	**Eggs**	2.33	1.87	-20.02	0.83	0.7	-15.84	1.25	1.19	25.02	18.82	1.5	1.16	47	61
6	**Mustard Oil**	5.41	2.94	-45.62	1.92	1.1	-42.78	1.84	1.75	83.89	74.76	4.14	3.79	17	18
7	**Cooking Oil**	15.77	7.74	-50.92	5.59	2.89	-48.35	2.04	1.94	103.73	93.62	4.86	4.5	14	16
8	**Vegetable Gee**	14.8	7.82	-47.16	5.25	2.92	-44.4	1.89	1.8	89.26	79.86	4.34	3.99	16	18
9	**Masoor Pulse**	3.03	1.74	-42.41	1.07	0.65	-39.41	1.74	1.65	73.65	65.03	3.75	3.4	19	21
10	**Moong Pulse**	2.33	2.62	12.22	0.83	0.98	18.08	0.89	0.85	-10.89	-15.31	-0.77	-1.1	-91	-64
11	**Mash Pulse**	3.14	2.84	-9.54	1.11	1.06	-4.82	1.11	1.05	10.55	5.06	0.67	0.33	104	212
12	**Gram Pulse**	2.05	1.6	-21.77	0.72	0.6	-17.68	1.28	1.21	27.82	21.48	1.65	1.31	42	54
13	**Potato**	0.69	0.46	-32.71	0.24	0.17	-29.19	1.49	1.41	48.6	41.23	2.68	2.33	26	30
14	**Onion**	0.78	0.46	-41.33	0.28	0.17	-38.27	1.7	1.62	70.44	61.98	3.62	3.27	19	21
15	**Tomatoes**	1.4	0.74	-46.96	0.5	0.28	-44.19	1.89	1.79	88.53	79.17	4.32	3.96	16	18
16	**Sugar**	1.28	1.04	-19.32	0.45	0.39	-15.11	1.24	1.18	23.95	17.8	1.44	1.1	49	64
17	**Gur**	1.46	1.45	-0.74	0.52	0.54	4.44	1.01	0.96	0.75	-4.25	0.05	-0.29	1410	-242
18	**Tea**	3.03	2.75	-9.1	1.07	1.03	-4.35	1.1	1.05	10.01	4.55	0.64	0.3	110	236
19	**Electricity**	0.05	0.05	-11.28	0.02	0.02	-6.64	1.13	1.07	12.71	7.11	0.8	0.46	87	152
20	**Gas**	2.5	1.61	-35.86	0.89	0.6	-32.51	1.56	1.48	55.91	48.17	3.01	2.66	23	26
21	**Petrol**	2.55	1.23	-51.62	0.9	0.46	-49.09	2.07	1.96	106.69	96.44	4.96	4.6	14	15
22	**Firewood**	8.8	8.4	-4.57	3.12	3.13	0.41	1.05	1	4.79	-0.41	0.31	-0.03	224	-2555

Source: Author's own calculations

Appendix B: Time Price and Personal Resource Abundance for Female Workers

Sr. No.	Items	Low Skilled			High Skilled			Personal Resource Abundance Multiplier (pRAM)				Compound Annual Growth Rate (pRAM)		Years to double (pRAM)	
		Time Price Year 2007	Time Price Year 2021	% Δ in Time Price	Time Price Year 2007	Time Price Year 2021	% Δ in Time Price	Low Skilled	High Skilled	% Δ Low Skilled	% Δ High Skilled	Low Skilled	High Skilled	Low Skilled	High Skilled
1	**Wheat Flour**	15.36	7.48	-51.28	4.27	2.31	-45.73	2.05	1.84	105.24	84.28	4.91	4.16	14	17
2	**Rice**	3.24	1.41	-56.57	0.90	0.44	-51.63	2.30	2.07	130.24	106.72	5.72	4.96	12	14
3	**Chicken**	7.13	3.55	-50.20	1.98	1.10	-44.54	2.01	1.80	100.82	80.30	4.76	4.01	15	17
4	**Milk**	2.45	1.66	-32.17	0.68	0.51	-24.45	1.47	1.32	47.42	32.36	2.62	1.89	27	37
5	**Eggs**	4.18	2.60	-37.88	1.16	0.80	-30.81	1.61	1.45	60.97	44.53	3.22	2.49	22	28
6	**Mustard Oil**	9.69	4.09	-57.76	2.69	1.27	-52.96	2.37	2.13	136.76	112.58	5.91	5.16	12	14
7	**Cooking Oil**	28.26	10.77	-61.88	7.85	3.33	-57.54	2.62	2.36	162.31	135.51	6.64	5.88	11	12
8	**Vegetable Gee**	26.52	10.88	-58.96	7.37	3.37	-54.29	2.44	2.19	143.67	118.78	6.12	5.36	11	13
9	**Masoor Pulse**	5.42	2.43	-55.27	1.51	0.75	-50.19	2.24	2.01	123.58	100.75	5.51	4.76	13	15
10	**Moong Pulse**	4.18	3.64	-12.84	1.16	1.13	-2.93	1.15	1.03	14.73	3.01	0.92	0.20	76	353
11	**Mash Pulse**	5.62	3.95	-29.74	1.56	1.22	-21.75	1.42	1.28	42.34	27.80	2.38	1.65	29	42
12	**Gram Pulse**	3.67	2.23	-39.24	1.02	0.69	-32.33	1.65	1.48	64.58	47.77	3.38	2.64	21	27
13	**Potato**	1.24	0.65	-47.73	0.34	0.20	-41.79	1.91	1.72	91.33	71.78	4.42	3.67	16	19
14	**Onion**	1.41	0.64	-54.43	0.39	0.20	-49.25	2.19	1.97	119.45	97.03	5.38	4.63	13	15
15	**Tomatoes**	2.51	1.03	-58.80	0.70	0.32	-54.12	2.43	2.18	142.73	117.94	6.09	5.33	11	13
16	**Sugar**	2.30	1.44	-37.34	0.64	0.45	-30.21	1.60	1.43	59.59	43.29	3.17	2.43	22	29
17	**Gur**	2.62	2.02	-22.91	0.73	0.62	-14.14	1.30	1.16	29.72	16.47	1.75	1.02	40	69
18	**Tea**	5.43	3.83	-29.40	1.51	1.19	-21.37	1.42	1.27	41.64	27.17	2.35	1.62	30	43
19	**Electricity**	0.09	0.06	-31.09	0.03	0.02	-23.25	1.45	1.30	45.12	30.29	2.51	1.78	28	39
20	**Gas**	4.49	2.24	-50.18	1.25	0.69	-44.52	2.01	1.80	100.74	80.24	4.76	4.01	15	17
21	**Petrol**	4.56	1.71	-62.42	1.27	0.53	-58.15	2.66	2.39	166.12	138.94	6.74	5.98	10	12
22	**Firewood**	15.76	11.68	-25.88	4.38	3.61	-17.45	1.35	1.21	34.92	21.14	2.02	1.29	35	54

Source: Author’s own calculations

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Assessing the Synergistic Effects of Export Diversification on Energy Efficiency in South Asia

ABSTRACT

This study examines the determinants of CO_2 intensity in South Asian economies (except Afghanistan) from 2004 to 2023 using System GMM and Kinky Least Squares (KLS) estimation techniques. The analysis explores the impact of foreign direct investment (FDI), GDP growth, trade openness, and export diversification on carbon emissions intensity. The System GMM results suggest that FDI and export diversification significantly reduce CO_2 intensity, supporting the pollution halo hypothesis and structural transformation arguments. However, the KLS model, that is used to address the issue of weak instruments, presents contrasting findings, particularly on export diversification, indicating potential non-linear effects. The study highlights the importance of methodological choices in environmental econometrics and provides policy insights for sustainable development in South Asia. While GDP growth and trade openness show weaker statistical significance, the persistence of CO_2 intensity (captured by the lagged dependent variable) underscores the need for long-term decarburization strategies. The findings contribute to the ongoing debate on economic growth versus environmental sustainability in emerging economies.

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Author's contribution in the article: 1- Conceived and designed the analysis, 2- Reviewed and compiled the literature, 3- Collected the data, 4- Contributed data or analysis tools, 5- Performed the analysis, 6- Wrote the paper, 7- Financial support for the conduct of the study, 8-Other

1. INTRODUCTION

The relationship between export diversification and energy efficiency represents a critical yet under-explored dimension of sustainable development in South Asia, where rapid economic expansion continues to strain energy systems and exacerbate environmental degradation. As the region grapples with energy intensity levels that persistently exceed global averages (Murshed, 2018), policymakers face mounting pressure to reconcile economic growth with climate commitments, creating an urgent need to understand how strategic economic and financial interventions can jointly enhance energy performance. The theoretical foundations of this inquiry draw from multiple strands of economic and environmental literature, beginning with the diversification-innovation nexus articulated in endogenous growth theory (Romer, 1990), which posits that diversified export structures facilitate knowledge spillovers and technological upgrading. Can et al. (2021) recently extended the framework for energy systems, who explain how export diversification in developing countries incentivizes the use of energy-efficient production systems due to stiff competition and access to modern technologies. At the same time, green finance has emerged as a field establishing clear relationships between sustainable financial products and their environmental impacts. Iqbal et al. (2023) showed how specially designed financial policies can assist in overcoming capital constraints to energy efficiency investments in emerging markets.

Distinctive pattern of South Asia's development makes it an important region to consider at how these factors interplay. South Asia still depends upon fossil fuels for more than 75% of its primary energy sources (IEA, 2023), yet it has already started diversifying its exports. For example, countries like India is making real progress by diversifying their exports beyond traditional goods (Ali & Memon, 2019), and Bangladesh is utilizing new ideas to finance green projects (Kumar et al., 2024), but still the gap exists especially in South Asian region in suggesting that diversifying exports may affect positively to energy efficiency. Although there is increasing evidence from other areas that suggest that diversifying exports may strengthen energy efficiency, for example, Rehman et al. (2023) using BRICS found that export diversification initially reduces renewable energy use but eventually promotes it as countries gain comparative advantage. This study aims to fill this important gap in knowledge by looking closely at how these two policy levers work together in South Asia's unique institutional and economic setting, where old energy infrastructure, limited access to financial markets, and a high concentration of exports make it both hard and easy to make the switch to sustainable energy.

A new methodical framework is used to analyze the function of export diversification in improving energy efficiency. It builds on recent methodological advances in energy economics, such as Hu et al.'s (2020) use of synergistic effect models and Qudrat-Ullah (2023) development of threshold analysis techniques. The study is especially timely because the region's climate vulnerabilities are getting worse and there is an urgent need for policy solutions that are based on evidence and can improve both the economy and the environment at the same time. The study's goal is to give policymakers useful information on how to best use their resources between export promotions to get the most energy efficiency gains by looking at whether and how these two strategies make each other more effective. Additionally, the analysis advances practical knowledge of how developing economies can use financial innovation to accelerate sustainable energy transitions in line with both national development priorities and global climate objectives, while also contributing to theoretical discussions about the circumstances under which economic diversification strategies yield environmental co-benefits.

While previous studies have advanced our understanding of export diversification's role in sustainable development, much less is known about how it interacts with other factors to enhance energy efficiency. There may be interaction effects, as suggested by emerging research from other regional contexts. For example, the analysis on East Asian economies of Ulucak (2020) suggested that financial policy interventions can substantively enhance the positive environmental externalities originated from trade diversification, suggesting possible complementarity mechanisms running between economic domains. Nevertheless, the inherent structural features of South Asian economies — such as policy fragmentation, financial market underdevelopment and a path-dependent energy sector — may alter these dynamic interactions in a manner that calls for further investigation into their region-specific nature.

This study thus attempts to fill this crucial knowledge void by conducting a thorough empirical investigation of the case in South Asia (all countries except Afghanistan) for the period ranging from 2004 up to 2023; incorporating state-of-the-art panel data econometric tools that also incorporate South Asian issues like endogeneity using system GMM and Kinkly least square method. The analysis will systematically evaluate three key dimensions: first, the individual marginal effects of export diversification on energy efficiency metrics; second, the nature and magnitude of its interactive relationship (whether complementary, substitutive, or neutral); and third, the policy implications of these findings for sustainable energy transitions in developing economy contexts.

By establishing empirical evidence for these relationships within South Asia's distinctive institutional environment, this research makes three substantive contributions to the literature: it advances theoretical understanding of the trade-environment nexus in development economics, extends methodological approaches to analyzing complex policy interactions in energy systems, and provides actionable insights for policymakers seeking to optimize the trade for enhanced energy efficiency outcomes. These insights are especially relevant for South Asian governments grappling simultaneously with economic transitions and climate commitments, providing country-specific evidence on how policy synergies across export diversification policies could drive shared value creation through rapid progress in the attainment of sustainable development goals while ensuring sustained economic competitiveness.

2. LITERATURE REVIEW

The literature on sustainability, trade policy and environmental economics has largely explored the relationship between export diversification (EDIV) and Carbon Intensity (CI). As nations seek to balance economic aspirations with environmental sustainability, understanding how export structures influence carbon emissions is of critical importance. This literature review brings together existing theories and empirical evidence on the relationships between EDIV and CI with a focus on key mechanisms, regional differences, and policy implications.

There is a de facto consensus that export diversification stimulates industrial upgrading and creates economic resilience (Hesse, 2008). In macroeconomic terms, diversified export patterns lead to a structural change in the trading profile towards cleaner manufacturing and services at the expense of carbon heavy industries (as primary commodities and fossil fuels). Hesse (2008), identified that the CI was negatively related to EDIV, higher in economies with higher EDIV because they were more efficient in their production and therefore needed less volatile energy. This is particularly evident in countries that change from being exporters of almost exclusively raw materials to exporting high value added, product-intensive manufactures.

Technological spillovers from international trade serve to strengthen this relationship. According to Adom et al. (2022), there is a considerable influence of international markets, particularly on energy-efficient technologies uptake in developing nations. In their research focusing on sub-Saharan Africa, they show that EDIV has a CI effect by supporting the use of cleaner industrial processes and diminishing dependency on carbon-intensive energy sources. Can et al. (2021) also discover that export diversified economies suffer less diffusion of green technologies leading to less CI in manufacturing.

EDIV also elicits competition at the firm level to support increased energy efficiency. Cadot et al. (2015) for enterprise-level data in developing economies find the export-oriented firms systematically decrease CI to satisfy international environmental standards. This work also exposes how being part of an international market pushes businesses to use low-carbon production systems, resulting in the reduction of their global CI.

Nonetheless, for some sectors, this relationship is stronger than others. Ali and Memon (2019) and South Asian economies, observe that EDIV decreases CI in the manufacturing category but with weaker results than agriculture and extractive industries. This indicates that the environmental benefits of EDIV are highly dependent on their economic structure.

Due to the differences in institutional quality, or policy frameworks and industrial structure, EDIV does not have the same effect across regions. Qudrat-Ullah (2023) claim that in the South Asian region, no stringent policies relevant to environmental protection and infrastructural bottlenecks dock the potential of EDIV to decrease CI. Their study emphasizes that without strong governance, EDIV may merely shift carbon emissions rather than reduce them.

In contrast, East Asian economies exhibit stronger EDIV-CI linkages due to better policy coordination and technological absorption capacity (Ulucak, 2020). Chen et al. (2023) further identify threshold effects, where the combination of EDIV and robust green finance mechanisms leads to disproportionately large reductions in CI. This suggests that EDIV alone is insufficient; complementary policies are needed to maximize its environmental benefits.

Despite growing evidence, critical gaps remain. First, most studies focus on developed or rapidly industrializing economies, leaving South Asia underrepresented (World Bank, 2022). Second, the interaction between EDIV and institutional quality requires deeper empirical investigation (Rashid, 2025). Finally, the role of sectoral heterogeneity in shaping EDIV-CI dynamics remains under-explored. A detail findings for developing countries with respect to different economic indicators are discussed in (Akbar et al., 2024(a); Akbar et al., 2024(b); Ali et al., 2024; Raza et al., 2024; Sana et al., 2024; Khan et al., 2023; Raza et al., 2021(a); Raza et al., 2021(b)).

This study contributes by: (1) analyzing EDIV's impact on CI in South Asia, (2) assessing how institutional quality moderates this relationship, and (3) providing policy recommendations for leveraging EDIV in decarbonization strategies.

3. DATA AND METHODOLOGY

This research employs an econometric model to analyze the interplay between foreign direct investment (FDI), trade openness (TO), gross domestic product (GDP), export diversification (EDIV), and carbon intensity (CI). The baseline specification is given by equation (1) as:

$$CI_{it} = \beta_0 + \beta_1 FDI_{it} + \beta_2 EDIV_{it} + \beta_3 GDP_{it} + \beta_4 TO_{it} + \mu_i + \vartheta_t + \varepsilon_{it} \qquad (1)$$

Here, μ_i accounts for country-specific fixed effects, capturing unobserved time-invariant factors that influence the dependent variable. The term ϑ_t represents time-fixed effects, accounting for period-specific shocks that affect all countries uniformly. The residual variation is captured by the error term, $\boldsymbol{\varepsilon}_{it}$, which varies across both countries and time. EDIV is taken from UNCTAD sources while all other variables are taken from world development database (WDI). Descriptive statistics of these variables are given in Table 1.

To address potential endogeneity, we extend the analysis beyond standard Fixed Effects (FE) and Random Effects (RE) models by incorporating the System GMM estimator and Kiviet's (2020) correction method. This leads to a dynamic model specification depicted as equation (2):

$$CI_{it} = \gamma_0 + \gamma_1 CI_{it-1} + \gamma_2 FDI_{it} + \gamma_3 EDIV_{it} + \gamma_4 GDP_{it} + \gamma_5 TO_{it} + \epsilon_{it} \qquad (2)$$

Unlike conventional time-series analysis, our study utilizes panel data techniques to explore the dynamic linkages among FDI, GDP, TO, EDIV, and CI. By leveraging both cross-country and temporal variations, we mitigate unobserved heterogeneity and enhance estimation precision. To ensure robustness, we apply three distinct econometric approaches. The choice of econometric methodology are comprehensively discussed in (Akbar et al., 2024(c); Akbar et al., 2023; Waheed et al., 2021; Akbar et al., 2019; Hussan et al., 2019). Methodology selection of system GMM and Kinky least square (KLS) is done based on the following criteria:

Table 1: Comparison between System GMM and Kinky Least Square (KLS) estimations

Features	**System GMM**	**Kinky Least Square (KLS)**
Motive	Estimates dynamic panel models with endogenous regressors	- Estimates piecewise linear models with a structural break - Handles weak or potentially invalid instruments in IV settings
Data Setting	Panel data: large N, small T (many cross-sections, few time periods)	Cross-section or panel data where IV/2SLS struggles
Treatment of Endogeneity	Uses lagged variables as internal instruments	Allows instruments to be correlated with error up to a "kink" bound
Estimator Type	Point estimates (single coefficient values)	Interval estimates (bounds instead of exact values)
Validity	- Deals with endogeneity, autocorrelation, heteroscedasticity - Widely accepted in applied economics - Strong software support	- Robust to weak instruments - Provides sensitivity analysis - Relaxes strict exogeneity assumption
Deficiencies	- Instrument proliferation can bias results - Weak instruments if variables are persistent - Requires strong assumptions about error structure	- Less common in applied work - Harder interpretation (intervals) - Requires subjective kink parameter choice
Usage	- Dynamic models with lagged dependent variables - When valid internal instruments exist - Standard for growth, finance, and development studies	- When instruments are weak or possibly invalid - As a robustness check to System GMM or 2SLS results - When testing sensitivity to exogeneity assumptions
Output Display	Coefficient estimates + diagnostics (Hansen test, AR(2) test)	Bounds/intervals for coefficients depending on kink restriction

Source: Table extracted from Arellano and Bover (1995), Andrews and Armsrong (2017).

4. ANALYSIS AND RESULTS

The regression results, Table 2, from the Fixed Effects (FEM) and Random Effects (REM) models present a consistent picture of the factors influencing CO_2 intensity, with both approaches yielding remarkably similar coefficient estimates and significance patterns. The near-identical results across the two specifications suggest that the unobserved heterogeneity in the data may be largely uncorrelated with the explanatory variables, making both models appropriate for this analysis. The key variables - FDI, GDP, TO, and EDIV - all show statistically significant relationships with CO_2 intensity, with coefficients generally aligning in direction and magnitude between the two models. FDI demonstrates a small but statistically significant negative effect on CO_2 intensity in both specifications, with coefficients of -0.039 in FEM and -0.042 in REM, both significant at the 5% level. This consistent finding across models suggests that FDI inflows are associated with modest reductions in emissions intensity, possibly through technology transfer or the adoption of cleaner production methods by foreign-affiliated firms. GDP shows a negative and significant relationship with CO_2 intensity in both models, though the coefficient magnitude differs substantially (-0.0101 in FEM versus -0.0421 in REM). This discrepancy might reflect how the fixed effects specification accounts for country-specific time-invariant factors that influence both economic growth and emissions patterns. Both coefficients are statistically significant at the 5% level, confirming that economic development generally correlates with lower emissions intensity, though the exact magnitude of this effect depends on model specification.

Trade openness exhibits a negative and statistically significant (at 10% level) association with CO_2 intensity in both models, with coefficients of -0.002 in FEM and -0.001 in REM. The slightly larger magnitude in the fixed effects specification might suggest that within-country changes in trade patterns have a somewhat stronger association with emissions intensity than between-country differences. Export diversification shows the largest and most statistically significant (1% level) negative coefficients across both models (-1.429 in FEM and -1.411 in REM), indicating that more diversified economies tend to have substantially lower CO_2 intensity. The minimal difference between the FEM and REM coefficients for this variable suggests that export structure affects emissions intensity similarly both within countries over time and across different countries.

The overall consistency between FEM and REM results strengthens confidence in the findings, as it suggests the relationships are robust to different modeling assumptions about unobserved heterogeneity. The results collectively point to export diversification as the most powerful explanatory factor among those considered, followed by more modest but consistent effects from FDI, GDP growth, and trade openness.

Table 2: Descriptive Statistics of the Variables

Variable	Obs	Mean	Std. dev.	Min	Max
FDI	133	2.24	3.27	-0.64	16.78
GDP	133	24.67	2.29	20.73	28.72
TO	133	57.38	32.73	24.70	165.98
EDIV	133	0.73	0.11	0.44	0.90
CO2Intensity	133	0.53	0.27	0.16	1.19

Table 3: Estimates of FEM and REM

Variables	FEM	REM
	CO_2 - Intensity	CO_2 - Intensity
FDI	-0.039**	-0.042**
	(0.007)	(0.007)
GDP	-0.0101**	-0.0421**
	(0.001)	(0.011)
TO	-0.002*	-0.001*
	(0.001)	(0.001)
IDIV	-1.429***	-1.411***
	(0.31)	(0.326)
Constant	1.399***	1.355***
	(0.159)	(0.182)
Observations	118	118

The regression results of Table 3 from the System GMM and KLS models present strikingly different patterns in their estimation of CO_2 intensity determinants, highlighting how methodological choices can substantially influence findings. The System GMM approach, which accounts for dynamic endogeneity through instrumented lags, produces results that differ markedly from KLS method, particularly regarding FDI and export diversification effects.

FDI shows a significant negative coefficient (-0.097) at the 10% level in System GMM, suggesting potential emissions-reducing technology transfer effects, while KLS estimates an insignificant positive coefficient (0.001). This stark contrast implies that FDI's environmental impact may be sensitive to model specification - either due to GMM's treatment of endogeneity is some way different as compared to KLS's method. The GDP coefficients are negative in both models (-0.010 in GMM, -0.032 in KLS) but insignificant, indicating no robust relationship between economic growth and emissions intensity once accounting for dynamic effects.

Trade openness coefficients are negative but insignificant in both specifications (-0.0009 in GMM, -0.0002 in KLS), with relatively small magnitudes suggesting minimal independent impact. The most dramatic divergence appears in export diversification effects: System GMM shows a large negative coefficient (-3.161) significant at 5%, potentially indicating strong emissions-reducing structural effects, while KLS paradoxically estimates a significant positive coefficient (0.804). This contradiction likely stems from KLS down weighting influential observations that drive GMM's results, revealing fundamentally different interpretations of how export structure affects emissions. The lagged dependent variable shows puzzling results - insignificant in GMM (0.033) where it should theoretically matter most, while KLS shows near-unit persistence (0.971) despite not being designed for dynamic estimation. The constants are significant but oppositely signed (positive in GMM, negative in KLS), further underscoring the models' divergent baseline assumptions. With 119-126 observations covering 7 cross-sectional units, the sample remains constant enough that these differences primarily reflect methodological variation rather than data coverage issues.

Table 4: Estimates of Two Step System GMM Method and Kinky Least Square Method

Variables	**Sys-GMM**	**Kinky Least Square (KLS)**
	CO_2 - Intensity	**CO_2 - Intensity**
FDI	-0.0971*	0.0012
	0.0449	0.0015
GDP	-0.0101	-0.0321
	0.002	0.0140
TO	-0.0009	-0.0003
	0.0002	0.0001
IDIV	-3.1610**	0.8041***
	1.1356	0.1849
L. CO_2-Intensity	0.0332	0.9707***
	0.3925	0.0293
Constant	2.2803**	-0.3735***
	0.8317	0.0911
Observations	119	126

These results collectively demonstrate that conclusions about emissions drivers depend heavily on modeling choices - particularly regarding how to handle endogeneity. The GMM results would support policies promoting FDI and export diversification for emissions reduction, while the KLS findings would reject such conclusions. This tension suggests the need for deeper diagnostic analysis to determine which specification better captures the true underlying relationships.

Empirical findings based on the System GMM, KLS estimations are in agreement and in contrast with the corpus of knowledge regarding the factors affecting the CO_2 intensity. The pollution halo hypothesis, which hypothesizes that a transfer of cleaner technology in host countries is promoted by multinational corporations, is congruent with System GMM outcome involving significant negative effect of FDI (-0.097*) (Perkins & Neumayer, 2008). The conclusion is even more relevant to the developing countries, where the foreign direct investment has been associated with more energy efficiency and less emissions (Hubler & Keller, 2010). However, the small positive coefficient (0.001) exhibited by the KLS model provides important depths to the research, potentially demonstrating the way FDI changes the role in different sectors and countries (Cole et al., 2017). The hypothesis of the

Environmental Kuznets Curve that economic development will lead to eventual improvement in the environment can be corroborated by only weakly by the negative but insignificant coefficients of GDP in both of the models (Grossman & Krueger, 1995). The insignificance, nevertheless, aligns with the current criticisms that have challenged the universality of the EKC in the backdrop of increasing new disparities in developing countries whereby environmental pressures can cool initially during growth (Kaika & Zervas, 2013).

Being little negative yet insignificant in both models, the results of trade openness provide an interesting twist to part of the ongoing literature so far published. Such relationship might be less universal and perhaps it varies with the comparative advantage and trade structure of a country (Managi et al., 2009), though there are details that trade can affect the intensity of emissions by efficiency growth, as well as diffusion of technology (Frankel & Rose, 2005). The most significant difference is observed in the results of export diversification, where System GMM indicates the strong negative correlation (-3.161), whereas KLS suggests the great positive impact (0.804). Such a difference could represent different underlying mechanisms that each methodology was capable to represent. The KLS result could indicate the possibility that diversification into specially clean industries (such as renewable energy technologies) does more work in reducing emissions than unspecified distribution (Acemoglu et al., 2012), whereas the GMM result aligns with the notion that diversified export structure leads to a more balanced energy consumption and decreased emissions rate (Cadot et al., 2013). The discrepancies in these models underline the importance of considering the general patterns and unique situations in the process of industrial policy-making to lessen emissions.

The findings have important implications to policymakers that need to reduce CO_2 intensity as an economical objective. The results suggest that the export diversification and FDI promotion policy, in general, can contribute to possible declines in the intensity of emissions, albeit significantly dependent on the implementation peculiarities and national conditions. The differences between the findings of the results of the KLS and the GMM remind us that results need to be checked on heavily on sensitivity and a wide range of analytical instruments need to be applied to the policy choices. In order to learn more about the non-linear connections between these economic factors and intensities of emissions and particularly in different types of development, future studies may want to utilize different techniques such as quantile regression (Binder & Coad, 2011). The presented study has shown unequivocally that the intensity of the CO_2 is influenced by economic factors, however, the nature and direction of these associations can substantively differ based on the methodological choices and the particulars and subject to context, making the informed, evidence-based policy formulation a necessity.

5. CONCLUSION AND POLICY IMPLICATIONS

Using System GMM and KLS to account for endogeneity, this study examined the factors influencing CO2 intensity in South Asian economies (except Afghanistan) between 2004 and 2023. The results reveal that FDI has a significant negative effect on emissions intensity in the System GMM model, aligning with the pollution halo hypothesis, which posits that foreign investment facilitates cleaner technology adoption. However, the KLS model's insignificant coefficient suggests that this effect may not be uniform across all economies, possibly due to varying sectoral compositions of FDI inflows.

Export diversification presents the most striking divergence between models: System GMM indicates a strong negative relationship with CO_2 intensity, while KLS shows a positive effect. This contradiction suggests that while diversification generally reduces emissions through balanced energy use, certain highly specialized (but clean) industries may achieve even greater efficiency. GDP growth and trade openness exhibit weaker and less consistent impacts, implying that economic expansion alone does not guarantee lower emissions intensity without complementary green policies.

The persistence of CO_2 intensity (evident in the lagged dependent variable) highlights the path-dependent nature of emissions, emphasizing the need for sustained policy interventions. For South Asian economies, these findings suggest that attracting environmentally conscious FDI and promoting strategic export diversification could be effective decarburization strategies. However, policymakers should consider contextual factors, as the relationship between economic variables and emissions varies across countries. Future research could explore sector-specific analyses and non-linear models to refine these insights further. Ultimately, achieving sustainable development in South Asia will require a balanced approach that integrates economic growth with stringent environmental regulations and technological innovation.

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REFERENCES

Acemoglu, D., Aghion, P., Bursztyn, L., & Hemous, D. (2012). The environment and directed technical change. *American Economic Review, 102*(1), 131-166.
Adom, P. K., Agradi, M., & Vezzulli, A. (2022). Import diversification and energy efficiency: Evidence from emerging markets. *Energy Economics*, 110, 106025.
Akbar, S., Iqbal, M., & Munir, F. (2024a). A Structural Break Unit Root Test to Test Purchasing Power Parity Hypothesis: An Empirical Analysis of South Asian Economies. *Kashmir Economic Review*, *33*(1), 14-23.
Akbar, S., Munir, F., & Iqbal, M. (2024b). Asymmetric Dynamics between Exchange Rates and Crude Oil Prices: A Cross-Country Assessment. *Pakistan Journal of Humanities and Social Sciences*, 12(4), 3141–3152.
Akbar, S., Idrees, M., & Ali, M. (2024c). Fluctuations in electricity prices and the identification of bubbles in Italy during COVID-19. *Journal of Social Sciences and Economics*, *3*(2), 241-249.
Akbar, S., Raza, A., & Riaz, Y. (2019). A Monte Carlo Simulation Analysis of Panel Stationarity Tests under a Single Framework. *European Online Journal of Natural and Social Sciences: Proceedings*, 8(1(s)), 34-41.
Akbar, S., Kafayat, S., & Iqbal, M. (2025). Trade Structure and Energy Performance: How Import Diversification Shapes Efficiency in Central Asian Economies. *ACADEMIA International Journal for Social Sciences*, *4*(3), 1196-1205.
Ali, M., Zahid, M., & Akbar, S. (2024). FDI and Industrialization: Evidence from Selected Asian Developed and Developing Countries. *Pakistan Journal of Humanities and Social Sciences*, 12(4), 3093–3101.
Ali, M., & Memon, M. H. (2019). Economic diversification and human development in South Asia. *Journal of Asian and African Studies*, *54*(5), 674-690.
Andrews, I., & Armstrong, T. B. (2017). Unbiased instrumental variables estimation under known first-stage sign. *Quantitative Economics*, *8*(2), 479-503.
Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, *68*(1), 29-51.

Binder, M., & Coad, A. (2011). From average Joe's happiness to miserable Jane and cheerful John: Using quantile regressions to analyze the full subjective well-being distribution. *Journal of Economic Behavior & Organization, 79*(3), 275-290.

Cadot, O., Carrère, C., & Strauss-Kahn, V. (2013). Trade diversification, income, and growth: What do we know? *Journal of Economic Surveys, 27*(4), 790-812.

Cadot, O., Fernandes, A. M., Gourdon, J., & Mattoo, A. (2015). Are the benefits of export support durable? Evidence from Tunisia. *Journal of International Economics, 97*(2), 310-324.

Can, M., Ahmad, M., & Khan, Z. (2021). The impact of export composition on environment and energy demand: evidence from newly industrialized countries. *Environmental Science and Pollution Research, 28*(25), 33599-33612.

Chen, L., Zhang, X., & Wang, J. (2023). Import sophistication and energy performance. *Journal of Environmental Economics*, 115, 102712.

Cole, M. A., Elliott, R. J., & Zhang, J. (2017). Foreign direct investment and the environment. *Annual Review of Environment and Resources, 42*, 465-487.

Frankel, J. A., & Rose, A. K. (2005). Is trade good or bad for the environment? Sorting out the causality. *Review of Economics and Statistics, 87*(1), 85-91.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *Quarterly Journal of Economics, 110*(2), 353-377.

Hesse, H. (2008). Export diversification and economic growth. *World Bank Policy Research Working Paper, 21.*

Hubler, M., & Keller, A. (2010). Energy savings via FDI? Empirical evidence from developing countries. *Environment and Development Economics, 15*(1), 59-80.

Hu, H., Xie, N., Fang, D., & Zhang, X. (2020). The role of renewable energy consumption and commercial services trade in carbon dioxide reduction: Evidence from 25 developing countries. *Applied Energy, 257,* 113909.

Hussan, M., & Akbar, S. (2019). A Monte Carlo Comparative Simulation Study for Identification of the Best Performing Panel Cointegration Tests. *European Online Journal of Natural and Social Sciences, 8*(2), 366.

International Energy Agency (IEA). (2023). *World energy outlook 2023: Special report on Southeast Asia*. https://www.iea.org

Kaika, D., & Zervas, E. (2013). The Environmental Kuznets Curve (EKC) theory—Part A: Concept, causes and the CO_2 emissions case. *Energy Policy, 62*, 1392-1402.

Khan, W. M. ., Sana, M. ., & Akbar, S. (2023). The Effect of Petroleum Prices on Basic Food and Energy Commodities: An investigation through Sequential ADF tests. *Bulletin of Business and Economics (BBE), 12*(3), 912-921.

Kiviet, J. F. (2020). Testing the impossible: identifying exclusion restrictions. *Journal of Econometrics, 218*(2), 294-316.

Kumar, R., Goel, R., Singh, T., Mohanty, S. M., Gupta, D., Alkhayyat, A., & Khanna, R. (2024). Sustainable finance factors in Indian economy: analysis on policy of climate change and energy sector. *Fluctuation and Noise Letters, 23*(02), 2440004.

Managi, S., Hibiki, A., & Tsurumi, T. (2009). Does trade openness improve environmental quality? *Journal of Environmental Economics and Management, 58*(3), 346-363.

Murshed, M. (2018). Does improvement in trade openness facilitate renewable energy transition? Evidence from selected South Asian economies. *South Asia Economic Journal, 19*(2), 151-170.

Perkins, R., & Neumayer, E. (2008). Fostering environment efficiency through transnational linkages? Trajectories of CO_2 and SO_2, 1980-2000. *Environment and Planning A, 40*(12), 2970-2989.

Qudrat-Ullah, H. (2023). A review and analysis of green energy and the environmental policies in South Asia. *Energies, 16*(22), 7486.

Rashid, A. (2025). Nexus of economic diversification, institutional quality, and CO_2 emissions: Evidence from emerging economies. *Journal of Accounting and Finance Review*, 1(2), 81-93.

Raza, A., Akbar, S., & Raza, Z. (2021a). Does Greenfield Foreign Direct Investment Inflow Contribute in Socioeconomic Development? Empirical Evidence from Developing Countries. *Pakistan Journal of Humanities and Social Sciences*, 9(3), 469-481.

Raza, A., Akbar, S., & Sadiqa, B.A. (*2021b)* Relationship among Economic Growth, Health, Education, Economic Development and Greenfield Investment as Mode of FDI: Evidence from MENA Countries. *International Review of Social Sciences, Vol. 9 (5), PP 271-280.*

Rehman, F. U., Noman, A. A., Islam, M., Wu, Y., & Metwally, A. S. M. (2023). Export diversification and disaggregate energy consumption in BRICS economies: Does environmental degradation matter?. *Energy & Environment*, 0958305X231210992.

Romer, P. M. (1990). Endogenous technological change. *Journal of Political Economy, 98*(5, Part 2), S71-S102.

Sana, M., Khan, M.W., & Akbar, S. (2024). The Effect of Monetary Policy on Import, Export, and Foreign Direct Investment: An Empirical Investigation. *Bulletin of Business and Economics*, 13(1), 874-884.

Iqbal, N., Taghizadeh-Hesary, F., & Phoumin, H. (2023). The role of green finance in renewable energy deployment in the Republic of Korea. In *Green Finance and Renewable Energy in ASEAN and East Asia* (pp. 164-184). Routledge.

Ulucak, Z. Ş., İlkay, S. Ç., Özcan, B., & Gedikli, A. (2020). Financial globalization and environmental degradation nexus: evidence from emerging economies. *Resources Policy*, *67*, 101698.

Waheed, A., Rashid, A., & Akbar, S. (2021). Detecting the best performing time-variant cointegration test using the consumption function. *International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies*, 12(4), 1-5.

World Bank. (2022). *South Asia's Energy Efficiency Potential: A Regional Assessment*. World Bank Group. https://www.worldbank.org

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Impact of Trade on Poverty and Inequality: Empirical Evidence from SAARC Countries

ABSTRACT

This study investigates the impact of trade on poverty and inequality within the South Asian Association for Regional Cooperation (SAARC) countries. Using balanced panel data spanning from 1990 to 2022, the research focuses on understanding the connection between international trade and poverty on the one hand, and on the other trade and inequality. Poverty and inequality equations were separately estimated by employing pooled ordinary least squares (POLS) method on balanced panel data. Through regression analyses and econometric modelling, the study aims to uncover the nuanced relationship between trade policies, economic growth, poverty alleviation, and inequality within the SAARC region. The findings reveal a negative link between trade openness and poverty indicating that increasing trade helps in alleviating poverty in the SAARC region. However, the link between trade and inequality is positive. This indicates that trade policies must be thoughtfully crafted to promote fair economic growth. These insights are crucial for policymakers aiming to balance the trade expansion with social welfare in SAARC countries. The findings of this research contribute to the literature on the trade-poverty and trade-inequality nexus, offering insights for policymakers to formulate effective strategies for sustainable economic development and social inclusion in SAARC countries.

Keywords

Trade openness, Poverty, Inequality

JEL Classification

F10, I32, D31

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1. INTRODUCTION

Trade plays an important role in reducing poverty by promoting economic growth and well-being, creating new jobs, expanding the industry, and providing more access to goods. However, its influence on income inequality often depends on how the gains of trade are dispersed across different segments of society. Numerous countries across the globe have experienced economic growth as a result of recent trade openness (Banday et al., 2021; Kumari et al., 2023; Nam & Ryu, 2024). The impacts, however, vary among nations across the region with varying stages of economic development and growth. The rise in trade openness in the developing economies has supported growth and development; however, it has also widened the income inequalities (Xia et al., 2022; Tabash et al., 2024). The subject of economic imbalance has sparked significant discussion over its effects at both the national and global levels. In an era marked by global interdependence, the intricate interplay between economic growth, trade openness, and their ramifications on poverty and inequality has taken centre stage in both scholarly discourse and policy deliberations. In the case of SAARC economies, characterized by varying levels of development, the influence of trade on poverty and inequality is particularly evident, influenced by factors such as sectoral shifts, regional disparities, and differing government policies (Ouni et al., 2025).

SAARC[1]was established in 1985 with an agenda to promote regional economic integration, promote regional cooperation, and improve connectivity to reduce the widespread poverty and economic inequality among the South Asian states. Poverty in terms of income refers to a situation where individuals or households have an insufficient level of income to meet basic needs and achieve a reasonable standard of living (Al Kez et al., 2024). It encompasses a condition of material deprivation, where limited financial resources hinder access to essential goods and services such as food, housing, education, healthcare, and other necessities required for a dignified life . However, inequality refers to the disparities in income, wealth, and opportunities that exist among individuals or groups within a society (Hwang, 2024). It can manifest as differences in access to education, healthcare, employment, and other essential resources (Atkinson, 2015). In general, the nexus between trade openness, economic growth, and poverty reduction has been a subject of considerable interest within the realm of international development. This study seeks to empirically explore this intricate nexus within the context of the SAARC countries. The overarching objective is to examine how the interplay between openness and growth influences poverty dynamics across this diverse group of nations.

Trade in SAARC economies affects poverty and inequality by shaping economic growth, altering sectoral employment, and influence the affordability of essential goods. Increased openness can lower poverty through job creation and improved access to markets, yet may also worsen inequality if benefits are unfairly distributed across the social groups. This study empirically investigates the trade–poverty–inequality linkages using region-specific evidence to examine the SAARC's unique structural and policy context. Existing empirical literature on trade, poverty, and inequality mainly focus on developed countries or cross-regional analyses, overlook the SAARC region's unique structural and institutional context. Empirical evidence explicit to SAARC economies, considering heterogeneity in trade patterns, poverty dynamics, and inequality drivers, remains scarce. Moreover, in the literature, the association between trade, economic growth, and income inequality reveals mixed results.

Existing literature does not have any consensus because the overall influence of trade and growth on poverty and inequality differs from country to country; therefore, we cannot generalize the results of one country to all other countries (Cerra et al., 2021; Dorn et al., 2022). Therefore, this study helps to find the result of the impact of trade on poverty and inequality in the case of SAARC countries with the data set that ranges from 1990 to 2022. This study addresses the lack of region-specific evidence on the association between trade, poverty, and inequality in SAARC economies. Even though increase

[1]Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka

in trade integration, outcomes for poverty reduction and income distribution remain inconsistent across the region. Understanding these different impacts is crucial for designing trade policies. This research is essential for policymakers and economists in the region to develop strategies that not only promote economic growth and poverty reduction but also address the pressing issue of income inequality, ensuring a more equitable and sustainable future for the people of SAARC nations.

2. LITERATURE REVIEW

The relationship between trade, economic growth, poverty, and inequality has been a subject of substantial scholarly interest. Literature consistently upholds the notion that trade and economic growth plays a crucial role in combating poverty and inequality. Nevertheless, it is imperative to recognize that the relationship between trade, growth, and poverty is intricate and diverse. Policymakers must adopt comprehensive approaches that take into account the unique circumstances of each country and tackle issues, i.e., income inequality, dynamics in the labor market, and the establishment of robust social safety nets. This approach ensures that the advantages of trade and growth are distributed equitably, leading to sustainable poverty reduction.

In principle, trade and economic growth are powerful instruments for poverty alleviation; they should be complemented by other measures such as investments in education, healthcare, and infrastructure to foster an environment where the benefits of growth are widely shared among the population. Previous studies have shown how trade liberalization and growth affect poverty reduction. These studies, in particular, have concentrated on the role of trade openness and growth in determining poverty reduction. The literature review highlights the intricate and context-specific nature of the connection between trade, economic growth, poverty, and income inequality in SAARC countries. While trade and economic growth have the potential to contribute to reducing inequality, their impact can vary depending on factors such as initial inequality levels, sectoral dynamics, and policy frameworks. Policymakers should consider these nuances when designing strategies to promote sustainable and inclusive development in the SAARC region. Further research is essential to deepen our understanding of the relationship between trade, growth, poverty, and inequality in SAARC countries and to guide evidence-based policy decisions that foster equitable growth and reduce income disparities.

Ghazanfar et al. (2021) document that trade openness has a varying influence on poverty across selected SAARC economies. Their empirical findings reveal that in some countries, trade openness lowers the poverty rate by enhancing employment and income levels. Nonetheless, in others, it aggravates income inequality. Rahman and Khondker (2007) examined Bangladesh and concluded that trade liberalization played a role in reducing poverty and income inequality. The relationship between economic growth, inequality, and poverty reduction has been extensively explored. Qayyum et al. (2008) studied Pakistan and found that while economic growth contributed to poverty reduction, income inequality remained a concern. Dorn et al. (2022) suggest that while trade openness in general promotes economic growth, its influence on income inequality differs depending on country-specific factors, for example, redistribution policies and labor market strategies. The authors find that in advanced economies, trade openness has a weaker connection with rising inequality, while in developing economies, increased trade can worsen income disparities, mainly by benefiting high-skilled workers more than low-skilled labor. Chaudhry and Imran (2013) report that trade liberalization reduces poverty in the long run but not in the short run. To maximize the positive effects of trade and minimize its downsides, it is important to implement complementary policies that encourage inclusive growth and equitable distribution of benefits. This entails a holistic approach that combines trade policy with investments in education, infrastructure, social protection, and labor market regulations, ensuring that the gains from trade contribute to sustainable and inclusive development. The findings of the previous studies reveal that the influence of trade on poverty and inequality is not uniform across the SAARC countries. While some nations experience substantial reductions in poverty and inequality as trade increases and economies grow, others may find more modest effects or encounter challenges that necessitate targeted interventions (Kitole & Sesabo, 2024).

These variations underscore the importance of context-specific policies that consider unique socio-economic, cultural, and institutional factors within each country. After conducting a literature review on trade, poverty, and inequality, specifically in SAARC countries, it becomes evident that these issues are interconnected and of great importance. The studies and research indicate that promoting trade within the SAARC region can lead to increased economic growth, job creation, and poverty reduction. However, based on the existing literature, it is imperative to enhance regional cooperation, reduce trade barriers, and implement inclusive policies, which are crucial for achieving sustainable development and reducing poverty and inequality in SAARC countries. Further research and policy interventions are needed to explore innovative approaches and strategies to tackle these challenges effectively. Together, by fostering trade, promoting economic growth, and addressing poverty and inequality, the SAARC countries can work towards a more prosperous and equitable future for all.

To sum up, existing empirical literature provides mixed and ambiguous results. However, these disparities in the empirical findings can be associated with different factors, for instance, country-specific studies, estimation techniques, heterogeneity among the member countries, and also time span. Using POLS, this study investigates the influence of trade on poverty and inequality in SAARC countries over the period of 1990-2022. These countries, even though their diverse culture, norms, and languages appear to have broader parallel comparisons in terms of the infrastructure, domestic market conditions, and, most importantly, the level of their economic growth. However, there is little existing empirical evidence to hold up the claim that trade liberalization policies, particularly in developing economies, offer economic growth and reduce poverty rates and also income disparities. Nevertheless, in the literature, proponents of the trade liberalization policies argue that these trade liberalization policies in the developing world lead to benefits for the individuals and society in the long run if prudent domestic policies are adopted (Freund &Bolaky, 2008). However, on the other hand, literature also documented that trade policies can often result in greater income inequality in the developing economies (e.g., Siddiqui et al., 2012; Musila&Yiheyis, 2015; Ulaşan, 2015; Kitole&Sesabo, 2024; Nam et al., 2024).

3. METHODOLOGY

3.1 Data Source and Model Specification

The data for the sample countries are drawn from the World Bank Database, for instance, World Development Indicators (WDI). The selection of SAARC economies is purely based on the availability of data. The list of selected variables and their sources is provided in Appendix A. To empirically investigate the association between trade and poverty outcomes in SAARC economies, the study specifies two econometric models focusing on poverty and income inequality respectively. The first model as presented in Equation (1) estimates the influence of trade and other macroeconomic variables on poverty, while the second as presented in Equation (2) assesses their effect on income inequality. Both models incorporate relevant control variables to account for structural and economic differences across countries and over time. The main variables of interest are trade liberalization as a % of GDP (represented TRD), economic growth (represented by GDP), and poverty proxied by the head count ratio (represented by POV). In addition to that, the control variables are employment (EMP), population (POP), foreign direct investment (FDI), and inflation rate (INF). The study utilizes POLS method in a panel setting to investigate the impact of trade liberalization and economic growth on poverty and inequality in SAARC countries. Further, the empirical model is presented in Equation (1) below:

$$POV_{it} = \beta_0 + \beta_1 TRD_{it} + \beta_2 EMP_{it} + \beta_3 GDP_{it} + \beta_4 POP_{it} + \beta_5 FDI_{it} + \mu_{it} \qquad (1)$$

The above empirical model represents that poverty (POV) is a function of trade (TRD), employment (EMP), Gross Domestic Product (GDP), population (POP), and foreign direct investment (FDI). The selection of these variables is based on economic theory and existing relevant literature. All these variables influence the poverty directly or indirectly. For instance, increasing trade openness and GDP increases economic development and growth by creating more job opportunities and raising employment levels across various sectors of the economy. Moreover, as businesses expand and industries flourish, overall productivity increases, new technologies are adopted, leading to higher wages and improved living standards. This economic progress, in turn, helps reduce poverty by providing greater access to resources and opportunities for individuals and communities. However, it is often observed that the unequal distribution of income results in increasing poverty in economies. To determine how the variables interact, we use the model presented in Equation 2:

$$GINI_{it} = \gamma_0 + \gamma_1 TRD_{it} + \gamma_2 EMP_{it} + \gamma_3 GDP_{it} + \gamma_4 FDI_{it} + \gamma_5 INF_{it} + \varepsilon_{it} \qquad (2)$$

In principle, the impact of trade openness on income inequality is shaped by how gains from trade are distributed among the individuals in the society, government policies, and dynamics in the labor market. However, the uneven distribution of gains can increase the income inequality in the society, whereas government intervention may decrease it. Further, the shifts in labor demands and wage rates can also play a crucial role in this connection.

3.2 Data Source

The study uses key economic variables to empirically investigate the relationship between trade, poverty, and inequality in SAARC economies. Poverty is measured as the number of people living below the poverty line, while inequality is captured through the GINI index. Trade openness (% of GDP) and annual GDP growth are included to capture the broader economic environment affecting these outcomes. The data for the sample countries are drawn from the World Bank Database, for instance, World Development Indicators (WDI). The selection of SAARC economies is purely based on the availability of data.

4. RESULTS AND DISCUSSION

4.1 Descriptive Statistics

Table 1 describes the descriptive statistics and tells that the average value of poverty is smaller than the median value, which suggests that the distribution of the poverty is leftward skewed. That is, most of the observations are concentrated around the bigger value. Also, poverty is the second volatile variable in our model, as shown by the relatively bigger value of standard deviation. Similarly, the average value of foreign direct investment is greater than the median value, which tells that the distribution of the FDI is rightward skewed. Also, the average value of employment is greater than the median value, which means that the distribution of the employment is rightward skewed. Hence, most of the observations are concentrated around the lesser value, and employment is also a less volatile variable, as shown by the value of standard deviation.

Table 1: Summary Statistics

Variable	Mean	Median	Std. Dev.
POV	26.317	29.246	12.075
FDI	1.005	0.616	0.876
EMP	1.305	0.278	1.080
GDP	5.207	5.572	3.102
POP	1.412	1.433	0.908
TRD	51.062	31.57	25.682
GINI	31.45	31.76	2.261

The average value of GDP is approximately equal to the median value, which suggests that the distribution of the GDP is symmetric. That is, most of the observations are concentrated around the average value. Also, GDP is a less volatile variable as shown by the value of standard deviation and range. Similarly, the average value of the population is approximately equal to the median value. Which means that the distribution of the population is symmetric; that is, most of the observations are concentrated around the average value. Accordingly, the average value of trade openness is greater than the median value, which suggests that the distribution is rightward skewed; that is, most of the observations are concentrated around the lesser value. Also, trade openness is the most volatile variable in our data, as shown by the bigger value of standard deviation. Finally, the average value of GINI inequality is approximately equal to the median value, which suggests that the distribution is symmetric; that means most of the observations are concentrated around the average value. Furthermore, the GINI inequality is a less volatile variable in our data, as shown by the value of standard deviation.

4.2 Correlation Matrix

Table 2 below discusses the matrix of correlation between all variables used in this empirical analysis. Our main dependent variable, GINI inequality, is positively correlated with GDP, inflation, and trade openness. However, it is negatively correlated with FDI and employment (EMP). GINI inequality has the highest correlation with trade openness, whereas the lowest correlation is with FDI. The correlation between GINI and trade openness (TRD) is 0.3433, indicating a moderate positive relationship. This suggests that higher trade openness is associated with higher inequality. However, the correlation between GINI and FDI is -0.0029, indicating a near-zero relationship, suggesting that FDI does not have a significant linear association with inequality.

Table 2: Correlation Matrix (I)

Variables	**(GINI)**	**(GDP)**	**(INF)**	**(TRD)**	**(FDI)**	**(EMP)**
(1) GINI	1.0000					
(2) GDP	0.1828	1.0000				
(3) INF	0.0480	-0.2244	1.0000			
(4) TRD	0.3433	0.1528	-0.0448	1.0000		
(5) FDI	-0.0029	0.2889	0.0093	0.2311	1.0000	
(6) EMP	-0.2350	-0.0292	0.1792	-0.2270	0.1157	1.0000

Table 3 discusses the matrix of correlation for poverty and other explanatory variables. Our main variable, poverty, is only positively correlated with the population, and it is negatively correlated with all the other variables, such as foreign direct investment (FDI), employment, GDP, and trade openness. Poverty has the highest positive correlation with the population and the lowest negative correlation with FDI. The correlation between poverty and trade (TRD) is -0.5360. This moderate to strong negative correlation indicates that greater trade openness is associated with lower poverty levels. However, the correlation between poverty and population (POP) is 0.4811. This moderate positive correlation suggests that higher population levels are associated with higher poverty levels. And the correlation between poverty and GDP is -0.0887. This weak negative correlation indicates that higher GDP might be associated with slightly lower poverty levels, but the relationship is not strong. The correlations among other variables such as FDI, EMP, GDP, POP, and TRD show varying degrees of weak to moderate relationships, indicating complex interactions that might influence poverty and inequality in different ways.

Table 3: Correlation Matrix (II)

Variables	(POV)	(FDI)	(EMP)	(GDP)	(POP)	(TRD)
(1) POV	1.0000					
(2) FDI	-0.0138	1.0000				
(3) EMP	-0.1307	0.1157	1.0000			
(4) GDP	-0.0887	0.2889	-0.0292	1.0000		
(5) POP	0.4811	-0.0447	-0.1902	0.0898	1.0000	
(6) TRD	-0.5360	0.2311	-0.2270	0.1528	-0.3519	1.0000

4.3 Regression Analysis

Table 4 represents the results of the empirical model presented in Equation(1). In this model the dependent variable is poverty, which is represented by POV_{it} and the variable of interest is trade. The results show that the coefficient value of trade (TRD) is -0.242 and the p-value is 0.000, which indicates that trade has a significant negative relationship with poverty. It implies that an increase of 1 unit in trade will result in a decrease of 0.242 units in poverty. An increase in trade results in creating more jobs and employment levels as a result of poverty reduction. The results are consistent with the previous study (Zhu et al., 2022; Ngubane et al., 2023). Further, employment has a negative relationship with poverty. As the coefficient value of employment (EMP) is -2.429 and the p-value is 0.001, which indicates that EMP has a significant negative relationship with poverty, an increase in employment by 1 unit results in decreasing poverty by 2.429 units. Likewise, the results show that the coefficient value of GDP is -0.351 and the P value is 0.099, which describes that GDP has a significant negative impact on poverty, as a 1-unit increase in GDP will result in decreasing 0.351 units in poverty.

On the contrary to this, population and foreign direct investment have a positive relationship with poverty. The results show that the coefficient value of population (POP) is 3.660 and the p-value is 0.000, which indicates that population has a significant positive relationship with poverty. It implies that an increase of 1 unit in population will result in an increase of 3.660 units in poverty. Likewise, the coefficient value of FDI is 2.332, and the p-value is 0.009, which shows that FDI has a significant positive relationship with poverty. It is observed that FDI raises the poverty rate in our sample SAARC countries. The possible explanation can be that FDI inflows are typically directed at projects that often generate high profit and offer benefits directly or indirectly to the poor.

Table 4: Regression Analysis Considering Poverty as a Dependent Variable

Variables	Coefficients	Std. Error	Probability
TRD	-0.242***	(0.033)	0.000
EMP	-2.429***	(0.727)	0.001
GDP	-0.351*	(0.245)	0.099
POP	3.660***	(0.896)	0.000
FDI	2.332***	(0.886)	0.000
CONS	36.141***	(3.033)	0.000
Wald Chi2(5): 125.83	Prob>Chi2: 0.000	R. squared: 0.87	

In Table 5, we present the result based on the empirical model as presented in Equation (2). In this model the dependent variable is inequality, which is measured by $GINI_{it}$ and the variable of interest is trade. The results show that the coefficient value of trade (TRD) is 0.093 and the p-value is 0.000, which indicates that trade has a significant positive relationship with GINI. It implies that an increase of 1 unit in trade will result in an increase of 0.093 units in inequality. The results are consistent with the study (Ranamagar, 2022). Moreover, inflation and GDP have a positive association with GINI. As an increase in inflation by 1 unit results in increasing inequality by 0.182 units, the coefficient value of inflation is 0.182, and the p-value is 0.066, which shows a significant positive relationship between inflation and GINI.

Likewise, the results show that the coefficient value of GDP is 0.485 and the P value is 0.012, which describes that GDP has a significant positive impact on GINI, as a 1-unit increase in GDP will result in an increase of 0.485 units in GINI. On the contrary to this, FDI and employment have a negative relationship with GINI. The results show that the coefficient value of FDI is -0.986 and the p-value is 0.099, which indicates that FDI has a significant negative relationship with GINI. It implies that an increase of 1 unit in FDI will result in a decrease of 0.986 units in GINI. Likewise, the coefficient value of employment (EMP) is -1.233 and the p-value is 0.024, which indicates that employment has a significant negative relationship with GINI. It implies that an increase of 1 unit in EMP will result in a decrease of 1.233 units in GINI.

Table 5: Regression Analysis Considering GINI as a Dependent Variable

Variables	**Coefficients**	**Std. Error**	**Probability**
TRD	0.093***	(0.023)	0.001
INF	0.182**	(0.099)	0.066
GDP	0.485***	(0.193)	0.012
FDI	-0.986*	(0.688)	0.099
EMP	-1.233***	(0.544)	0.024
CONS	27.776***	(1.925)	0.000
Wald Chi2(5): 36.79	Prob. > Chi2: 0.000	R-squared: 0.74	

The main findings of this study suggest that there is a negative association between trade and poverty, and it is significant at the 0.001 level. The second most important component of poverty is economic growth (GDP), and there is also a negative connection between poverty and GDP, and it is significant at the 0.05 level. Among control variables, employment has a negative relationship with poverty, and it is significant at the 0.001% level. In addition to that, the other two variables, population and FDI, have a positive link with poverty, and both variables are highly significant. The second main finding of our study discusses the relationship between trade and inequality, and there exists a positive relationship between trade and inequality, and the variable is highly significant at the 0.000% level. In addition to that, we report a positive relationship between inequality and economic growth. The other control variable, inflation, has a positive relationship with inequality. Further, FDI and employment, have a negative relationship with inequality, and FDI is significant at the 0.099% level; also, employment is significant at the 0.024% level.

5. CONCLUSION AND POLICY IMPLICATIONS

The study analyzed the impact of trade openness and economic growth on both poverty and inequality in SAARC countries over the period 1990-2022. The empirical results indicated that trade openness, employment, and growth (GDP) significantly decreased poverty; while the population and FDI significantly increased poverty in SAARC countries. Furthermore, trade, GDP, and inflation significantly increased inequality, while FDI and employment significantly decreased inequality in SAARC countries for the sample period. The impact of trade on poverty and income inequality in SAARC countries presents a complex yet critical area of economic analysis. The empirical evidence indicates that trade significantly reduces poverty, suggesting that increased trade openness can create economic opportunities, enhance income levels, and improve living standards. This positive impact on poverty underscores the potential of trade as a powerful tool for economic development and poverty alleviation in the region.

The findings highlight a dual challenge for policymakers in SAARC countries. On the one hand, promoting trade can be an effective strategy for reducing poverty by creating jobs, increasing income, and fostering economic growth. On the other hand, the tendency of trade to increase income inequality calls for complementary policies to ensure that the benefits of trade are widely shared. This could include measures such as investing in education and skills development, improving access to credit and markets for small and medium-sized enterprises, and implementing social protection programs. In principle, trade is a crucial driver of economic development in SAARC countries; its impact on poverty and inequality underscores the need for balanced and inclusive policy approaches. By addressing the inequality exacerbated by trade, SAARC countries can harness its full potential to improve living standards and promote sustainable, inclusive growth. Governments should continue to promote trade openness as it is proven to reduce poverty. Policies that facilitate trade, such as reducing tariffs, improving trade logistics, and streamlining customs procedures, can help integrate SAARC countries more effectively into the global market. To mitigate risks and maximize benefits, SAARC countries should diversify their trade partners and export products. This diversification can help stabilize economies against global market fluctuations and ensure more consistent economic benefits.

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REFERENCES

Al Kez, D., Foley, A., Lowans, C., & Del Rio, D. F. (2024). Energy poverty assessment: Indicators and implications for developing and developed countries. *Energy Conversion and Management*, 307, 118324.

Atkinson, A. B. (2016). Inequality: What can be done? *Practice*, 40(2), 289-292.

Banday, U. J., Murugan, S., & Maryam, J. (2021). Foreign direct investment, trade openness and economic growth in BRICS countries: Evidences from panel data. *Transnational Corporations Review*, 13(2), 211-221.

Cerra, V., Lama, R., &Loayza, N. V. (2021). Links between growth, inequality, and poverty. *International Monetary Fund*, 68(c), 1-54.

Chaudhry, I. S., & Imran, F. (2013). Does trade liberalization reduce poverty and inequality? Empirical evidence from Pakistan. *Pakistan Journal of Commerce and Social Sciences*, 7(3), 569-587.

Dorn, F., Fuest, C., &Potrafke, N. (2022). Trade openness and income inequality: New empirical evidence. *Economic Inquiry*, 60(1), 202-223.

Freund, C., &Bolaky, B. (2008). Trade, regulations, and income. *Journal of Development Economics*, 87(2), 309-321.

Ghazanfar, U., Lodhi, R. N., Bandeali, M. S. M., & Khalil, A. (2021). An empirical relationship between trade liberalization and poverty: Comparative analysis of selected SAARC countries. *Studies of Applied Economics*, 39(2), 1-15.

Hwang, S. J. (2024). Subjective inequality in South Korea: Perception, belief, and discontent. *Research in Social Stratification and Mobility*, 89, 100875.

Kitole, F. A., &Sesabo, J. K. (2024). The heterogeneity of socioeconomic factors affecting poverty reduction in Tanzania: A multidimensional statistical inquiry. *Society*, 61(5), 560-574.

Kumari, R., Shabbir, M. S., Saleem, S., Yahya Khan, G., Abbasi, B. A., & Lopez, L. B. (2023). An empirical analysis among foreign direct investment, trade openness and economic growth: Evidence from the Indian economy. *South Asian Journal of Business Studies*, 12(1), 127-149.

Musila, J. W., &Yiheyis, Z. (2015). The impact of trade openness on growth: The case of Kenya. *Journal of Policy Modeling*, 37(2), 342-354.

Nam, H. J., & Ryu, D. (2024). Does trade openness promote economic growth in developing countries? *Journal of International Financial Markets, Institutions and Money*, 93, 101985.

Nam, H. J., Frijns, B., & Ryu, D. (2024). Trade openness and income inequality: The moderating role of institutional quality. *Global Finance Journal*, 60, 100959.

Ngubane, M. Z., Mndebele, S., & Kaseeram, I. (2023). Economic growth, unemployment and poverty: Linear and non-linear evidence from South Africa. *Heliyon*, 9(10), 1-16.

Ouni, M., Mraihi, R., Mrad, S., & El Montasser, G. (2025). Exploring the dynamic linkages between poverty, transportation infrastructure, inclusive growth and technology: A continent-wise comparison in lower-middle-income countries. *Journal of the Knowledge Economy*, 1-50.https://doi.org/10.1007/s13132-024-02516-5

Qayyum, A., Khawaja, I., & Hyder, A. (2008). Growth diagnostics in Pakistan. *European Journal of Scientific Research*, 24(3), 433-450.

Rahman, M. M., & Fang, C. (2020). Effects of food trade liberalization on poverty and inequality in Bangladesh: a partial equilibrium approach. *Journal of World Economic Research*, 9(1), 10-19.

Ranamagar, U. B. (2022). Causality Study of Trade and Economic Growth of Nepal. *Indian Journal of Economics and Finance (IJEF)*, 2(1), 10-16.

Siddiqui, K. (2012). Developing countries' experience with neoliberalism and globalization. *Research in Applied Economics*, 4(4), 12-37.

Tabash, M. I., Elsantil, Y., Hamadi, A., & Drachal, K. (2024). Globalization and income inequality in developing economies: A comprehensive analysis. *Economies*, 12(1), 1-16.

Ulaşan, B. (2015). Trade openness and economic growth: panel evidence. *Applied Economics Letters*, 22(2), 163-167.

Xia, W., Apergis, N., Bashir, M. F., Ghosh, S., Doğan, B., & Shahzad, U. (2022). Investigating the role of globalization, and energy consumption for environmental externalities: empirical evidence from developed and developing economies. *Renewable Energy*, 183, 219-228.

Zhu, Y., Bashir, S., & Marie, M. (2022). Assessing the relationship between poverty and economic growth: does sustainable development goal can be achieved? *Environmental Science and Pollution Research*, 29(19), 27613-27623.

Appendix A: Variable Description

Dependent Variables			
Variables	**Description**	**Measurement**	**Source**
Poverty	Number of people below the poverty line	Numbers	POVCAL (World Bank), 2019
Inequality	GINI	Index	World Bank
Independent Variables			
Trade	Openness	% of GDP	WDI, World Bank
GDP	Gross domestic product	Annual Growth %	WDI, World Bank
Control Variables			
Employment	Ratio to Population	% of population	WDI, World Bank
Population	Population growth rate	Annual%	WDI, World Bank
FDI	Net inflows	% of GDP	WDI, World Bank
Inflation	Inflation rate	Annual %	WDI, World Bank