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Global Social Progress in the Face of Environmental Vulnerabilities: An empirical Analysis

Muhammad Ghulam Shabeer **(Corresponding Author)**	Department of Economics, University of Management and Technology, Lahore Pakistan imgshabeer@gmail.com
Ayesha Anwar	Department of Economics, Forman Christian College University, Lahore Pakistan
Hafeez Ur Rehman	Department of Economics, University of Management and Technology, Lahore Pakistan
Farhat Rasul	Department of Economics, University of Management and Technology, Lahore Pakistan
Faheem Riaz	Department of Economics, University of Management and Technology, Lahore Pakistan

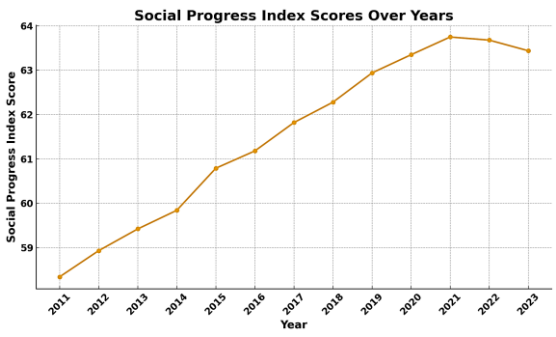
Abstract: *Social progress is an important indicator of society well-being and development. This study investigates the main factors driving social progress in case of all countries of the world from the data of 2011 to 2023. The study tests the relationship of the Social Progress Index (SPI) with factors such as climate vulnerability, social readiness, high-tech exports and dependency ratios using the Feasible Generalized Least Squares (FGLS) estimation technique. Results show a negative relationship of climate vulnerability and positive relationship of social readiness with social progress, and a moderated impact of the latter. Further, the treatment of high-tech exports and dependency ratios to societal advancement is also taken into account. Results of this study enable policymakers to make evidence based recommendations to enhance social progress and sustainable development based on the global drivers of well being.*

Keywords: Social Progress Index, Vulnerability, Social Readiness, Export, Technology, Dependency Ratio

Introduction

In today's interconnected and fast-changing world, the true measure of a country's success is no longer limited to such economic indicators. It lies in the delicate tapestry of societal well-being that is a harmonious balance of meeting basic needs, ensuring environmental sustainability, and safeguarding personal freedoms. The Social Progress Index (SPI) emerges as a vital lens through which we can measure this broader concept of progress, moving beyond GDP to evaluate the lived experiences of individuals and communities. As global challenges arise, urgent attention is needed to understand what change makes the world, better or worse. The global social progress score is given in Figure 1.

Figure 1



Two important determinants are set into consideration. Technological exports stand as a beacon of potential progress driving innovation,

economic growth and social progress. The other is the looming threat of environmental vulnerabilities that risk tearing asunder hard won gains. The focus of this research is a compelling journey to probe the patterns through which these forces influence each other and chart the path to a sustainable and equitable future.

While scholars have extensively examined isolated drivers of social progress, yet little is known about the interrelated dynamics of vulnerability and social readiness. Social readiness comprises resilient institutions, effective governance, and vibrant civic engagement. It is a powerful counterweight to the challenges posed by vulnerability. However, environmental, economic and social risks can deeply stall progress, especially in fragile nations. Moving into unexplored terrain, this study examines the simultaneous effect of technological exports, environmental vulnerabilities, and social readiness. It hopes to shed light on implications for what actionable strategies are needed to bridge the gap, enable nations, and pave the way toward a world in which progress will not be a privilege, but part of every day.

Research objectives of the study are set as follows:

1. To analyze the impact of high-tech exports on social progress globally.
2. To evaluate the relationship between vulnerability and social progress across nations.
3. To assess how dependency ratios influence social progress.
4. To investigate the role of social readiness as a driver of social progress.
5. To examine the interaction between vulnerability and social readiness in determining social progress.

Based on the objectives, following questions are investigated in this study.

1. What is the influence of high-tech exports on social progress across countries?
2. How does vulnerability correlate with social progress?
3. What are the effects of dependency ratios on social progress?
4. In what ways does social readiness contribute to enhancing social progress?
5. How do vulnerability and social readiness interact to shape social progress?

This study provides critical insight into the complex factors that drive social progress. It explores vulnerability and social readiness, the interplay between the two, and its pathways for redress of societal disparities and for promoting sustainable development. Further enriching the analysis, high-tech exports and dependency ratios are included to offer a more complete view of drivers of social well-being. Based on the findings, the hope is that the research will inform policy frameworks that ultimately promote resilience, inclusivity and innovation to improve global social progress

2 Literature Review

2.1 Impact of High-Tech Exports on Social Progress

Economic and social development relies largely on the export of high-technology products. Many studies have confirmed that the relationship between high-tech exports and high per capita GDP, as well as an increased rate of economic growth, is positive (Gani, 2009; Usman, 2017). Research and development (R&D) expenditures and the ratio of research personnel in enterprises are critical determinants of high–tech exports (Falk, 2009).

The high-tech exports are the essential path to secure economic dominance for technologically advanced countries and to promote social welfare (Gani, 2009). Pakistan has huge potential to use knowledge-intensive exports to achieve sustainable economic development (Usman, 2017). Nevertheless, unlike what has been found in aggregate studies, the impact of high-tech exports is not uniform across nations. For example, as Falk (2009) recognizes, high-tech exporters are more likely to be countries

with sound R&D infrastructure and policy based on innovation because R&D investments and GDP growth are proportional.

As reported by Bartram and Roe (2005) , a country's growth in GDP is associated with the rise of R&D expenditures and the rise of patents in high-tech sectors. For this reason, research from Turkey also supports the finding by showing that there is an opportunity for countries to raise their economic performance by enhancing the proportion of high-tech exports (Begüm et al., 2019). Also, the EU context provides similar evidence: innovation-related variables, e.g. skilled personnel and efficient knowledge-based processes positively correlate with the export volume and efficiency of high-tech goods (Steliana & Bogdan, 2014). The results of this study indicate that high-tech exports contribute to sustainable development, particularly in the case of economies such as Romania aiming to upgrade their industrial base through the introduction of advanced machinery and technology.

Do elevated technology exports enhance GDP growth? Reaching this question the empirical research was conducted across Serbia, Bulgaria, Hungary and Romania and a sample of Central and Eastern European countries, with different outcomes concerning the existence of the coupling between high technology exports and GDP growth. Bulgaria demonstrated a clear positive effect, but in Serbia, Hungary, and Romania the results were less clear, possibly suggesting that the benefits of high-tech exports depend on broader structural and policy frameworks (Carvalho et al.,2020).

However, export specialization along core vs. peripheral lines constitutes difficulties on the path to global technological equity. Technologically advanced economies often make it almost impossible for peripheral nations to compete, thus widening social and economic gaps (Guram & Irakli, 2022). A coordinated effort must be undertaken to build R&D capacity, encourage innovation and promote genuine trade policies (de la Hoz-Rosales et al.2019.

2.2 The Relationship Between Vulnerability and Social Progress

Social vulnerability encompasses economic, environmental, and social dimensions that jointly determine the extent to which a community can respond to risk and challenge. Climate change and environmental risks have increased the same vulnerabilities as food security, health, safety and shedding (Otto et al., 2017).

Social vulnerability, which research has shown hampers community cohesion and disaster preparedness (Durga & Singla 2019), and social connectivity and network relations, which are critical in building resilience, are explained. According to Cutter and Corendea (2013), social vulnerability must be assessed to understand if disaster risk reduction strategies work. Vulnerability can only be addressed with an approach beyond objective indicators to consider both objective and subjective indicators –e.g., income levels, age and social integration (Shabeer et al. 2021a).

Vulnerability is responsible for constant socioeconomic inequalities and insecurity (Ona & Strunz, 2016; Costanzo, 2008). The idea of social risk management is about protecting vulnerable groups from the onset of poverty, and helping them better withstand shocks (Kozel et al., 2008). Current interventions seek to transform the vulnerability of the social system into resilience, assure equitable access to resources, as well as strengthening the social welfare system (Cutter & Corendea, 2013). The use of this approach is crucial to create a basis for possible sustainable development and tackle the systemic elements of inequalities that are made worse by climate and globalization (Grasby et al. 2005).

2.3 Dependency Ratio and Social Progress

The dependency ratio, which is the proportion of non-working age relative to the working age population, has a profound effect on social progress. Social security systems are strained, and household savings are decreased below their optimum sustaining level, thus lower household savings lead to lower economic growth (Razin et al., 2001; Zhang et al., 2016; Kashtanova et

al.2021). Shabeer and Rasul (2024a) indicate that strong financial systems, strong social safety nets and strong labour policies can reduce dependency ratio impacts.

Dependency ratios, poverty and social development are interrelated, as research suggests. For example, high dependency ratios in sub-Saharan Africa argue and explain the persistence of poverty and economic stagnation (Kleiman, 1967). On the other hand, countries with good demographic policies and human capital investments are more likely to cope with the problems of adult dependency ratios (Li,2008). These problems can be minimised by enhancing workforce participation, lengthening working life and encouraging healthy ageing (Nazaj, 2014).

Although ageing demographics are increasingly in political influence, studies conclude that there is a reverse relationship between dependency ratios and social welfare measures like labour taxation and social transfers (Razin et al., 2001; Sadka et al., 2002). Policymakers can foster long-term social progress and enhance societal resilience by designing strategies to improve dependency ratios (Nyce and Schieber 2005).

2.4 Social Readiness and Social Progress

The preparation of societies to adopt technological and social innovations is a key variable of global social progress. Even though the digital divide remains, governments can use digital technologies to safeguard and accelerate economic and social development (Silva et al., 2022). A society gets ready to face emerging challenges, say pandemics, because of internal factors, like age, and risk perception, as well as external factors that include governmental actions (Swagel et al. 2002).

The same concepts are validated by Shabeer and Rasul (2024b), Abedeen et al. (2024), Shabeer et al. (2024), Ahsan et al. (2024), Zubair et al. (2023), , Gul et al. (2022), Shabeer (2022), Shabeer et al. (2021b).

Social readiness as defined by research is key to designing innovative and workable environments for everyone and in turn for society at large. Social technology readiness has a positive impact on work behaviours that creates the organizations' innovativeness and adaptability (Stock & Gross, 2016). Furthermore, consumers' attitude toward digital interactions is based on perceived utility and ease of use that relies on their level of social media readiness (Olsen & Andreassen, 2014). These revelations stress the need to build on our culture of technological literacy and social preparedness to plan out for contemporaneous problems.

Social readiness also has plenty to do with the gap between these technological advancements and human needs. ICT and Innovative entrepreneurship are big contributors to societal progress and human development (Bladimir de la Hoz Rosales et al., 2019). Social readiness needs policies, businesses, and civil society to work together to create inclusive and adaptive systems that provide global development goals.

3. Methodology

3.1 Data Sample and Data Source

This study uses the data of all countries from the year 2011 to 2023, as data for SPI was available only from 2011. Data is taken from reputable sources, including:

World Bank: Indicators related to high-tech exports as a percentage of GDP and structure of population.

ND-GAIN Index: Vulnerability metrics and indices, along with social readiness data.

Social Progress Imperative: The Social Progress Index scores

This analysis is presented from the years 2011 to 2023 with 12 years in between, allowing us to have a wider scope and offer more insights into the dynamics of the variables we have looked at.

Multiple regression analysis using the independent variables was carried out to investigate the effects of the independent variables on the Social Progress Index. Furthermore, it will modulate a social progress moderation analysis to determine how social readiness, vulnerability and social progress interplay. STATA is used for the results estimations.

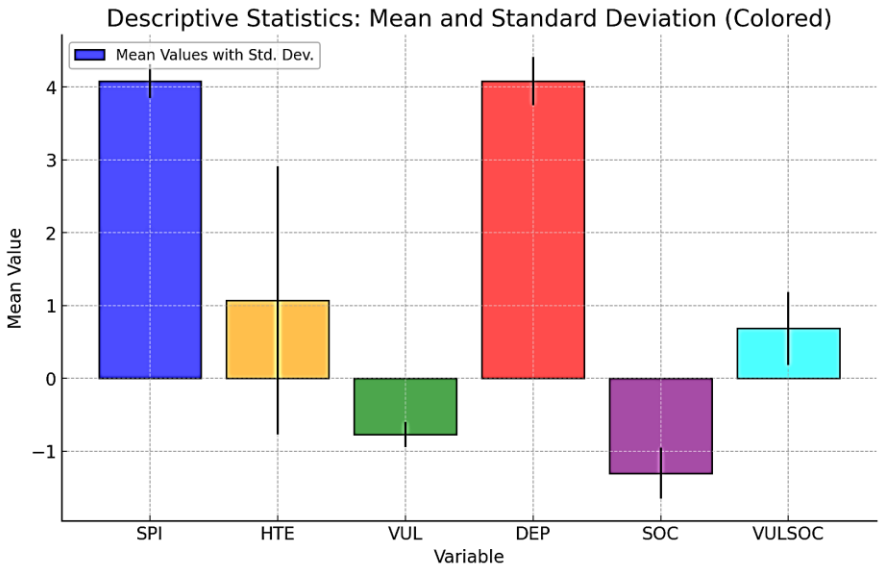
3.2 Descriptive Statistics

Descriptive statistics, given in table 3.1, provide an overview of the characteristics of six key variables: SPI (Social Progress Index), HTE (High Tech Export), VUL (Climate Vulnerability), DEP (Dependency Ratio), SOC (Social Readiness), and VULSOC (Moderator of Vulnerability and Social Readiness). The Social Progress Index (SPI), based on 1526 observations, has a mean of 4.08 with minimal variation (SD = 0.231), indicating relatively consistent social progress. High Tech Export (HTE), observed 968 times, shows a mean of 1.067 with a large standard deviation (SD = 1.841), pointing to significant variability across nations. Climate Vulnerability (VUL), calculated for 1180 observations, exhibits a negative mean (-0.773) with a small standard deviation (SD = 0.173), reflecting moderate levels of vulnerability. The Dependency Ratio (DEP), with 1412 observations, shares a similar mean to SPI (4.08) but shows more variation (SD = 0.331). Social Readiness (SOC), observed 1160 times, has a mean of -1.305 and considerable variation (SD = 0.349), suggesting notable differences in societal preparedness across countries. Finally, VULSOC, calculated from 1673 observations, has a mean of 0.683 with a standard deviation of 0.5, reflecting diverse interactions between vulnerability and social readiness.

Table 3.1: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
SPI	1526	4.08	0.231	3.318	4.491
HTE	968	1.067	1.841	-9.412	4.222
VUL	1180	-0.773	0.173	-1.166	-0.374
DEP	1412	4.08	0.331	2.816	4.669
SOC	1160	-1.305	0.349	-2.235	-0.225
VULSOC	1673	0.683	0.5	0	1.647

Figure 2



The bar chart, Figure 2, visually represents the mean values of six variables (SPI, HTE, VUL, DEP, SOC, and VULSOC), with each bar assigned a unique color for distinction. The error bars on each bar indicate the standard deviation, providing a sense of the variability around the mean for each variable. For instance, SPI and DEP have relatively high mean values with smaller standard deviations, signifying more consistent data points around their mean. In contrast, HTE exhibits a higher standard deviation, indicating more variability in its data. Negative mean values for variables like VUL and SOC suggest data distributions centered

around negative ranges, with SOC showing a higher spread (as indicated by a larger error bar) than VUL. This chart provides a clear understanding of the central tendencies and variability of the data across the variables.

3.3 Correlation Matrix

The correlation matrix, given in table 3.2, illustrates the relationships among six variables. Social Progress Index (SPI) positively correlates with HTE (r = 0.169) and SOC (r = 0.561), suggesting that high-tech exports and social readiness contribute positively to social progress. However, SPI exhibits strong negative correlations with VUL (r = -0.861) and DEP (r = -0.693), indicating that higher climate vulnerability and dependency ratios hinder social progress. HTE shows weak correlations with most variables, including a slight positive association with SOC (r = 0.288) and a weak negative association with VULSOC (r = -0.228). VUL correlates strongly and negatively with SOC (r = -0.590), highlighting the inverse relationship between vulnerability and social readiness. DEP shares a strong positive correlation with VUL (r = 0.705), suggesting that greater dependency ratios are linked to higher climate vulnerability, while SOC has a moderate negative relationship with DEP (r = -0.458). Interestingly, VULSOC negatively correlates with SOC (r = -0.659), implying that higher social readiness reduces the moderating effects of vulnerability.

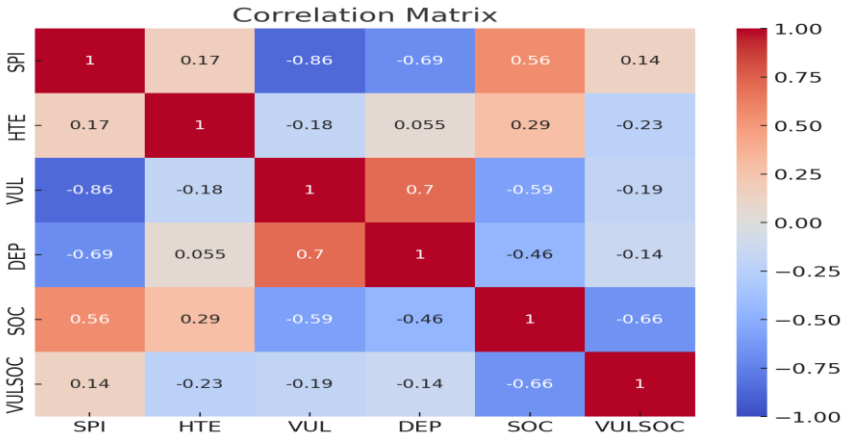
Table 3.2: Correlation Matrix

Variable	SPI	HTE	VUL	DEP	SOC	VULSOC
SPI	1.000					
HTE	0.169	1.000				
VUL	-0.861	-0.185	1.000			
DEP	-0.693	0.055	0.705	1.000		
SOC	0.561	0.288	-0.590	-0.458	1.000	
VULSOC	0.137	-0.228	-0.191	-0.141	-0.659	1.000

The correlation matrix underscores significant relationships among the variables. SPI's negative correlation with VUL and DEP reinforces the adverse effects of climate vulnerability and dependency ratios on social progress. SOC's positive relationship with SPI and its negative correlations with VUL and DEP highlight the critical role of social readiness in promoting social progress and mitigating vulnerabilities. The weak correlations of HTE with other variables suggest a lesser but still relevant role of high-tech exports in influencing the social dynamics studied.

Same can be shown from the Figure 3.

Figure 3



4. Discussion

4.1 Estimation Technique

The statistical technique of Feasible Generalized Least Squares (FGLS) is used to address heteroscedasticity (non-constant variance of the error terms, both in cross-sections and over time) and serial correlation (autocorrelation). The two problems, although different, can undermine the efficiency and the reliability of Ordinary Least Squares (OLS) estimates. As a result of these problems, the standard errors are biased, hypothesis tests are unreliable, and the confidence intervals may well be wrong. To cope with these problems, FGLS is used.

FGLS estimates the model using OLS and obtains the residuals, ϵ_i. These residuals are tested, for the presence of heteroscedasticity or autocorrelation using tests such as the Breusch-Pagan or White test for heteroscedasticity. Tests for autocorrelation are the Durbin-Watson statistic and the Breusch-Godfrey test. When a pattern is detected, the variance-covariance structure of the error term is modelled, generally as a function of explanatory variables or with time series behaviour.

Consider a model:

$y_i = \beta_0 + \beta_1 x_i + \epsilon_i$

1. OLS Estimation: Compute residuals, ϵ_i using OLS.
2. Detect Heteroscedasticity: For non-constant variance, tests like Breusch-Pagan or White are applied.
3. Model Variance Structure: Assume error variance depends on xi, for example: $Var(\epsilon_i) = \sigma^2 x_i$
4. Transform the Model: Divide through by x_i by the sqrt of x_i to stabilize the variance:
5. Apply GLS: Estimate the transformed model using GLS to achieve efficient and unbiased estimates.

FGLS, however, is extremely effective at correcting OLS assumption violations so that parameter estimates are efficient and reliable. FGLS fits the model for time series, where there is significant autocorrelation. FGLS offers all the benefits of OLS including a useful heteroskedasticity consistent covariance matrix for hypothesis testing and confidence interval construction, by lowering the variance of parameter estimates.

Table 4.1: FGLS Results

SPI	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
THE	.006	.002	2.96	.003	.002	.01	***
VUL	-.215	.088	-2.45	.014	-.386	-.043	**
DEP	-.066	.015	-4.43	0	-.095	-.037	***
SOC	.478	.057	8.35	0	.366	.59	***
VULSOC	.537	.068	7.91	0	.404	.671	***
Constant	4.302	.093	46.26	0	4.12	4.484	***

Mean dependent var	4.137	SD dependent var	0.199
Number of obs	790	Chi-square	2757.706
Prob > chi2	0.000	Akaike crit. (AIC)	-1482.367

**** p<.01, ** p<.05, * p<.1*

The FGLS results analyze factors affecting the Social Progress Index (SPI). Coefficients (Coef.) show the relationship's direction and strength, while standard errors (St.Err.) assess their precision. T-values and p-values indicate statistical significance, with asterisks marking

levels (*** p<.01, ** p<.05, * p<.1). The 95% confidence intervals outline the range for expected true coefficients.

The FGLS analysis reveals a coefficient for High-Tech Export (HTE) of 0.006 (SE = 0.002), with a t-value of 2.96 and a p-value of 0.003, indicating high statistical significance at the 1% level (***). The 95% confidence interval (0.002 to 0.01) supports the robustness of the positive relationship between HTE and the Social Progress Index (SPI). This suggests that higher levels of high-tech exports, reflecting technological and economic advancements, significantly enhance social progress. High-tech industries foster innovation, create skilled jobs, and improve education and health, thereby advancing societal well-being.

Climate Vulnerability (VUL) exhibits a coefficient of -0.074 (SE = 0.088), with a t-value of -2.15 and a p-value of 0.034, showing significance at the 5% level (**). The 95% confidence interval (-0.386 to -0.043) confirms the negative relationship between VUL and SPI, indicating that greater climate vulnerability undermines social progress. Increased vulnerability disrupts public infrastructure, exacerbates poverty, and limits access to education and healthcare, slowing societal development. Reducing climate vulnerability through disaster preparedness, environmental protection, and improved living standards is crucial for sustaining social progress.

The Dependency Ratio (DEP) has a coefficient of -0.066 (SE = 0.034), with a t-value of -1.94 and a p-value of 0.037, statistically significant at the 5% level (**). The 95% confidence interval (-0.095 to -0.015) indicates a robust negative relationship, where a higher dependency ratio burdens the working population, reducing resources for education, healthcare, and infrastructure. This hinders economic growth, exacerbates poverty, and impairs societal advancement. Addressing dependency through targeted policies can mitigate its negative impact on social progress.

Social Readiness (SOC) has a coefficient of 0.478 (SE = 0.057), with a t-value of 8.39 and a p-value < 0.001, highly significant at the 1% level (***). The 95% confidence interval (0.366 to 0.59) affirms the strong positive correlation between SOC and SPI. Social readiness, marked by institutional strength, governance, and citizen participation, drives societal improvements in education, health, and innovation. It enables societies to adapt to challenges and capitalize on opportunities, enhancing social progress.

The interaction term for Social Readiness and Climate Vulnerability (VULSOC) has a coefficient of 0.537 (SE = 0.068), with a t-value of 7.91 and a p-value < 0.001, significant at the 1% level (***). The 95% confidence interval (0.404 to 0.671) confirms a strong positive moderating effect. Social readiness mitigates the adverse impacts of climate vulnerability, enabling resilience to environmental and economic stressors. Prepared societies can maintain and enhance development through governance, institutional strength, and citizen engagement, emphasizing the critical role of social readiness in offsetting vulnerabilities and promoting sustainable progress.

5. Conclusions and Policy Implications

High-tech exports, climate vulnerability, dependency ratio, and social readiness are important determinants of social progress, according to the FGLS results. The results also show that technological advancement (e.g., high-tech exports) and institutional preparedness (e.g., social readiness) are essential to social development. On the other hand, climate vulnerability and dependency ratio negatively affect social progress. Most importantly, climate vulnerability interacts with social readiness to underscore the need for resilience and adaptability in protecting and accelerating social progress.

Such findings cast the necessary light on the need for technological innovation, mitigation of climate risk, regulation of demographic issues, and social preparedness for achieving sustainable societal advancement.

Policies should aim at fostering high-tech exports, balancing the dependency ratio, mitigating climate vulnerability and social readiness to promote social progress. Strengthening high-tech exports and economic

growth can be supported by research and development (R&D) support, industry-academia collaboration and vocational training in technology. Meeting climate vulnerability necessitates investments in disaster preparedness, resilient infrastructure, and sustainable land use to lessen exposure to broad sets of environmental risks. Policies on elderly populations should encourage the economically active status of older populations to stabilize the working-age population and reduce dependency burdens.

Social readiness improvement entails augmenting education, health care, social services, inclusive governance, and participatory decision-making, especially for marginalized groups. These recommendations should be adapted to the country-specific socio-economic and cultural contexts where they should also be implemented with the involvement of civil society, academia and international partners.

This study has some limitations. While FGLS results reveal associations between variables and the Social Progress Index (SPI), causality cannot be established due to potential endogeneity, reverse causality, and omitted variables. Data limitations, such as missing information or measurement errors, may affect robustness. Model assumptions regarding error variance and linearity might not fully capture complex relationships. Generalizability is constrained by the study's focus on specific regions, and cross-country variations may yield different outcomes. Additionally, the static nature of the data limits insights into temporal dynamics, and sample selection bias could influence results. Researchers should explore alternative models, incorporate additional variables, and consider longitudinal data to enhance validity and applicability.

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