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EFFECT OF FOREIGN DIRECT INVESTMENTS AND ADVANCEMENTS OF TECHNOLOGY ON CARBON DIOXIDE EMISSION IN SOUTH ASIAN COUNTRIES

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ABSTRACT

Foreign Direct Investments (FDI) and Technological Advancements (TA) are significant driving forces of economic growth. However, the consequences of the FDI and TA on the environment remain controversial due to the contradictory findings of the empirical studies. Therefore, this study examined the short-run and long-run impacts of FDI and TA on the Carbon Emissions (CO_2) of South Asian countries. The sample consisted of six South Asian countries and data were collected for 19 years from 2000 to 2018. The three-panel ARDL models namely, Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed Effect (DFE) estimations were used as main panel data analysis tools. The findings indicated that the rapid advancement of technology and the rise in foreign direct investment (FDI) contribute to a rise in long-term CO_2. However, there is no noteworthy relationship between CO_2 and FDI or TA)in the short term. The main findings of this research deliver key policy directions for South Asian nations to consider. The conclusions demonstrate and emphasize the significance of establishing policy frameworks and guidelines for the elimination or effective management of CO_2emission. Additionally, this study suggests the need for greater investment in research and development of technological innovations aimed at reducing CO_2. Furthermore, it highlights the importance of adopting a unified policy stance to achieve long-term sustainable development goals within the region.

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1. Introduction

Moving towards sustainable economic goals, creating a green economy, and uplifting environmental quality have become the top priorities in the last couple of decades. The stage of development theory by Kuznets and Rostow (1970) explains the importance of economic growth to a country. Economic growth leads to eradicating poverty, and income inequality, and the development of the industrial sector and financial system is vital to achieving economic growth.

A main source of funding for the industrial sector is FDI. In addition to the funds, FDI generates room for industrial startups, buys new machinery, motivates innovations, transfers technology, promotes research and development, and many more through transferring technological assistance, human capital transferring, and new operational techniques (Abdouli & Hammami, 2017). Furthermore, FDI contributes to the financial development of the host country. It brings capital resources to host countries; which leads to the development of capital markets, banking systems, financial institutions, and financial intermediary services.

However, economic development creates many unprecedented and unsolved matters for humans and other organisms. By Engle's Law (1857), the economy grows when individuals spend a lower share of their income on necessities and more on luxuries. This increases the demand for energy at a lower cost, eventually leading to the use of low-cost natural energy sources such as charcoal and fusain. Scholars have discovered that CO_2 emanations and growth in the economy exhibit an inverted U-shaped relationship (Lorente & Álvarez-Herranz, 2016). This has been well explained by the Environmental Kuznets Curve (EKC) by Kuznets in 1955. According to EKC, until a country reaches the threshold of economic development, rising per capita income causes a high carbon emission to the environment. Hewage et al., (2022) emphasized that the rapid development of economies leads to high environmental degradation, and the researchers found that ASEAN countries followed the EKC curve and that environmental pollution has increased with the economic development in ASEAN countries.

Based on these theoretical perspectives, researchers highlight that FDI is quite essential in impairing environmental pollution. Empirical findings suggest that some developed countries make direct investments in pollution-intensive industries in developing countries which results in high greenhouse gas emissions and dumping (Shahbaz, Nasir, & Roubaud, 2018; Aydemir & Zeren, 2017). Further to FDI,TA is also identified as a vital factor when discussing economic development and environmental pollution. Even though TA brings many economic benefits to society, it has several negative environmental effects including higher carbon emissions in industries (Paramati et al., 2021).

In contrast, another line of researchers emphasizes the opposing viewpoint where they argue that FDI and TA spur CO_2emi. According to the halo hypothesis, FDI and TA motivate green innovations and zero carbon emission projects, fund research and development activities in the industrial sector to move towards environmentally friendly energy sources, green technologies, and renewable energy usages that eventually decrease the environmental degradation (Aydemir & Zeren, 2017; Shahbaz et al., 2016). Moreover, advancements in technology within the industrial sector result in the more efficient utilization of energy, leading to reduced consumption of energy and enhanced quality of the environment (Abbasi & Riaz, 2016; Saud et al., 2018; Zafar et al., 2019).

The impact created by the FDI, as well as TA on the degradation of the environment, has been a subject of extensive discussion in finance and environmental studies. Consequently, this study aims to explore the connection between FDI, TA, and CO_2 emissions in South Asian nations. The study focuses on the South Asian region since it has strategic importance to the world economy as the Indian Ocean bridges the East Asia Pacific region and African Middle East region. According to the 2019 report by the Asian Development

Bank, South Asia has emerged as the world's fastest-growing sub-region since 2014, with an average annual economic growth of 7% until 2018. According to the latest Asia Economic Focus report published by the World Bank, the projected average economic growth in 2022 was 5.3% irrespective of the Covid-19 outbreak and the global economic crisis (United Nations, 2022). Moreover, all Asian countries except Afghanistan, Nepal, and Bhutan are in middle-income status. Hence, the outcomes of this study hold crucial strategic importance for policy decision-makers in shaping sustainable environmental and economic development policies for South Asian countries.

2. Literature Review

The exploration of the interplay between FDI and TA in CO2emi has brought substantial scholarly interest in both theoretical and empirical literature for several decades. Consequently, the literature review can be divided into two main aspects: the examination of the connection between FDI and CO_2 emissions, and the analysis of the relationship between TA and CO_2 emissions.

Relationship between Foreign Direct Investments and Carbon Dioxide Emissions

Even though FDI results in many advantages to the host countries such as the transfer of technology, a case for financial development, investment for the industrial sector, and transfer the of human capital and technology, it also causes environmental degradation. Therefore, the empirical literature demands a comprehensive study to address how FDI relates to environmental degradation, investment in renewable energy projects, and usage of natural energy sources. Hence, there is a handful of studies have been carried out in the last couple of decades concerning the effect of FDI on CO_2emi.

According to various scholars (Ganda, 2020; Salahuddin et al., 2018; Shahbaz et al., 2018; Behera & Dash, 2017), there is a positive relationship between FDI and CO_2 emissions. The Neoclassical trade theory supports this argument by suggesting that developing countries, in their pursuit of attracting FDI, tend to have lower environmental regulations to encourage more foreign investments (Shahbaz et al., 2015). In contrast, developed countries impose stringent environmental regulations to combat environmental pollution (Abdouli & Hammami, 2018).

Another school of thought argues that FDI reduces CO_2 emissions (Khan et al. 2021; Sung et al., 2018). Even though renewable energy sources are considered environmentally friendly projects, most countries are not interested in shifting over to these energy sources due to the high initial cost of establishing those renewable energy sources (Khan et al. 2021). Thus, FDI can be used as a key funding source to invest in such green technology projects, promote innovations to improve the productivity of raw materials and plants, and do research and development to find new renewable energy sources, that result in improved environmental quality (Ganda, 2020).

Impact of Technological Advancements on Carbon Dioxide Emission

TA is one of the vital factors when focusing on the environment and its quality. The innovations in the industrial sector may cause to increase in CO_2 emission because some innovations in the industrial sector may reduce the production cost but increase the use of natural resources elevating CO_2 emission (Khan et

al., 2021; Ozatac et al., 2017; Lorente & Álvarez-Herranz, 2016). Further, innovations in the consumable goods sector create changes in the consumption patterns of customers. Hence, people move towards using luxury goods like automobiles, air conditioners, refrigerators, washing machines, and heaters that utilize more energy and emit carbon dioxide (Salahuddin et al., 2018; Salahuddin & Gow, 2019). Moreover, to fulfill the increasing energy requirement, countries have to produce more energy using low-cost natural energy sources which also leads to many unprecedented matters to environmental quality.

Meanwhile, some researchers argue that TA alleviates CO_2 emissions. They state that investing in research and development of green technologies in products and production processes deteriorates carbon emissions by creating sustainable ecological technologies in the production sector (Othman et al., 2022; Liu & Song, 2020; Ardito et al., 2019; Jebli et al. 2019; Balsalobre-Lorentea et al., 2018; Alvarez-Herranz et al., 2017; Lorente and Álvarez-Herránz, 2016). Moreover, the scholars promote investigations to develop technology for using alternative environmentally friendly raw materials in the production process that dilutes carbon emissions. For instance, the scholars suggest introducing technology to carbon dioxide as a raw material to create bi-products, reduce resource consumption, increase the reusability and recyclability of products, and eco-friendly waste disposable techniques (Salem et al., 2020; Chiou, et al., 2011) .

However, the findings of previous studies claim that technological development alone could not reduce CO_2emi, but the imposition of rules mandating the use of renewable eco-friendly energy sources for production, green marketing techniques, and environmentally sustainable transport methods for delivering goods and services, as well as educating customers about the environmental benefits of using these products and encouraging them to buy ecological products are also important to prevent the carbon emission (Paramati et al., 2021; Xu et al., 2021; Khan, et al. 2021; Alvarez-Herranz et al., 2017). The existing literature concerning the South Asian region lacks consensus on the effects of FDI and TA on environmental quality. Hence, this study aims to investigate on this gap by examining the relationship between FDI, TA, and CO_2 emissions.

3. Research Methodology

Identification of Variables and Data Sources

The study used six South Asian countries namely Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka, and 19 years from 2000 to 2018 as the sample. The study purposefully excluded the last three years (2019, 2020, and 2021) since the authors considered it difficult to measure the exact influence of selected variables during the Covid 19 pandemic.

The measurement of carbon dioxide emissions was represented by the metric tons of carbon dioxide emission per capita. FDI was quantified as the net foreign direct inflow as a percentage of GDP. TA were measured using the technological achievement index. The specific variables and their respective proxies, along with the collected data sources, are summarized in below Table.

Table 1: Key Variables

Variable Name	Proxy and the Calculation Mechanism	Data Collection Source
Carbon Dioxide Emission (CO_2emi)	Carbon dioxide emission (metric tons per capita)	World Development Indicators (WDI, 2021)
Foreign Direct Investments (FDI)	Foreign Direct Investments are proxied by net foreign inflows as a percentage of GDP	World Development Indicators (WDI, 2021)
Technological Advancement (TA)	Technology Achievement Index (TAI) which includes patents granted per capita, receipts of royalty and license fees from abroad per capita, internet users per 100 people, high technology exports, electricity consumption, telephone subscribers, gross enrolment ratio, and gross enrolment in science	European Patent Office (EPO), World Development Indicators, International Telecommunication Union (ITU), United Nations Development Programme (UNDP)

Source: Authors constructed with previous literature

Model Specification

The study used Equation (1) as the main model to examine the impact of FDI and TA on carbon emissions in South Asian countries. Here the response variable is carbon emissions while FDI and TA play the explanatory role. According to Ganda (2020) and Salahuddin et al., (2018), FDI has a significant positive influence over the high carbon emission.

However, Khan et al. (2021) and Sung et al., (2018) argued that the impact of FDI on CO_2 emission get changes accordingly when countries invest in green technology. Therefore, they argue that when investing in eco-friendly projects with FDI, there is a negative association built between FDI and carbon emission.

Moreover, TA is one of the vital factors causing environmental degradation. Thus, intellectuals claim that most of the TA projects in the industrial sector lead to an increase in carbon emissions since they highly focus only on improving productivity and efficiency and reducing production costs (Kong, 2021; Saud et al., 2018). Therefore, Kong (2021) highlighted that countries must focus on eco-friendly raw materials, and renewable energy sources for the production sector and should use green marketing technologies, environmentally friendly transportation sources, and eco-friendly consumable products (Murshed et al., 2021; Ganda, 2020). Furthermore, Murshed et al., (2021); Liu & Song, (2020) stress that motivating eco-friendly projects and promoting eco-friendly innovations causes reduced wastage and carbon emission.

$$〖CO_2 emi〗_it=∝_0+ ∝_1 〖fdi〗_it+∝_2 〖tech\_adv〗_it+ε_t \quad (1)$$

Where; CO_2emi indicates the carbon dioxide emission, FDI represents the foreign direct investments, and TA shows the Technological Advancements while ε denotes the error term. The study used panel data analysis with unrestricted specification. Here, 'i' represents the cross-sectional country (six South Asian countries), and 't' denotes the respective time.

Construction of the model

The techniques namely; Fully Modified Ordinary Least Squares (FMOLS), and panel Dynamic Ordinary Least Squares (DOLS) are available to measure the long-run and short-run effect of explanatory variables over the regressor variable. However, there are many limitations to using the Dynamic Ordinary Least Squares (DOLS) model since it does not cater to endogeneity among the variables. Therefore, the study moved toward the dynamic panel data analysis techniques. There are many techniques to examine the relationship between explanatory and predecessor variables. This study used three-panel ARDL models named; Pooled Mean Group (PMG) (Pesaran et al., 1999), Mean group (Pesaran & Smith, 1995), and Dynamic Fixed Effect (Pesaran et al., 1999) to investigate the short and long-run relationship between CO_2emi with FDI and TA in South Asian countries. The PMG technique enables the identification of the long and short-run effects with the convergence of the parameters because it assumes that the long-run coefficients are identical but differ across the cross-sections in the short-run and heterogeneity bias. The study employed the PMG technique to estimate how explanatory variables affect the regressor while fixed effect and mean group estimation techniques were utilized for comparison purposes.

Cross-sectional Dependency

This test was used to measure the interdependency of the cross-sectional data. Since it is obvious that cross-sectional dependency in panels is common given the countries have linked in several ways like free trade agreements, spillovers, share market transactions, investments, and market capturing, analysis is done without testing the cross-sectional dependency makes the results biased. Therefore, this study used Breush-Pagan's (1980) LM test, Pesaran's (2004) scaled LM test, Baltagi, Feng, and Kao's (2012) bias-corrected scaled LM test, and Pesaran (2004) to estimate the cross-sectional dependency.

Panel Unit Root Test

To ensure the reliability of test results, this study employed second-generation cross-sectional dependency panel unit root tests. It is crucial to select the most appropriate unit root test, as highlighted in previous research (Zafar et al., 2019; Paramati et al., 2017). The use of first-generation unit root tests may not be reliable when there is a cross-sectional dependency that is not accounted for. Thus, the study utilized the Cross-sectional dependency Im-Pesaran-Shin (CIPS) test and the Cross-sectional Augmented Dickey-Fuller (CADF) test to test for unit roots. The CIPS test incorporates lagged cross-sectional individual means values to control for the influence of common factors across the cross-sections.

Hausman Test

To determine the appropriate model for estimating the short-run and long-run effects, the Hausman test was employed. The test results were as

sessed by comparing the probability value with the predetermined confidence level (0.05). If the probability value is higher than the confidence level, the PMG model can be considered the suitable choice for estimation.

4. Analysis and Discussion

Descriptive Statistics

Descriptive statistics were obtained to get an insight into the selected variables, and shown in Table 02. As per the results, the mean value of carbon emission is 0.998 metric tons per capita, and the standard deviation is 0.869. The maximum carbon emission was reported by Maldives (3.703675 metric tons) in 2018 and the minimum was 0.101 reported by Nepal in 2006. The average FDI during the sample period was 2.072 percent of GDP with a standard deviation of 2.760. The maximum FDI percentage was reported in 2011 by the Maldives and the recorded amount was 15.266 while the minimum was reported by Nepal in 2002. Further, the highest Technological Achievement index has been reported by the Maldives in 2018. The mean index was 0.3182 and the standard deviation was 0.0735.

Table 2: Descriptive Statistics

Vari.	Mean	Median	Max.	Mini.	Std. Dev.	Skew.	Kurt.
CO_2emi	0.998	0.759	3.704	0.101	0.869	1.403	4.315
FDI	2.072	1.103	15.266	-0.098	2.760	2.479	9.111
TA	0.080	0.067	0.318	0.000	0.073	1.362	4.535

Source: Authors constructed using E-Views output

According to the table results, all the variables have mean values greater than their median and more than one indicates the data set is positively skewed or tailed to the right. Kurtosis represents the degree of outliers in the distribution, and as per the analysis results, all the variables have taken more than 4 kurtosis values. Hence it can be concluded that variables are patterning the Leptokurtic distribution.

Correlation

Correlation Metrix shows the association of CO_2emi with independent variables, FDI and TA. The test results for correlation are illustrated in Table. According to the results table, CO_2 emission shows a significant strong positive correlation with FDI and TA.

Table 3: Correlation Metrix

Correlation Probability	CO_2EMI	FDI	TA
CO_2EMI	1.000		

FDI	0.872	1.000	
	0.000	-----	
TA	0.738	0.638	1.000
	0.000	0.000	-----

Source: Authors constructed using E-Views output

Multi Collinearity Test

The study utilized the Variable Inflation Factor (VIF) analysis to test the multi-collinearity among the explanatory variables. As per the results in Table 04, the VIF values are less than five and the tolerance value (1/VIF) values are above 0.2 which highlights the absence of the multicollinearity issue in the data set used in the study.

Table 4: Multi-collinearity

Variable	VIF	1/VIF
FDI	1.69	0.592
TA	1.69	0.592
Mean VIF	1.69	

Source: Authors prepared with E-Views output

Cross-sectional Dependency

The test results in Table 05 demonstrate the presence of cross-sectional dependency within the panels. Various tests, including the Breush-Pagan (1980) LM test, Pesaran (2004) scaled LM test, Baltagi, Feng, and Kao (2012) bias-corrected scaled LM test, and Pesaran (2004) CD test, were employed to assess cross-sectional dependency. The null hypothesis of no cross-sectional dependency was rejected in favor of the alternative hypothesis of cross-sectional dependency, with all tests indicating a significant level of cross-sectional dependency at the 1% level.

Stationarity in the data set in this study was measured using the CIPS and CADF (Pesaran,2007). It proves that there is a cross-sectional dependency using the first-generation unit root test and is not reliable. Therefore, it requires utilizing the second-generation unit root tests. Table 06 shows the results of the unit root test. CIPS indicates that CO2emi is not stationary at level but shows that there is no unit root at its 1st difference opening to move forward with PMG, MG, and DFE techniques. Further, CIPS illustrates that FDI and TA are stationarity at their level and the 1st difference. However, CADF states both explanatory variables

have the unit root at their level but are stationary at the 1st difference. Therefore, following Sohag and Bamanga (2018) there is no obligation to use ARDL, PMG, MG, or DFE methods when the independent variable gets stationary at its first difference but the dependent variables are stationary at either level or first difference.

Table 5:Cross-sectional Dependency

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
CO_2emi	209.977***	35.600***	35.431***	14.430***
FDI	42.750***	5.066***	4.900***	3.761***
TA	230.995***	39.435***	39.268***	15.180***

show significance at the 1%, 5% and 10% levels.

Source: Authors constructed using STATA output

Unit Root Test

Table 6:Unit Root Test

Variable	CIPS		CADF	
	Level	First Difference	Level	First Difference
CO_2emi	-1.276	-2.509**	-1.546	-4.663***
FDI	-2.944***	-3.840***	-2.560	-4.493**
TA	-2.228*	-3.670***	-0.998	-4.678***

Source: Authors constructed using STATA output

Panel Data Estimation

The study used the MG, PMG, and DFE models to estimate the short-run and long-run association, and the results are shown in Table 07 with the respective parameter values. Further, the Hausman test was employed and the results are shown in Table 08. According to the Hausman test results, PMG can be used for further analysis, and therefore, the study used PMG analysis as the main model along with MG and DFE methods for comparison purposes.

The explanatory variables of interest are FDI and TA, and the results indicate that both variables are significant in explaining the CO_2emi. Accordingly, the findings reveal that FDI ($\beta = 0.053$, $p = 0.011$) and TA ($\beta = 5.660$, $p = 0.000$) positively and significantly influence carbon emission in the long run. However, none of the variables influences CO_2 emission in the short run, and therefore, it is statistically evident that the influence of the FDI and TA on the environment takes a long period. Further, the Pooled Mean Group model suggests that a one percent increase in net FDI to GDP causes the carbon emission to increase by 0.0532

metric tons. This significant positive impact is consistent with the studies conducted by scholars in different contexts (Ganda, 2020; Salahuddin et al., 2018; Shahbaz et al., 2018; Behera & Dash, 2017). Nevertheless, Khan et al., (2021) and Sung et al., (2018) have suggested contrasting opinions, where they suggest the significant negative influence of FDI on CO_2 emission. The coefficient for TA in the long run is 5.66 which implies that an increase of one unit in TA makes the CO_2emi to be increased by 5.66 metric tons and it corroborates the findings of Chishti et al., (2021), Liu and Song (2020) and Sulaiman et al., (2020).

The model revealed that, in the short run, there is an insignificant influence by both independent variables on CO_2 emission. In general, FDIs are large-scale projects that are long-term in nature, and therefore, the industrial sector may not depict significant positive or negative impacts in the short term. Similarly, technological advancements require time to adapt and produce results, causing FDI and TA to have minimal or no short-term effects. This generalizes the insignificant influence of FDI and TA in the short run.

The reported speed of adjustment (convergent coefficient) shows a significant negative value of less than 1 (-0.1933256) as expected. That indicates it will take approximately 5 years (1/0.193) to correct the disequilibrium since the study has used annual data, in other words, it shows how long it will take to dilute the previous period's influence over the present value.

Table 7: Panel Cointegration

Dependent Variable (CO_2Emi)	**Mean Group (MG)**	**Pooled Mean Group (PMG)**	**Dynamic Fixed Effect (DFE)**
Long run			
FDI	-0.009	0.053**	0.022
	(0.10)	(0.02)	(0.02)
TA	4.283***	5.660***	4.292***
	(0.75)	(0.59)	(0.58)
Short run			
Speed of adjustment	-0.409***	-0.193***	-0.429***
	(0.15)	(0.06)	(0.08)
FDI	0.017	0.011	-0.001
	(0.02)	(0.01)	(0.01)
TA	-0.456**	-1.065	-1.143
	(0.19)	(0.82)	(0.70)
Number of countries	6	6	6
Number of observations	108	108	108

Source: Authors Constructed using STATA output

Table 8: Hausman Test

Test	Chi2 value	Prob. Value	Decision
MG vs PMG	3.51	0.173	PMG was selected
DFE vs PMG	0.00	1.000	PMG was selected

Source: Authors constructed using STATA output

5. Conclusion

The researchers in this study have examined the impact of FDI and TA on Carbon CO_2emi in six selected South Asian countries over 19 years from 2000 to 2018. Initially, second-generation cross-sectional dependency unit root tests were conducted to assess stationarity. The results indicated that the dependent variable (CO_2 emission) was stationary at its first difference, while the independent variables (FDI and TA) were stationary at both the level and first difference. Based on these findings, the Pooled Mean Group (PMG), Mean Group (MG), and Dynamic Fixed Effect (DFE) methods were selected for further analysis (Sohag & Bamanga, 2018). The empirical results obtained from the PMG model revealed a significant positive impact of FDI and TA on CO_2 emissions. An increase in FDI and TA was found to contribute to a sustained increase in CO_2 emissions over a longer period, with this influence lasting for approximately 5 years. These findings highlight the co-movement of FDI and TA with CO_2 emissions in the long run. However, neither FDI nor TA exhibited any significant influence on CO_2 emissions in the short run.

FDI and TA are identified as driving forces of economic growth. Since the economy operates within the ecosystem, merely achieving economic growth would not develop a country. Therefore, a country should focus on sustainable economic growth and the results of this study direct significant policy orientation to consider for South Asian countries. First, findings reveal that a greater degree of FDI lessens the environmental quality by increasing carbon emissions in the long run. Hence, it suggests an environmentally friendly fiscal policy should be maintained by South Asian countries and focus on maintaining strict environmental rules and regulations when attracting foreign investments to lower pollution. Further, they can raise the prices of traditional energy sources to discourage consumption and improve efficiency in energy consumption. In addition, the government can promote research and development for technological innovations to reduce fossil fuel consumption, and carbon emission and increase productivity. Simultaneously, countries must promote green and renewable energy consumption investments, and promote the development of plants and machinery to reduce energy consumption and mitigate waste. Further, the government can impose taxes on environmental degradation projects to motivate eco-friendly foreign investments.

Second, South Asian countries need to develop a common policy document as a region to achieve long-term sustainable development goals. Hence, having a balanced economic policy to invest in technological

advancement projects and attracting foreign direct investments towards to country at an optimal level is vital to achieving economic development in a healthy environment. Additional research is needed to examine how various economic factors impact CO_2 emissions, as well as to delve into the potential mediating and moderating roles these variables may play within this context. In addition, future researchers could expand the scope of this study to include other regions and compare the substantial differences with their underlying reasons.

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