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Navigating Sustainable Development Goals: Driving Progress for Sustainable Future and Climate Resilience

Zarith Sofia Jasmi[1]* and Nurfarhana Hassan[2]

[1]Department of Economics and Financial Studies, Faculty of Business and Management, Universiti Teknologi MARA Cawangan Johor, Kampus Segamat, 85000 Segamat, Johor, Malaysia
[2]Mathematical Sciences Studies, College of Computing, Informatics, and Mathematics, Universiti Teknologi MARA Cawangan Johor, Kampus Segamat, 85000 Segamat, Johor, Malaysia

ABSTRACT

The Sustainable Development Goals (SDGs) serve as a global imperative, uniting efforts to preserve the environment and economic stability. However, global disparities persist in terms of progress towards the SDGs, with some regions making significant strides in the environment and economy while others may face obstacles. These issues necessitate sustained focus and the application of innovative approaches for resolution. This research, therefore, explores trends and challenges across four economic development categories, ranging from high-income to low-income, in their quest to achieve the SDGs. Employing econometric regression, Principal Component Analysis (PCA), and the fuzzy graph technique, this research analyses eight pivotal variables, namely poverty, unemployment, literacy among youth, undernourishment, food insecurity, electricity availability, carbon dioxide (CO_2) and greenhouse gas (GHG) emissions. This investigation seeks to unveil the pivotal determinants and causal factors impacting a nation's progress in achieving SDGs by utilising empirical data spanning the years 1998 to 2021 from 215 nations worldwide. The findings reveal that high-income and upper-middle-income economies face issues related to CO_2 and GHG emissions, respectively. Meanwhile, lower-middle and low-income economies struggle with unemployment and food insecurity, respectively. This research provides valuable insights for decision-makers and policymakers to identify the important areas in addressing goal development disparities and emphasises the role of tailored policies and global collaboration in advancing sustainable development. Additionally, the nation can develop an effective mitigation plan, particularly on climate resilience, since it has been a concerning issue among the income economies and requires constructive resources and support.

Keywords: CO_2 emissions, climate resilience, different economic development, Greenhouse Gas (GHG) emissions, Sustainable Development Goals (SDG)

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E-mail addresses:
zarithsofia@uitm.edu.my (Zarith Sofia Jasmi)
farhanahassan@uitm.edu.my (Nurfarhana Hassan)
* Corresponding author

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INTRODUCTION

In 2015, the United Nations established a global agenda, namely the Sustainable Development Goals (SDGs) (United Nations, 2023). The SDGs are initiatives to tackle global issues such as socio-economic and climate issues (Schmidt-Traub et al., 2017). There are 17 goals in the SDGs that cover each of the global issues. The SDGs also correlate with international consensus, namely the Addis Ababa Action Agenda. The Addis Agenda was introduced during the Third International Conference on Financing for Development 2015 (United Nations, 2023). The implementation of the SDGs requires support and financial resources. Hence, the Addis Agenda helps support the SDG implementation through financing tools and policies. Moreover, the Paris Agreement, enacted from the 21st Conference of the Parties (COP21), also correlates with the SDGs. Its objective is to achieve sustainable climate change resolution (Schmidt-Traub et al., 2017). All nations globally are expected to submit Nationally Determined Contribution (NDC), which was issued from the Paris Agreement (Schmidt-Traub et al., 2017). Each nation has to prepare its climate mitigation and adaptation to address climate change issues, which can be achieved through climate finance. Climate finance, such as green innovation investment, plays a significant role in promoting climate resilience. Climate resilience is crucial to adapt to climate change. Climate change is the main cause of disruption in implementing the SDGs. Thus, countries are encouraged to focus on climate resilience to advance sustainable development (Chandel et al., 2024).

In achieving the SDGs, nations face several challenges that influence the progress of SDGs implementation. Climate change, environmental deterioration, and socio-economic challenges include poverty, unemployment, and gender inequality. Climate change and environmental deterioration are the main challenges faced by nations globally (Kopnina, 2016). According to Mirasgedis et al. (2024), 21 per cent of global greenhouse gas (GHG) emissions are generated from infrastructure. The GHG is released mainly from electricity. Climate change mitigation can reduce emissions. Thus, it could improve social and economic values to achieve the SDGs. Moreover, deforestation and pollution are examples of environmental deterioration. Such human activities could affect water and food resources. Meanwhile, poverty, socio-economic inequality, and unemployment influence individuals and society. Poverty may limit access to healthcare, education and others. In addition, unemployment leads to mental health problems and crime rates due to the distress of financial situations. These obstacles could impact social mobility and the progress of the economy. Thus, there is a critical need for comprehensive policies that address education, healthcare, and economic opportunities in order to create more equitable and affluent communities. Moreover, gender inequality can hinder progress towards the SDGs by limiting women's and girls' access to education, healthcare, and economic opportunities

(Biswal et al., 2023; Meka & Venkateswarlu, 2024). Furthermore, it is crucial to acknowledge the interrelated nature of the SDGs. Each goal is intricately linked to the others, and progress in one area can have ripple effects on achieving other goals.

Few earlier studies attempted to provide a succinct synthesis of scientific literature on SDG interconnection, focusing on their framework and implementation process. Limited research focuses on the current trends and challenges posed by different economic developments to achieve the SDG agenda by 2030, as well as discusses their interconnections to identify the most crucial challenge that has a high impact on others. It is necessary to unveil key trends, gaps, and challenges. This research analyses the trends and challenges in achieving the SDG 17 Agenda among four economic developments through econometric regression and thematic analysis to achieve the SDGs. Then, statistical and fuzzy analyses are performed to verify the results. This research contributes to the existing literature on SDGs analysis by expanding their trends, progress and challenges of different economic development. The findings reveal that carbon dioxide (CO_2) emissions are a crucial challenge in high-income economies. High energy consumption and industrial emissions due to energy demand and lifestyle are the main causes of CO_2 emissions (Dagnachew & Hof, 2022). Next, for upper-middle-income countries, greenhouse gas (GHG) emissions are identified as a significant challenge. The high emissions are caused by industrialisation, agricultural practices, and infrastructure development (Burja et al., 2020; Mirchi et al., 2012; Xu et al., 2022). Moreover, food insecurity is a vital challenge for upper-middle-income countries, similar to low-income economies. This is due to economic challenges, high food prices, maldistribution of food, dependency on imported foods, and poverty (Sinaga et al., 2022). Meanwhile, unemployment is a prominent issue for lower-middle-income economies and a challenge to achieving the SDGS. Population growth, limited industrial diversification, economic instability, lack of education, and inadequate infrastructure are among the leading factors causing unemployment in lower-middle-income economies (Bussiere & Mulder, 2000; Fox & Gandhi, 2021; Juárez et al., 2022).

This research offers guidelines for decision-makers, stakeholders, and policymakers to identify priorities for action when gaps in the development of the goals are identified and linking sociotechnical systems, directionalities, and governance to advance a transformative agenda. This research also benefits practitioners to reframe the SDGs from global calls to action to contextually relevant, manageable goals that fit within an industry. In addition, from the results obtained, the correlation between the challenges is discussed further to identify the most crucial challenge that greatly impacts the others. Hence, effective reconstruction and mitigation plans can be developed to overcome the significant challenge that affects the implementation of the SDGs. In particular, proper strategy and

financial resources are needed to execute the plans and enhance the initiatives.

LITERATURE REVIEW

Theoretical Underpinnings

Modernisation Theory and Ecological Modernisation Theory

Modernisation theory started in the 1950s when it focused on societal changes from traditional to modern (Moore, 1963). Rostow (1991) explained further that there are five stages of growth in modernisation theory: the traditional society, the preconditions for take-off, the take-off, the drive to maturity and the age of high-mass consumption. A traditional society structure is limited by the inaccessibility of modern science, either in agriculture, production, infrastructure, trade and industry (Rostow, 1991). The preconditions for take-off involve a transition process from a traditional society to take advantage of the advancement of modern technologies (Rostow, 1991). For instance, the appearance of banks and financial institutions for capital and investment, modern manufacturing, improvement in communication and transportation, and broadening education (Preston, 2022; Rostow, 1991). In the take-off stage, traditional society becomes familiar with modern technologies, leading to rapidly expanding industries and the economy taking advantage of underutilised resources (Ntini, 2016; Rostow, 1991). The drive to maturity involves the sustainability of the national income, whereby the economy is more refined towards complex technology such as coal, iron, heavy engineering, machine tools, and electrical equipment (Rostow, 1991). The last stage is the age of high-mass consumption, where the economy focuses more on durable and sustainable consumer goods and services (Rostow, 1991). This is due to increased household income and high interest in social welfare (Ntini, 2016; Rostow, 1991). Ecological Modernisation Theory is one of the re-evaluations and reorientations of modernisation theory for more reflexive forms. Ecological modernisation studies have gained attention from many scholars in social science regarding the environmental deterioration due to social, political, and economic conditions in modern societies (Mol et al., 2014). The contribution of Ecological Modernisation research to social theory involves innovative concepts through the role of technological innovations as a critical factor in ecological modernisation across geographical locations (Mol & Sonnenfeld, 2000; Mol et al., 2014). This theory explores how modern societies respond to environmental challenges (Mol & Sonnenfeld, 2000; Mol et al., 2014).

Dependency Theory

The dependency theory has been debated among scholars in terms of development, economics, and the environment. This theory responds to the discussion pertaining to the Modernisation Theory by highlighting the reality that historical connections between colonisation and discrimination have rendered poor countries impoverished and disadvantaged despite access to technologies, investment, and collaboration

in the global market (Akbari, 2025; Frank, 1974). However, scholars critically addressed the flaws of the Dependency Theory in scrutinising the relationship between the industry and the government in capital accumulation and exploitation for sustainable development (Omvedt, 1994). This failure of the Dependency Theory led to the transition to the Development Theory.

Development Theory and Sustainable Development Theory

Development Theory can be explored in comparative economic growth through historicised development due to the complex geopolitical landscape, such as market inefficiencies and government rigidness in resource allocation (Peet & Watts, 1993). Empirical evidence by Antle and Heidebrink (1995) explores the relationship between development and the environment, highlighting that economic growth is accompanied by environmental quality, whereby income growth increases environmental protection for better development sustainability. Sustainable Development Theory appears more conducive to explaining environmental change in this new era. This theory emphasises that sustainable development depends on natural, manufactured, human, and social capital (Deng, 2007; Ekins et al., 2008). The goal of this sustainable development has changed over time. It starts with single-factor development goals through sustainable utilisation of natural resources to conserve the environment (Lele, 1991). Next, the Millennium Development Goals were set in the 2000s by the United Nations (UN) Summit to alleviate poverty and hunger in developing countries, empower women, promote gender equality, and reach universal primary education within 15 years (Asadullah & Savoia, 2018; Shi et al., 2019). In 2015, UN expand these goals into Sustainable Development Goals (SDGs), incorporating 17 SDG goals, categorised into four areas of development: (1) governance (SDG 17), (2) economy (SDG 8, SDG9, SDG 10, SDG 12), (3) society (SDG 1, SDG 3, SDG 4, SDG 5, SDG 11, SDG 16), and (4) environment (SDG 2, SDG 6, SDG 7, SDG 13, SDG 14, SDG 15) (Lu et al., 2015; Shi et al., 2019). Recent studies (Nguyen et al., 2023; Nguyen et al., 2025) use Sustainable Development Theory to explain environmental sustainability and economic growth, stressing the relations between financial practices and the environment. A lack of research has been explored in sustainability, environment, climate, and financial practices using the Sustainable Development Theory. Prior research applies the Collective Impact Theory (Ostrem & Hvenegaard, 2023), Environmental Kuznets Curve Hypothesis (El Khoury et al., 2025) and Natural Resource-Based View Theory (Farrukh Shahzad et al., 2025) to unfold the relationship of economics and environment. This research, therefore, employs Sustainable Development Theory as a lens to unveil the trends and challenges of SDGs between different income countries in relation to financial practices.

Hypothesis Development

The empirical literature on challenges to achieving the Sustainable Development Goals provides valuable insights into the obstacles and complexities associated with implementing these goals. Prior research addressed the challenges of nations in achieving SDG differences in economic development.

In pursuing Sustainable Development Goals (SDGs), high-income economies that defined themselves with their developed economies and infrastructures also faced challenges in balancing economic growth with environmental sustainability to achieve the SDGs. Despite advanced environmental policies, high-income countries remain prominent contributors to global pollution and climate change (Rajbhandari et al., 2018). This conflict is especially visible in areas such as manufacturing and industry, where economic progress frequently comes at the expense of environmental damage (Durán & Durán, 2019). Vagin et al. (2022) argue that investments in sustainable development are susceptible to financial risks, which may impede the achievement of the SDGs. In addition, carbon dioxide (CO2) emissions significantly increase when using fossil fuels such as coal, oil, and natural gas (Lotfalipour et al., 2010; Soeder, 2020). When these fuels generate electricity, they emit significant volumes of CO_2 and other greenhouse gases into the environment (Soeder, 2020). This mechanism is a main driver of anthropogenic climate change since higher CO_2 concentrations trap heat in the Earth's atmosphere, resulting in global warming and a variety of negative environmental consequences (Soeder, 2020). The literature emphasises the need for these nations to lead in climate action, transitioning to renewable energy, reducing carbon emissions, and investing in sustainable technologies (Avşar et al., 2022; Chang & Lo, 2022; Zafeiriou et al., 2022). Challenges include policy implementation, balancing economic growth with environmental protection, and encouraging sustainable consumption among affluent populations (Bolson & Patzek, 2022). It is important to have sufficient financial resources to support the transition to clean and renewable energy sources, specifically in the context of clean and affordable energy (Čeryová et al., 2020). Thus, this led to the first hypothesis as follows:

> H1: CO_2 emissions are a major challenge in the SDGS for high-income economies.

Upper-middle-income economies have rapid industrialisation and economic growth, often dependent on fossil fuels and energy-intensive activities, contributing to high greenhouse gas (GHG) emissions. Most upper-middle-income economies are rapidly urbanising, whereby the population is concentrated in areas that require transportation hubs, intensive energy usage in homes, appliances and industry, leading to the utilisation of energy, emissions and fossil fuels (Al-Masri et al., 2022; Xu et al., 2022; Zhang et al., 2022). Additionally, agriculture practices with excessive use of fertilisers such as methane and nitrous oxide also contribute to high GHG emissions (Burja

et al., 2020; Myeni et al., 2021). Literature also discusses extensive infrastructure development, such as constructing and maintaining roads, bridges, and buildings involving energy-intensive materials and processes (Waldman et al., 2020). Therefore, to balance the demand for economic development and environmental sustainability, transitioning to green energy sources and greener construction materials and methods is encouraged, but it is costlier (Wu et al., 2019). Upper-middle-income economies often face challenges in effectively implementing and enforcing environmental regulations (Zulu et al., 2022). Balancing industry interests, job growth, and environmental protection necessitates strong policies and their implementation, which can be politically and economically difficult. Therefore, the second hypothesis is as follows:

H2: Greenhouse gas emissions (GHG) are a significant challenge in the SDGs for upper-middle-income economies.

Lower-middle-income economies sometimes suffer from a scarcity of different economic activities and industries. High unemployment rates suggest underutilising labour, restricting these countries' economic growth potential (Baah-Boateng, 2013). Sustainable economic growth is essential for achieving many SDGs, including poverty reduction (SDG 1) and decent work and economic growth (SDG 8). Economic volatility, triggered by political upheaval or global economic fluctuation, can deter businesses from investing and employing, resulting in a stagnant job market (Bussiere & Mulder, 2000). Lower-middle-income countries also primarily rely on a few industries, which limits work prospects, particularly for those with diverse abilities (Fox & Gandhi, 2021). Moreover, unemployment exacerbates income inequality within these economies (Lee et al., 2013). Individuals and families struggle to earn money in the absence of permanent work prospects, resulting in disparities in living standards and limited access to key services, impeding progress toward goals related to reducing inequalities. Besides, high unemployment rates frequently indicate that a large proportion of the population lacks access to excellent education and vocational training (Fox & Gandhi, 2021). This lack of skills and education impedes the achievement of SDG 4 (Quality Education) and SDG 8 (Decent Work and Economic Growth), which aim to offer inclusive and equitable quality education and foster sustained, inclusive, and sustainable economic growth. Prolonged unemployment can cause social discontent and instability (Badimon, 2013; Lagi et al., 2011). Countries with high unemployment rates frequently face social difficulties, such as increasing crime rates and political conflicts (Juárez et al., 2022; Mago, 2018). Social stability is crucial for achieving various SDGs, as it underpins efforts related to peace, justice, and strong institutions (SDG 16). Most importantly, unemployment limits individuals' ability to access basic needs such as food, shelter, and healthcare, hindering the achievement of SDG 2 (Zero Hunger), SDG 3 (Good

Health and Well-being), and SDG 6 (Clean Water and Sanitation). Therefore, this led to the third hypothesis:

> H3: Unemployment is the main challenge for achieving the SDGs in lower-middle economies.

Severe economic challenges, inadequate institutions, and fragility are primary contributors to food insecurity in low-income economies (Alinovi et al., 2007; Mwaniki, 2006). Poverty has the greatest impact on whether an individual has sufficient access to food (Gonzalez, 2014). Low-income economies with destitute populations lack the financial capacity to access adequate and nutritious food, resulting in hunger and malnutrition (Adeyeye et al., 2023). Low-income economies may lack access to agricultural land, water, and advanced agricultural technologies (Vogel & Smith, 2002). This constraint reduces agricultural output, making producing enough food to meet the rising population's demands difficult. Inadequate infrastructure, such as roads, storage facilities, and transportation networks, can lead to food waste (Alexander et al., 2013). Farmers may be unable to transport their produce efficiently to markets, resulting in economic losses and limited food availability. Rapid population expansion in economies with low incomes strains existing resources. Meeting the food demands of an expanding population becomes increasingly difficult in the absence of equivalent gains in agricultural production (Ayenew & Kopainsky, 2014). Furthermore, low-income economies may be subjected to unfair trade practices, reducing their ability to compete globally (Otaha, 2013). Subsidies in industrialised countries might result in lower-cost imports, making it difficult for local farmers to sell their products at competitive prices. Thus, the fourth hypothesis is as follows:

> H4: Food insecurity is a significant challenge for low-income economies.

MATERIALS AND METHODS

This research divides the panel data of 215 countries into four different economic developments, namely high-income economies (HIE), upper-middle-income economies (UMIE), lower-middle-income economies (LMIE) and low-income economies (LIE). The four income economies are depicted from the World Bank classification based on Gross National Income (GNI) per capita. This research involves 23 years, from 1998 until 2021, collected from the World Bank, publicly available at https://data.worldbank.org/. The longer timeframe is paramount to ensure consistency in determining the most crucial challenges associated with the countries, even during the pre-SDG era. This data is strongly balanced panel data of 171 observations.

There are nine variables, and the dependent variable is economic development, with GNI per capita as a measurement. Researchers widely use this GNI per capita to measure the economic growth and income of the countries (Pavliuk & Matyukhina, 2021; Yang, 2019). The independent variables involve eight variables mapping from SDG goals which are poverty (SDG1), unemployment (SDG8

and SDG10), literacy among youth (SDG4), health (undernourishment) (SDG3 and SDG6), food insecurity (SDG2), electricity availability (SDG7 and SDG11), carbon dioxide emissions (SDG13) and GHG emissions (SDG13).

This research runs Ordinary Least Squares (OLS) analysis on 4 different subsets of data referring to 4 types of economies. OLS regression is a straightforward assumption that the relationship between independent variables and dependent variables is a linear trend (Burton, 2021). This technique examines whether independent variables can predict the effects and relationship of the variation in dependent variables (Wooditch et al., 2021). This research also controls for years as it involves panel and time-series data. This research also tests for multicollinearity using the Variance Inflation Factor in Stata and finds the data has no multicollinearity issues, as all variables are below 5. The details of the variables are described in Table 1.

Table 1
Variable definition and descriptive statistics

Variables	Definition	Mean	Standard Deviation
Dependent:			
Economic Development	High-economies: over $13,845 in GNI per capita	8.35	0.64
	Upper-middle economies: Range between $4,466 and $13,845 in GNI per capita. Lower-middle economies: Range between $1,136 and $4,465	7.07 6.19	0.52 0.40
	Low-economies: $1,135 or less in GNI per capita	10.39	0.24
Independent:			
Poverty Headcount Ratio	Earnings less than $2.15 a day (percentage)	22.31	20.66
Unemployment Rate	The proportion of the labour force actively seeking job opportunities (percentage)	5.96	0.90
Literacy Rate of Youth	Youth ages 15–24 who are capable of reading and writing a short statement of life (percentage)	25.15	23.16
Prevalence of undernourishment (Health)	Population whose regular food consumption is inadequate to sustain a nutritious and healthy life (percentage)	33.40	26.38
Severe Food Insecurity	At least one single adult is forced to skip meals, cut back food intake due to insufficient funds or resources (percentage)	2.58	3.95
Access to electricity	Population with access to electricity (percentage gathered from surveys, industry and international sources)	75.21	32.63
CO_2 gas emissions	Carbon dioxide is generated from gas flaring and the usage of solid, liquid, and gas fuels	43.78	28.57
GHG emissions	By-product emissions of sulphur hexafluoride, perfluorocarbons and hydrofluorocarbons.	25.84	14.17
Control variables:			
Year (Time)	The period from 1998 to 2022		

Source: World Bank (2023)

This research also employs Principal Component Analysis (PCA) and fuzzy autocatalytic set (FACS) approaches to further enhance and verify the findings. The PCA method is an established statistical technique widely used in classification and cluster analysis. The PCA transforms the high-dimensional data into new vectors called principal components (PCS) while preserving the important features of the original data. The PCA involves several mathematical procedures and pre-processing, such as standardisation of the data and computation of the covariance matrix (Gewers et al., 2021). Finally, the projection of the principal components is plotted. The procedures are conducted using mathematical software. Meanwhile, a fuzzy autocatalytic set (FACS) is a mathematical method that integrates the concepts of fuzzy and graph theory. It was first established in 2010 to model and identify the significant variables in the waste incineration process (Ahmad et al., 2010). Later, the FACS method was modified for pattern and classification analyses (Hassan et al., 2020). The FACS method involves modelling the elements or variables in a graph consisting of vertices *(v1, v2, v3, ..., vn)* and edges (*e1, e2, e3, ..., en)*. Next, fuzzy values from 0 to 1 are assigned to each vertex to establish a fuzzy graph model. The fuzzy graph is then transformed into matrix form for further computation using the Perron-Frobenius Theorem to identify the most significant elements. Thus, the two methods are beneficial in analyses involving the identification of significant clusters and elements, respectively.

RESULTS AND DISCUSSION

Econometric Regression Analysis

The R-squared of all subsets are above 0.8 and closer to 1, which means that all relationships are strong, and more than 80 per cent of dependent variables are explained by the independent variables. Table 2 reports that poverty, unemployment, undernourishment, and food insecurity are negatively significant in high-income economies. This demonstrates that economic development can undoubtedly help to reduce poverty, enhance nutrition, and ensure food security. This is because greater resources are available in economically developed countries to invest in social welfare programs, education, healthcare, and infrastructure. These initiatives have the potential to reduce poverty and enhance access to key services. Jobs and employment opportunities are created because of developed economies (Kapsos, 2006). Poverty rates can fall when more people have work because individuals and families have a steady income to meet their bare necessities. Advances in agricultural technologies and practices can also be attributed to developed economies (Basnett & Sen, 2013). This innovation has the potential to boost food production in areas where irrigation infrastructure investments contribute to agricultural growth and poverty reduction in many industrialised countries (Mupaso et al., 2023).

In accordance with hypothesis 1, CO_2 emissions are positively significant. CO_2 emissions are the biggest challenge in high-income economies. This is because many

high-income economies have established industrial and manufacturing sectors that can contribute significantly to CO_2 emissions due to the energy-intensive nature of production processes (Durán & Durán, 2019). High-income economies are usually characterised by high rates of urbanisation and automobile ownership, where large amounts of energy are required in cities for transportation, buildings, and infrastructure. Private vehicle use, which is usually powered by fossil fuels, contributes significantly to CO_2 emissions (Soeder, 2020). Despite high-income economies' advances in renewable energy, several remain reliant on fossil fuels for energy generation (Lotfalipour et al., 2010; Soeder, 2020). CO_2 emissions from power plants remain a serious concern in such cases.

The challenges in achieving the Sustainable Development Goals are more evident in low and upper-middle-income economies. Results support hypothesis 2, showing greenhouse gas emissions are the major hurdle in achieving the SDGs for these nations. Rapid industrialisation, modernisation, and advanced energy consumption are reasons that particularly the upper-middle-income economies experience challenges from greenhouse gas emissions due to dependency on fossil fuels, which led to higher emissions (Mirchi et al., 2012; Xu et al., 2022; Zhang et al., 2022). However, reducing emissions concerning climate change while maintaining economic growth and development requires significant investment, which might strain the available resources.

Results also support hypothesis 3, emphasising that unemployment is the most significant barrier for lower-middle economies to achieve the SDG goals. For instance, South Africa reported the highest unemployment rate with 33.5 per cent, the Republic of Congo reported 19.8 per cent, and South Asia recorded 15.1 per cent (International Monetary Fund, 2024). This figure indirectly explains the reasons for poverty, high-income gaps, low educational achievement, and political tensions due to this social instability. Economic disparities, insufficient infrastructure, conflicts and unequal resource distribution also worsened the situation, which led this nation to experience inadequate access to nutritional foods (Alinovi et al., 2007; Mwaniki, 2006).

Findings also reveal that food insecurity is a significant challenge in low-income economies, supporting hypothesis 4 of this study. It is estimated that around 1.9 million people in Gaza, Sudan, Haiti, Mali, and South Sudan experienced a severe food shortage in 2024 (World Bank, 2024). Surprisingly, upper-middle economies encounter food insecurity issues despite improvement in GNI per capita. Statistics recently disclosed an increase of more than 5 per cent in domestic food price inflation globally, particularly in agricultural and commodity prices (World Bank, 2024). For these nations, climate might be the key driver of food insecurity issues (World Bank, 2024).

Overall, the findings of this research reflect the Sustainable Development Theory, in which a holistic strategy is

essential to integrate social, economic, and environmental objectives (Nguyen et al., 2025). These research findings are summarised in thematic analysis in Table 3.

Mathematical Analysis Using Statistical and Fuzzy Methods

This research applies a statistical method, principal component analysis (PCA) and

Table 2
Regression results

Variables	HIE	UMIE	LMIE	LIE
Poverty	-0.00285*	0.00228	-0.000772	0.00133
	(0.00149)	(0.00198)	(0.00243)	(0.00161)
Unemployment	-0.0752**	-0.0234	0.219***	-0.120***
	(0.0353)	(0.0469)	(0.0578)	(0.0381)
Literacy youth	0.00219	0.00236	-0.00890	0.00435
	(0.00832)	(0.0111)	(0.0136)	(0.00899)
Undernourishment	-0.0146*	0.00826	0.0197	-0.0134
	(0.00852)	(0.0113)	(0.0140)	(0.00921)
Food insecurity	-0.00201*	0.00680***	-0.0108***	0.00597***
	(0.00107)	(0.00142)	(0.00175)	(0.00116)
Access to Electricity	0.0126	0.00782	-0.0393***	0.0188**
	(0.00849)	(0.0113)	(0.0139)	(0.00918)
CO_2 emissions	0.0102***	0.00157	-0.00436	-0.00736***
	(0.00169)	(0.00225)	(0.00278)	(0.00183)
Greenhouse emissions	0.00228	0.00632***	-0.00552**	-0.00309*
	(0.00156)	(0.00207)	(0.00255)	(0.00168)
Constant	0.603**	-0.156	-0.803*	1.357***
	(0.247)	(0.328)	(0.404)	(0.267)
Years	Yes	Yes	Yes	Yes
R-squared	0.926	0.869	0.801	0.914

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3
Thematic analysis of findings

Theme	Trends
High-income Economies	Poverty, unemployment, undernourishment, and food insecurity decrease CO_2 emissions increase
Upper-middle-income Economies	Food insecurity and other greenhouse gas emissions increase
Lower-middle-income Economies	Food insecurity, access to electricity and other greenhouse gas emissions decrease Unemployment increase
Low-income Economies	Unemployment, CO_2 emissions and other greenhouse gas emissions decrease Food insecurity and access to electricity increase

a fuzzy graph technique to further analyse and verify the reliability of the findings. The techniques explore the relationship and significance of each indicator.

The PCA method is a statistical technique that can reduce the dimensionality of high-dimensional data while preserving its essential structure (Umar et al., 2019). The PCA score plot is used to visualise the results of the analysis. The plot's axes are represented by the principal components (PCs). The positions of data points on the score plot reveal trends or groupings in the data. Data points close to each other in the plot share similar characteristics and have strong relationships, while those farther apart may have different characteristics (Hassan et al., 2022). Figure 1 shows the results for the relationship and significance of the dependent variable towards each economic development. The analysis was performed using MINITAB 17 software (Minitab Inc., Pennsylvania, United States).

The PCA results show that the variables or indicators are clustered in certain regions for each category of economy. For the high-income economies, unemployment (V2), literacy (V3), undernourishment (V4), food insecurity (V5) and CO_2 emissions (V7) are variables that have strong relations to each other that could impact the progress in achieving the SDGs goals. The results

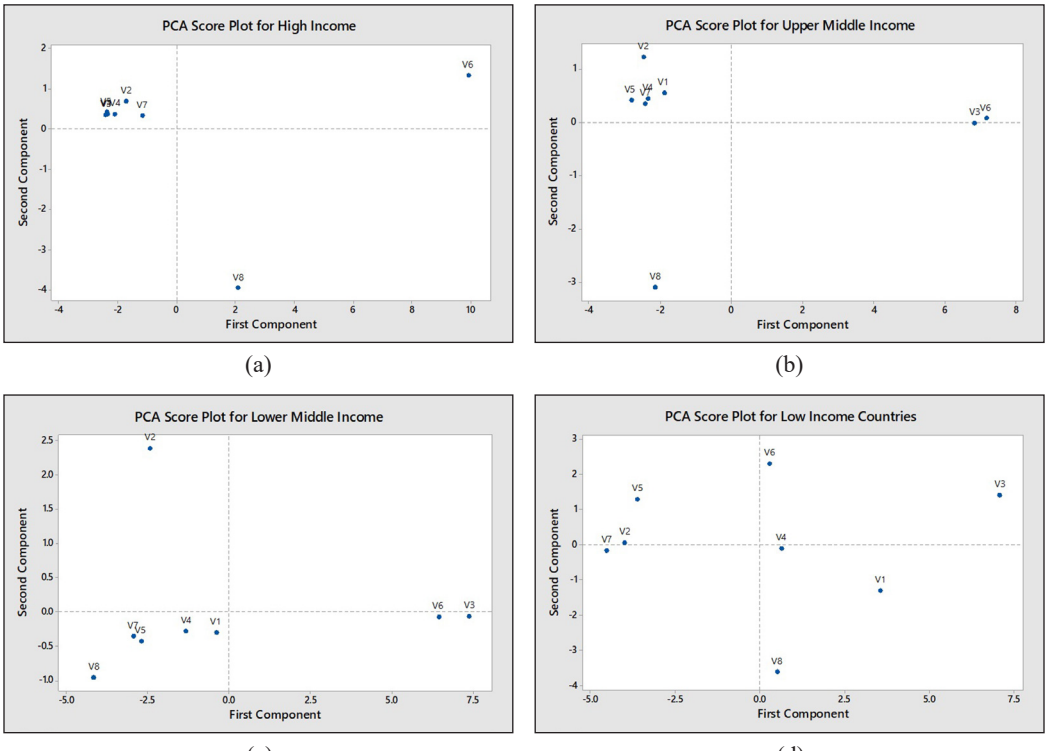

Figure 1. The score plot of variables for each income economy: (a) High, (b) Upper middle, (c) Lower middle, and (d) Low

coincide with the findings of regression analysis, whereby CO_2 emissions are the most significant challenge for high-income economies in achieving the SDGs goals. For the upper-middle-income economies, poverty (V1), unemployment (V2), undernourishment (V4), food insecurity (V5) and CO_2 emissions (V7) variables cluster close to each other at the upper left quadrant, while PCA score plot for lower-middle-income economies shows that unemployment (V2) has appeared at the upper left quadrant. This could indicate that the upper left quadrant is the region that signifies a strong relation or impact towards the economy. The results for upper-middle and lower-middle economies concur with the regression analysis, as food insecurity and unemployment are the most significant variables for each economic development. Meanwhile, for the low-income economies, unemployment (V2), food insecurity (V5) and CO_2 emissions (V7) clustered close to each other. However, CO_2 emissions (V7) are positioned slightly outside the region, while access to electricity (V6) appears close to the upper left region. These results indicate that unemployment and food insecurity are particularly significant challenges for low-income economies, with access to energy trailing closely behind.

The fuzzy autocatalytic set (FACS) method, which is a merge of fuzzy and graph theory techniques, is also used to further analyse the significance of the variable for the four economic developments. The FACS method transforms the variables into the graphical form of a set of vertices, V = *(v1, v2, v3, v4, v5, v6, v7, v8)* and a set of edges *E = (e1, e2, e3, e4, e5, e6, e7, e8)*. The FACS graph is then converted into matrix form. A mathematical software, namely, MATLAB version R2017b (Mathworks, Natick, MA), is then used for further analysis using Perron-Frobenius eigenvalues identification, whereby the less significant variables are depleted from the matrix. As a result, the last remaining matrix produced is the vital indicator (see Table 4).

The FACS results show that CO_2 emissions (V7) are the most significant variable for high-income economies, coinciding with PCA and regression analyses. Additionally, the FACS analysis reveals that poverty (V1) is the most significant factor in upper-middle-income economies, which coincides with PCA results. This indicates that the variable is one of the significant challenges for upper-middle-income economies, as well as for lower-middle-income and low-income economies. Another significant challenge

Table 4
Fuzzy autocatalytic set analysis result

Economic Developments (Income)	Variables in the Final Remaining Matrix
High	CO_2 emissions (V7)
Upper-middle	Poverty (V1)
Lower-middle	Poverty (V1) and Food insecurity (V5)
Low	Poverty (V1) and Food insecurity (V5)

identified for lower-middle-income and low-income economies is food insecurity (V5). This result agrees with the PCA and regression analyses for low-income economies.

The results of PCA and fuzzy graph methods reveal the significance of the variables towards the income level economy, and the results strengthen the findings of the regression analysis. The findings of all three analyses concur that CO_2 emissions are the most serious concern for high-income economies. For upper-middle-income economies, the findings from PCA and FACS analyses coincide in emphasising poverty as a preeminent challenge, while regression and PCA analyses concur in emphasising the notable issue of food insecurity. In particular, both PCA and regression analyses emphasise that gas emissions, which are CO_2 and greenhouse gas (GHG), are prominent indicators, respectively. Furthermore, regression analysis and PCA findings reveal that unemployment is the main challenge for lower-middle-income economies. Meanwhile, the FACS analysis revealed other key challenges, such as poverty and food insecurity. Lastly, for low-income economies, the three analyses concur that food insecurity is a significant challenge in achieving the SDGs.

CONCLUSION

This research explores trends and challenges across four economic developments using a balanced panel data of 215 countries from 1998 to 2021, using the OLS, PCA and FACS approach. Results reveal there is a significant increase in CO_2 emissions for high-income economies, while poverty, unemployment, undernourishment, and food insecurity show a declining trend. For upper-middle-income economies, food insecurity and other greenhouse gas emissions show an increasing trend over the past 23 years. On the other hand, lower-middle-income economies show a declining trend of food insecurity, access to electricity, and other greenhouse gas emissions, which is the opposite of upper-middle-income nations. However, they suffer from unemployment. Meanwhile, low-income economies experience huge food insecurity and limited access to electricity. Unemployment, CO_2 emissions and other greenhouse gas emissions show a declining trend in these nations.

Implications of the Study

Sustainable Development Theory is used as a lens to explore the trends and challenges of SDGs across four different types of economic development (high, upper-middle, lower-middle and low-income), even though there are tremendous improvements in achieving SDG goals globally. Findings reflect studies by Rajbhandari et al. (2018), where CO_2 emissions are the most significant in high-income economies. High energy usage and advanced industrial and manufacturing sectors are among the reasons for high CO_2 emissions in these nations. It is important for policymakers and practitioners to address climate change issues by integrating sustainable strategies into companies' business models.

Companies play an important role in promoting innovation in financial practices for corporate sustainability.

Furthermore, this research suggests that upper-middle-income countries address increased GHG emissions in these countries due to growing energy demands, heavy dependence on fossil fuels and urbanisation (Mirchi et al., 2012; Soeder, 2020; Xu et al., 2022). These findings extend to the practical implications from multiple sectors such as energy, transportation, industrials, buildings, and manufacturing. A large-scale investment of climate finance in green investment projects such as solar panels, renewable energy, electric vehicles, green manufacturing steel, green buildings, agroforestry, and reforestation is needed.

In addition, the findings of this research extend to policymakers in addressing food insecurity in low-income and upper-middle-income economies by promoting a sustainable agricultural approach and investing in technologies to help farmers and settlers increase the productivity of agriculture and commodities. Policymakers are also encouraged to review global economic policies to encourage fair trade and overcome the issue of food price inflation.

Meanwhile, this research suggests that low-income economies concentrate on increasing job opportunities to fight unemployment. This predominant challenge requires comprehensive policies on economic diversification, promoting entrepreneurship, and skills development. Job creation indirectly reduces income inequalities and improves education in these nations.

Limitations and Recommendations for Future Research

Limited data has restricted this study's ability to do comprehensive research on the SDGs. Improving the methods of data collection and analysis for tracking progress on the SDGs is an ongoing challenge. Furthermore, this research only focuses on determining the prominent challenges among income economies and suggesting mitigation and adaptation strategies to combat them without proposing comprehensive elaborations.

Hence, research into more accurate, timely, and comprehensive data collection methods is needed. Future research should focus on collecting local data to enhance nations' features and characteristics in terms of their challenges in achieving the SDGs. Moreover, future research on constructive climate finance mitigation plans, particularly related to climate resilience, is recommended, especially in high-income and upper-middle-income economies, to combat the CO_2 and GHG emissions challenges. Some of the initiatives recommended on climate finance are green innovation and investment projects, green financial practices, technological developments, public awareness initiatives, energy efficiency enhancement, comprehensive waste management, and international cooperation. Furthermore, environmentally friendly laws and regulations should be implemented to limit carbon-intensive sectors and promote low-carbon technologies.

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