Prosperity with a Purpose

Investigating the Possibilities for Economic Growth and Sustainability Development to Coexist

Ebba Bengtsson and Lilian Landström

Abstract: In the current landscape, policymakers are confronted with a formidable task: striking the delicate equilibrium between ongoing economic growth and a sustainable transition. This dilemma forces a difficult trade-off in various sectors, where the pursuit of sustainability often entails sacrifices and compromises with regard to economic growth. The intricate interplay between these two objectives underscores the complexity of the challenges faced by policymakers in charting a path forward. This study explores the interplay between sustainable development goals and economic growth in OECD member countries. Using the data throughout 2000–2021, a panel data estimation method is adopted with sophisticated econometric approaches. The findings challenge conventional wisdom and shed light on the complex relationships between economic, social, and environmental indicators. Notably, the obtained results identify a positive long-term impact when countries prioritize basic needs and services, including effective governance, social equality and empowerment, robust infrastructure, and transformative innovation. Remarkably, the analysis also uncovers a contrasting effect of natural resource conservation and management on economic growth in developed countries. These findings underscore the need for governments and associated policymakers to prioritize social development, human development, and innovation as drivers of sustainable economic growth. By doing so, policymakers can not only foster prosperity but also mitigate ecological footprints and ensure the preservation of natural resources.

Keywords: Panel data, SDG index, Environmental impact, Economic growth
Jel codes: 011 020 044

Bachelor's thesis in Economics, 15 credits
Spring Semester 2023
Supervisor: Christer Ljungwall

Department of Economics
School of Business, Economics and Law
University of Gothenburg

Acknowledgments

We extend our heartfelt gratitude and recognition to our supervisor, Christer Ljungwall, for his unwavering commitment, guidance, and encouragement throughout this thesis. We would also like to express our appreciation to our supervisors at SEB, Jens Magnusson, Filip Carlsson, and Seyran Naib for their invaluable contributions to this study's emergence.

Table of Contents

1. Introduction

The global gross domestic product (GDP) has doubled since 2000, resulting in enhanced living standards and poverty reduction (Azam, 2019). However, this development of the world economy has come at the expense of increased environmental degradation, social degradation, and depletion of natural resources, resulting in a nearly 40% increase in global carbon emissions during the same period (Statista, 2023). The concept of sustainable development was first defined in the Brundtland report, Our Common Future (1987), which emphasizes the need to balance economic development with social well-being and environmental protection (World Commission on Environment and Development, 1987). This has created a dilemma for policymakers who must choose between further economic growth and prioritizing sustainability. Thus, this study seeks to explore this trade-off by answering the following questions:

(1) What is the relationship between economic growth and sustainable development?
(2) How do United Nations' sustainable development goals influence economic growth?
(3) What are the potential challenges and trade-offs in designing effective policies for promoting sustainable economic growth?

Economic growth is widely acknowledged as a potent tool for generating employment, reducing poverty, and elevating living standards (Azam, 2019). The past few decades have witnessed a global transformation in which the well-being of humans is often measured by their consumption of goods and services, resulting in the upliftment of millions of people from poverty (Alden et al., 1999). The feeling of novelty in consumption creates a sense of freedom and empowerment, derived from the removal of past limitations and the ability to make independent decisions (Ger, 1997). For developing countries, economic growth has therefore become a primary policy objective (Rahman et al., 2019). Nonetheless, the enhancement of living standards has resulted in increased demand for goods and services, surpassing local production capabilities (Alden et al., 1999). This has led to the perception that gross domestic product (GDP) growth and consumption expansion have no limits and that natural resources are infinite, furthering the globalization of production and consumption (Rahman et al., 2019).

The impact of economic growth and consumer societies on global living standards has been a topic of interest in human development. While the United Nations Human Development

Report of 1998 recognizes the positive effects of economic growth on poverty reduction. It also highlights the unequal distribution of consumption and production, with the wealthiest 20 % consuming 86.6 % of all private consumption, while the poorest 20 % account for only 1.3 % (UNDP, 1999). This has prompted debate among researchers and policymakers on the best course of action. Some, like Helman (1995), point to negative externalities of production and consumption patterns in wealthy countries, such as environmental degradation. Other, as Li (2019) suggests reducing economic growth to safeguard the environment, while Jackson (2009) advocates for a transition to a sustainable economy that redefines wealth (Sprenger, 1994 ; Li, 2019). Grossman and Krueger (1995), on the other hand, argue that economic growth is necessary for improving environmental conditions.

Adrangi et al. (2004) used differential equations to show that as GDP levels rise, nations emit more CO_2, while countries with lower GDP levels have higher absolute CO_2 emissions. This can be explained by the Kuznets curve, where lower GDP countries experience higher consumption growth, leading to increased harmful emissions, see Figure 1 (Adrangi et al., 2004). However, increasing consumption as the primary strategy to improve living standards, especially in developing countries, which represent 80 % of the world population. This poses a potential threat of environmental catastrophe (Ger, 1997). A recent report by the UN Environment Programme highlights the value of investing in the environment, as nature supports 50 % of global GDP and can yield high returns on investment (United Nations Environment Programme, 2021).

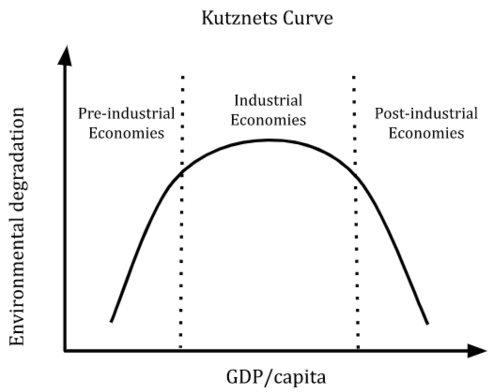


Figure 1. Kutznets curve.

The UN's 17 Sustainable Development Goals (SDG) were implemented in 2015 to guide nations towards sustainable improvements in living standards by addressing societal, economic, and environmental challenges through 169 targets, see Appendix A (UNSDG, 2023). According to Khan and Ozturk (2020), sustainable development should balance these three dimensions. The SDGs cover a wide range of issues and are not only interrelated but also interdependent, so minimizing trade-offs between them is crucial for successful implementation. For example, quality education for girls (SDG 4) can facilitate poverty eradication (SDG 1), gender equality (SDG 5), and economic growth (SDG 8) in the long term, as pointed out by Nilsson et al. (2016). A systematic approach to achieving a Pareto-efficient situation by the government at all levels - local, national, and global - is therefore important (Khan and Ozturk, 2020).

1.1 Objective

Previous studies on the relationship between sustainable development and economic growth have overlooked the interdependence of the SDG, not including all goals, and focused mostly on developing countries' adoption of higher consumption (Dasgupta, 2021; Bansal et al., 2021). Also, limited research has been done on already industrialized countries where consumption is high, but the growth rate has slowed down (Adrangi and Kerr, 2022).

Thus, this study aims to examine the statistical relationship between SDG and GDP per capita growth in developed countries, to shed light on the trade-off between economic growth and sustainable development where there is greater economic capacity to pursue sustainable practices (Dasgupta, 2021). The study will analyze data from all 38 Organisation for Economic Co-operation and Development (OECD) member countries and use reliable econometric methodologies to provide comprehensive insights, see Figure 2. The results can help policymakers design effective policies that support sustainable economic growth in the long term.

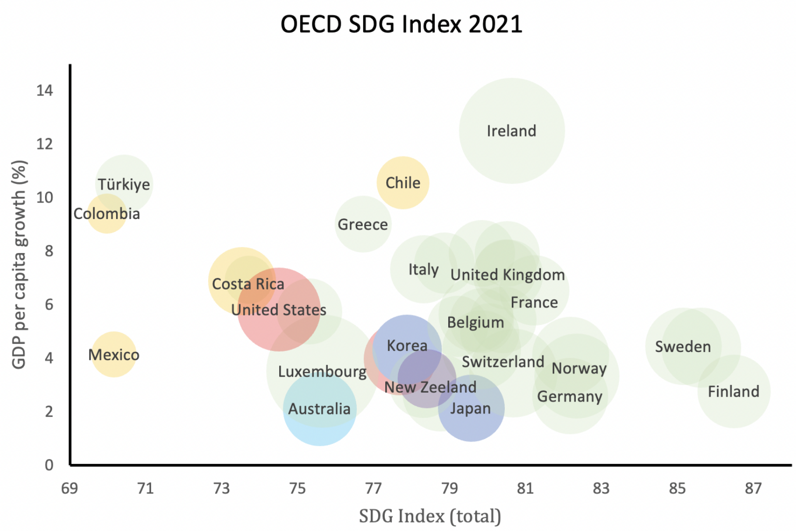


Figure 2. The performance of the OECD countries in the balanced SDG index (SDSN, 2022) *in relation to GDP per capita growth in 2021* (The World Bank, 2023a). *The income of each country is indicated by the size of the circle. The larger the GDP (constant PPP) per capita* (The World Bank, 2023)*, the larger the circle. Additionally, different colors are assigned to countries from different continents.*

This study makes two significant contributions to existing knowledge. Firstly, it examines the impact of all SDGs on economic development, specifically GDP per capita growth, among developed countries using a comprehensive and inclusive selection of relevant variables to cover all three dimensions of sustainability, see Appendix B. Secondly, it employs reliable and robust econometric methodologies to ensure conclusive results, including the first-generation unit root test, cross-sectional dependence test, D&H Granger non-causality test, and first-difference estimates. The findings provide policymakers with valuable insights into the development of holistic and comprehensive policies for sustainable economic growth in the long term, not only for the countries under study but also beyond.

The remainder of the study is organized as follows: section 2 presents a relevant review of existing literature, section 3 discusses the theoretical framework, section 4 introduces the data, section 5 explains the research methodology, section 6 presents the results, and section 7 and 8 concludes the paper with policy implications and suggestions for future research.

1.2 Hypothesis

The objective of this study is to examine the relationship between economic growth and the SDG Index across various dimensions of sustainable development. Based on the literature review carried out in this study, the following hypothesis has been developed: H_0*: SDG index does not impact economic growth.* H_a*: SDG index does impact economic growth.*

The above-mentioned hypothesis is detailed in Table 1 with the corresponding sub-hypotheses, illustrating the expected direction of each SDG goal's relationship. A positive sign (+) suggests a positive relationship and a negative sign (-) indicates a negative relationship.

Table 1. Null hypothesis and expected sign for each coefficient.

Explanatory variable	Expected sign	Null hypotheses
Basic needs and services (BASIC)	+	H_{0a}: Provision of basic goods and services do not impact economic growth.
Conservation and Management (CONMAN)	+	H_{0b}: Conservation of natural resources for environmental purposes has no effect on economic growth.
Equality and Empowerment (EQUEMP)	+	H_{0c}: Social equality and equity do not impact economic growth.
Governance (GOV)	+	H_{0d}: Governmental coaction and policymaking do not have any influence on economic growth.
Infrastructure and Innovation (INFINN)	+	H_{0e}: Instrustructure and technology have no impact on growth.

2. Literature Review

Considerable research endeavors have been dedicated to investigating the correlation between diverse societal, economic, and environmental variables and economic growth. Despite this, the extant literature is restricted in terms of its ability to investigate these variables in an aggregate manner. Therefore, it is imperative to conduct research that comprehensively accounts for all three mentioned dimensions. Our study addresses this gap by examining all the societal, economic, and environmental factors that affect economic growth, according to the UN's SDG Index categorized into basic needs and services, environmental conservation and natural resource management, equality and empowerment, governance and infrastructure, and innovation.

The reference literature is a consistent base in the theoretical and analytical framework for this study and is conducted by Professor Sir Partha Dasgupta (2021). He composed a revolutionary view of environmental threats against economic growth, advocating for a significant reevaluation of the relationship between the economy and natural resources. His work has had a significant and pertinent role in the basis for further research on the trade-off between economic growth and sustainable development, proposing the traditional economic system not taking into account the value of natural capital and ecosystem services, which are essential for human well-being and economic development (Dasgupta, 2021:335).

Similar to the sample choice of our study, Bassanini and Scarpetta (2001) conducted an estimation of the impact of human capital on economic growth across 21 OECD countries, utilizing data from the period 1971–1998. Notably, this study excluded the impact of various economic and environmental factors that are known to have an effect on economic growth. Wang and Wang (2020) studied 34 OECD members during the time period 2005–2016, estimating the impact of renewable energy consumption on economic growth, ignoring social and economic aspects. Contrarily, Narayan and Smyth (2008) investigated the relationship between capital formation, energy consumption, and real GDP by incorporating economic and environmental variables while excluding the societal aspect.

The robust and reliable econometric methodologies in this research have often been overlooked in previous studies. To illustrate, Singh et al. (2022) employed a panel unit root test, a Pearson correlation, and a heteroscedasticity test in order to investigate the correlation between chosen SDG goals and economic growth in Saudi Arabia. Arrow et al. (2003) used panel data and time series models to analyze data from multiple countries over an extended period, controlling for population growth, to investigate the relationship between economic growth and environmental degradation using fixed effects panel data models. Similarly, Daly and Farle (2011), employed fixed effects and tested for normality, multicollinearity, and stationarity for panel data and time series analysis. They estimated the value of externalities and incorporated the costs of economic activities to reflect the true cost of economic growth in their investigation. Lomborg (2020) further enhanced the econometric methods by adding causality tests, comparing the economic performance of different countries, and estimating the relationship between economic growth and various measures of well-being.

Dasgupta (2021) argues that GDP is an inadequate measure of sustainable economic development since it ignores natural and social capital. To provide a more accurate measure of a country's wealth and potential for sustainable economic growth, nations should use an economic accounting system that includes inclusive wealth, covering manufactured, natural, human, and social capital. Arrow et al. (2003) and Costanza et al. (2014) support the idea of inclusive wealth measurement and genuine progress indicator (GPI), respectively, as better indicators of genuine progress than GDP. The focus on consumption as a measure of well-being has also been criticized for neglecting non-material aspects of life, such as social relationships and environmental quality (Jackson, 2009). Lomborg (2020) argues in favor of GDP as a useful and widely accepted indicator of economic performance, providing valuable information for policymakers, businesses, and the public. He argues that GDP can be used to compare the economic performance of different countries over time and provide insights into changes in living standards, income distribution, and environmental sustainability.

The traditional economic model has prioritized economic growth over the natural world, but Dasgupta's (2021) review challenges this by incorporating development services into economic decision-making that can reveal the long-term costs and benefits of growth. Costanza et al. (1997) argue that ecosystem services should also be considered in economic decision-making. However, Tupy and Pooley (2021) argue that sustainable development policies may stifle economic growth and innovation, with negative effects on human well-being. They also question the Dasgupta Review's assumptions, stating that the concept of inclusive wealth is flawed and that natural capital is overstated in economic development.

The Dasgupta Review emphasizes the need to incorporate the value of sustainable services into economic decision-making. The true cost of economic activities must be reflected, including the economic value of externalities (Dasgupta, 2021). Daly and Farley (2011) argue that economic accounting should include the cost of externalities to ensure that the true cost of economic activities is reflected. The Stern Review (2007) opposes incorporating the value of sustainable services, instead advocating for a transition towards a regenerative economy that prioritizes both human welfare and environmental protection. The failure to account for externalities is a fundamental flaw of conventional economic models and has resulted in significant environmental and social challenges, including climate change and economic inequality (Stern, 2007).

The traditional economic system does not take into account the value of natural capital and ecosystem services, which are essential for human well-being and economic development. The trade-off implies that there are costs and benefits associated with both economic and sustainable development, and policymakers must make decisions about how to balance these factors to achieve long-term prosperity and well-being (Dasgupta, 2021:335). The alternative perspective is that the concept of a circular economy suggests that economic growth and sustainable development can be mutually reinforcing and that it is possible to decouple economic growth from resource consumption and environmental harm (Korhonen et al., 2018). Similarly, Costanza et al. (2017) argue that investing in natural capital and ecosystem services can actually promote economic growth and human well-being in the long run. The relationship between economic growth and sustainable development may be more complex and dynamic than the traditional trade-off model implies.

3. Theory

3.1 Dasgupta-Heal-Solow-Stiglitz (DHSS) Model

The Dasgupta-Heal-Solow-Stiglitz model (DHSS), developed by Professor Sir Partha Dasgupta (2021), is an extension of the classic Solow model. The model aims to describe the relationship between economic growth and environmental sustainability, taking into account the crucial role that the environment plays in production. The model considers economic growth as a function of four production factors:

$$Y = F(K, L, N, A) = F(K, L, E)$$

Where; K = produced capital; L = labor; N = natural capital; and A = technological change.

One of the unique features of the DHSS model is its recognition that natural resources can be non-renewable. This means that they cannot be replaced by capital or other production factors, leading to potentially significant implications for long-term economic growth and sustainability (Dasgupta, 2021:143). The change in capital over time is calculated using the following formula:

$$\frac{dK}{dt} = s\,F(K, L, E) - \Delta K - R(K, E)$$

Where; s is the proportion of GDP that is saved and invested; ΔK is the economic depreciation of capital over time; and R(K, E) is the repair costs to maintain the environment's production capacity.

The DHSS model provides a more comprehensive framework for understanding the relationship between economic growth and sustainability by demonstrating how investments in capital and labor influence economic growth and production, while the environment is also a crucial factor in the process. This model has had a profound impact on environmental economics and the development of policies for sustainable development (Dasgupta, 2021:143ff). It has also played a significant role in creating new metrics for measuring sustainability, such as natural capital sustainability, and has emphasized the significance of comprehending the correlation between environmental deterioration and economic growth (Ibid).

3.2 Classic Trade-Off between Economic Growth and Environmental protection

The classic trade-off between economic growth and environmental resources refers to the idea of using the Production Possibility Frontier (PPF), showing the opportunity cost of choosing either more environmental protection or more economic output, to analyze output and environmental protection, see Figure 3 (Yandle et al., 2004). Often, this trade-off is viewed as a choice between achieving economic growth or preserving the environment, with the two being seen as competing goals (Kubiszewski et al., 2013). The concave shape of the curve in Figure 3 indicates that there is a limited amount of non-renewable resources, and as they are used up, the opportunity cost of producing additional consumption goods increases. In other words, there is an external cost of economic growth, resulting in larger externalities in society (Yandle et al., 2004). The past century's rapid economic growth has resulted in a decline in natural resources, and this trade-off significantly impacts the environment and sustainability (Kubiszewski et al., 2013).

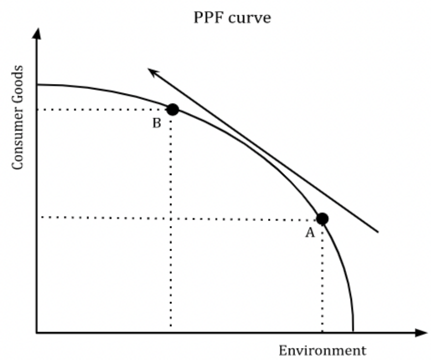


Figure 3. PPF curve. A and B are both productively efficient but reflect different trade-offs between environmental protection and economic output (Kubiszewski et al., 2013).

Countries that prioritize economic output with little environmental protection would be located on the far left of the graph at point B. On the opposite end of the spectrum, countries that prioritize environmental protection but allocate little resources to economic output would be located at point A (Yandle et al., 2004). Countries with lower per capita GDP tend to focus more on economic output to provide basic necessities, such as nutrition, shelter, health, education, and consumer goods. Conversely, countries with higher income levels and greater access to basic necessities may be more willing to allocate resources to environmental protection (Kubiszewski et al., 2013).

3.3 Externalities

Externalities are a key concept in economics, referring to the effects of economic activities on third parties who are not involved in a given transaction. These effects can be either positive or negative and occur when the actions of one person or firm impact the welfare of others in a way that is not reflected in the market price (McCoy, 2003). For example, pollution from a factory can harm the health of nearby residents, imposing an opportunity cost on society, see the gray area in Figure 4. The failure of competitive companies and consumers to pay for the harm they cause to others leads to the overproduction of negative externalities, which in turn renders market solutions inefficient (Baumol and Blinder, 2016).

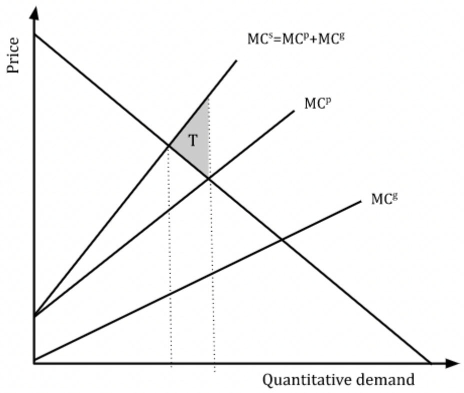


Figure 4. Externalities.

However, the neoclassical view of microeconomics suggests that regulations and policymaking that add costs to companies create deadweight loss and result in disadvantages for the affected companies (McCoy, 2003). For example, taxes can lead to efficiency loss by either increasing the cost of production or raising the purchasing price in the market, leading to a smaller production volume. Although such regulations can be detrimental to companies, if taxes equal the full external cost, it can lead to a socially efficient outcome by creating strong incentives for promoting growth that minimizes external costs (Mankiw, 2015).

While certain measures aimed at safeguarding and fostering the biosphere are technically and ecologically feasible, they are not always institutionally feasible (Baumol and Blinder, 2016). This implies the acknowledgment of unavoidable underinvestment in nature and the existence of environmental externalities that are inherently impossible to eliminate. Therefore, it is essential to identify the appropriate policy measures to minimize externalities and enhance economic efficiency while considering the limitations of institutional feasibility (McCoy, 2003).

3.4 Economic Growth and Environmental Damage

This thesis investigates the complex relationship between economic growth and environmental damage, as depicted in Figure 5. The figure visually presents three contrasting ideas surrounding the impact of growing GDP per capita on the environment: Limit to Growth (3.4.1), New Toxic and Davidson (3.4.2), and Race to the Bottom (3.4.3).

Figure 5. Economic growth and environmental damage (Davidson, 2000). The three different tables illustrate contrasting ideas on how growing GDP per capita will damage the environment. The theories Limit to Growth (3.4.1), New Toxic and Davidson (3.4.2), and Race to the Bottom (3.4.3) are described below.

3.4.1 Limits to Growth Theory

The limits to growth theory posits that economic growth will eventually deplete natural resources, degrade the environment, and increase pollution levels (Meadows et. al., 2004). These negative effects will, in turn, act as a limit or constraint on further economic growth, see Figure 5. This implies that the environment has a finite capacity to absorb the impacts of economic activity, and there is a limit to growth without causing irreversible damage to the planet. The theory highlights that the environment will act as a brake on growth, and economies will be forced to address the economic damage caused by environmental degradation. For instance, as natural resources become scarce, their prices rise, creating incentives for innovation and alternative resource development (Arrow et al., 1996:104-110). The outcome of the theory posits that the environment will eventually force societies to address the issue of environmental degradation and promote sustainable development.

3.4.2 New Toxics and Davidson

Carlos Davidson (2010) presented a more pessimistic view of the correlation between economic growth and environmental damage calling it New Toxics and Davidson, suggesting that economic growth leads to an ever-expanding range of toxic output and issues. While some problems may be resolved they are outweighed by newer and more pressing issues that may be impossible to overcome, see Figure 5. The model lacks confidence in the ability of the free market to address the problem since there is no ownership of air quality, and many of the effects of pollution accumulate over time and impact future generations and these forthcoming effects cannot be effectively addressed through the current price mechanism (Davidson, 2010:433-440).

3.4.3 Race to the Bottom

The premise of Race to the Bottom is founded by researcher Stern (2004), suggesting that in the early stages of economic growth, environmental concerns are often neglected, and countries may even undermine environmental standards to gain a competitive advantage, thus incentivizing free-riding on others' efforts. However, as the environment becomes increasingly degraded, it reluctantly forces economies to reduce the worst effects of environmental damage, albeit not enough to reverse past trends, see Figure 5. The theory cautions that this competition for growth can harm the environment by encouraging countries to prioritize economic growth over environmental protection (Stern, 2004). Nevertheless, as the negative impacts of environmental degradation become more evident, countries will feel the pressure to mitigate the worst effects of environmental damage, resulting in slower environmental degradation. However, it may not be feasible to fully reverse past trends. The theory underscores the need for a delicate balance between economic growth and environmental protection to avoid unsustainable practices that harm both the economy and the environment (Davidson, 2010).

4. Data

The present study investigates the relationship among the indicators of economic, societal, and environmental performance among OECD member countries from 2000 to 2021. Secondary data are collected from the World Bank for GDP, population, and labor force, and from Sustainable Development Solutions Network (SDSN) for SDG index (SDSN, 2023). Panel data estimation is utilized to analyze the dynamic behavior of the parameter and consider heterogeneity explicitly to handle all available evidence that cannot be measured in pure cross-section and time series (Plumper et al., 2005).

Using balanced panel data of all 38 OECD countries covering 21 years, the study covers all three dimensions of sustainability, see Appendix B. It also includes three macroeconomic indicators, GDP growth, Governance, and Labor force; three societal development indicators, Basic needs and services, Equality and Empowerment population; and one environmental development indicator, Conservation and Management. The measurement values of the time series are annual to correspond to the SDG index, which is only calculated on an annual basis. The estimated results are analyzed based on the data period of 2000-2021, which is the most prolonged period for which complete data is available. Table 2 presents the regressand, regressors, and control variables for this study. The regressors are categorized into explanatory variables for the 17 Sustainable Development Goals, see Appendix A, providing a more comprehensive picture of a country's progress toward sustainable development:

Table 2. Variables used in the regression.

Character	Variable	SDG	Variable description	Measurement
Regressand	Economic growth per capita (GROWTH)		The aggregate gross value added generated by all resident producers within an economy, inclusive of any product taxes and net of any subsidies that are not factored into the product's valuation.	Annually (%)
Regressor	Basic needs and services (BASIC)	1, 2, 6, 7	Providing essential goods and services for well-being and sustainable development.	Annually (%)
Regressor	Conservation and Management (CONMAN)	13, 14, 15	Preserving and sustainably managing natural resources and ecosystems to promote biodiversity, mitigate climate change, and ensure availability for future generations.	Annually (%)
Regressor	Governance (GOV)	16, 17	Governing and shaping interactions in politics, economics, and society, ensuring fairness, openness, involvement, and legal compliance.	Annually (%)
Regressor	Infrastructure and	8, 9, 11, 12	Improving economic productivity, innovation, sustainability, and access to basic services	Annually (%)

	Innovation (INFINN)		through physical and technological assets, systems, and processes.	
Regressor	Equality and Empowerment (EQUEMP)	3, 4, 5, 10	Advocating for equal opportunities, access, and outcomes in health, education, and social and economic participation, especially for marginalized and vulnerable groups.	Annually (%)
Control	Labor force (LABOR)		People >15 who supply labor for the production of goods and services.	Annually (million)
Control	Population (POP)		Population in millions.	Annually (million)

Source: United Nations Department of Economic and Social Affairs (2023) and the World Bank (2023).

4.1 GDP Growth per capita

$$Growth\ per\ capita\ =\ \frac{GDP_{it}}{N}\qquad \text{with } i\ =\ 1,\ldots,N \text{ and } t\ =\ 1,\ldots,T$$

Where; GDP_{it} = Gross domestic product at purchaser's prices in country *i* year *t*; and N = mid-year population.

This calculation does, however, not account for the depreciation of fabricated assets or the depletion and degradation of natural resources (The World Bank, 2023a). The United Nations System of National Accounts recommends two methods of valuing value added: basic prices, excluding net taxes on products, or producer prices, including net taxes on products paid by producers but excluding sales or value-added taxes (United Nations Statistics Division, 2023). In the provided data, the growth rates of GDP and its components are derived using the least squares method and constant price data in the local currency. Regional and income group growth rates are calculated using constant prices in US dollar series. Local currency series are transformed into constant US dollars using an exchange rate in the common reference year (The World Bank, 2023).

The growth of GDP per capita is autocorrelated, meaning that the present value of the time series is dependent on its past values (Daniels and Minot, 2020). Therefore, the effect of economic growth happening in year 1 may not be visible until year 2. In order to effectively address this issue, we incorporate lagged GDP per capita growth in our analysis.

4.2 Sustainability Goals Index

The United Nations' sustainable development goals include 17 goals containing 169 sub-goals. The measurement for each sub-goal is listed in Appendix A. However, the data availability pertaining to these is not consistently uniform across all countries and time periods. Properly, the SDG index assesses a country's performance on all 17 SDGs, with equal weightage given to each, to provide a holistic evaluation. This methodology acknowledges the paucity of data on the subgoals and endeavors to provide a comprehensive estimate of a country's advancements toward realizing the SDGs (Sachs et al., 2022). The index ranges from 0–100 percent and is interpreted as a percentage of SDG achievement. Scoring 100 indicates that the country achieved the national target set for 2030 that year. A score of 0 indicates that the country is not progressing toward achieving the SDGs (Sustainable Development Report, 2023).

In order to examine the impact of various dimensions of sustainable development, the 17 Sustainable Development Goals have been classified into five distinct explanatory variables stated in Table 2.

4.3 Control Variables

The choice of control variables is derived from the Dasgupta-Heal-Solow model which includes capital stock, labor force, natural resources, and technological progress (Dasgupta, 2021). These variables are crucial in understanding the dynamics of economic growth and the impact of natural resources on economic development.

4.3.1 Total Labor Force

The labor force comprises individuals aged 15 years and above who provide labor in producing goods and services, such as those who are employed, unemployed but actively searching for work, and first-time job seekers. However, the statistical data may exclude unreported employment, family workers, and students. Labor productivity, measured as real GDP produced per hour of labor, is a crucial economic indicator that helps assess a country's competitiveness and overall health on the global stage (The World Bank, 2023b). Dasgupta and Ray (1986) argue that a decrease in overall labor productivity is a crucial factor for growth and development. Levy, Brandon, and Studart (2020) resonate that labor-intensive sectors that involve connecting labor forces and sustainable restoration projects create over ten more jobs than comparable size investments in unsustainable industries like fossil-based industries. Further, this improves labor productivity and economic growth and attracts a growing labor force while decreasing the land/labor ratio.

4.3.2 Population

The de facto definition of the total population includes all residents, regardless of legal status or citizenship, estimated from mid-year (The World Bank, 2023c). Professor Dasgupta's growth model, DHSS, assumes exogenous population growth and no human capital accumulation, technological progress, or environmental constraints on the economy (Dasgupta, 2021). In the long run, GDP has the potential to grow infinitely, however, output per capita is limited from above. Dasgupta and Heal (2001) posited that substitution possibilities between produced capital and diminishing resources in production are adequate for eternal economic growth, and even as the availability of diminishing resources decreases, the population can continue to grow indefinitely, albeit at a decreasing rate over time. Thus, analyzing economic growth trends over time requires controlling for population (Dasgupta and Heal, 2001).

4.4 Data Concerns

One outstanding issue in this study's econometric model concerns the limited number of control variables, and the exclusion of crucial drivers of economic growth may lead to omitted variable bias (Daniels and Minot, 2020). Due to insignificant results, variables stated as direct drivers of economic growth have been excluded (Dasgupta, 2021). To substitute for this, Figure 1 on page 5, provides a visual representation of the GDP per capita level for the analysis. The investigation focuses on measuring economic indicators within OECD countries and does not consider their behavior or impact on each other. The potential issues with SDG data used in the study, such as retroactively calculated measurements, since the index was implemented in 2015 and our data reaches from 2000. Therefore, categorization biases should also be considered (UNSDG, 2023).

4.5 Descriptive Statistics

Table 2 presents descriptive statistics for the variables under study. These statistics provide a summary of the data, including measures such as mean, median, standard deviation, and minimum-, and maximum values. They offer insights into the characteristics, variability, and range of the variables.

Table 2. Descriptive statistics.

Variable	**Mean**	**Median**	**Std. Dev.**	**Min**	**Max**
$GROWTH_{t-1}$	1.8375	1.82033	3.4774	-14.4643	23.2009
$BASIC_{it}$	326.3238	326.7707	15.1478	282.4010	356.9796
$CONMAN_{it}$	192.3257	194.5144	26.6968	119.9638	246.8690
$EQUEMP_{it}$	330.8860	338.0798	36.8056	212.8020	385.1108
GOV_{it}	144.6775	144.4955	15.7491	114.9952	187.0192
$INFINN_{it}$	298.7714	303.4555	25.3560	237.9255	349.5842
$LABOR_{it}$	1.65e+07	5008189	2.77e+07	169444	1.67e+08
POP_{it}	34.0352	10.41772	55.37884	0.2812	331.8937

5. Empirical Methodology

The flowchart diagram presented in Figure 6 illustrates the methodology for cross-sectional panel data analysis adopted in this research.

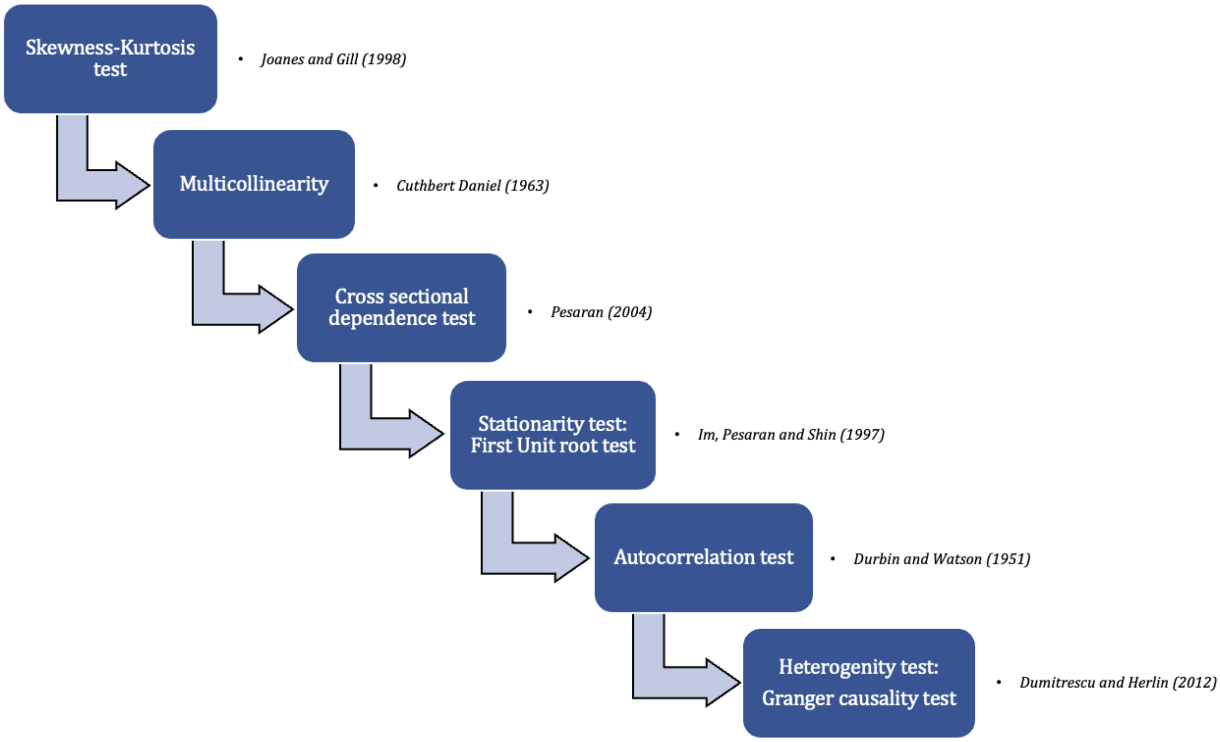


Figure 6. Flowchart summary of Panel Data Analysis.

5.1 Econometric model specification

The study proposes a production function where GDP per capita growth and its influencing variables are modeled as:

$$GROWTH_{t-1} = f(GOV_{it}, INFINN_{it}, CONMAN_{it}, EQUEMP_{it}, BASIC_{it})$$

Where; the subscripts i and t denote country and time period respectively. Here, GROWTH is the Gross Domestic Product growth (annually %); GOV is the explanatory variable for governance; INFINN is the explanatory variable for infrastructure and innovation; CONMAN is the explanatory variable for Conservation and Management; EQUEMP is the explanatory variable for equality and empowerment and BASIC is the explanatory variable for basic needs.

From this, equation (1) can be parameterized as follows:

$$GROWTH_{t-1} = BASIC_{it}^{\beta 1i}\ INCOMAN_{it}^{\beta 2i} EQUEMP_{it}^{\beta 3}\ GOV_{it}^{\beta 4}\ INFINN_{it}^{\beta 5}$$

To mitigate omitted variable bias arising from variations in the labor force and population size across countries, control variables are employed. The use of the first difference method is also implemented to account for the issue of omitted variables in panel data and stationarity

(Daniels and Minot, 2020). This leads to the development of the empirical equation, structured for first difference, presented in equation (2):

$$\Delta lGROWTH_{t-1} = \beta_0 + \beta_1 \Delta lBASIC_{it} + \beta_2 \Delta lCONMAN_{it} + \beta_3 \Delta lEQUEMP_{it} + \beta_4 \Delta lGOV_{it} + \beta_5 \Delta lINFINN_{it} + \beta_6 \Delta lLABOR_{it} + \beta_7 \Delta lPOP_{it} + \varepsilon$$

Where; β_1 to β_7 are elasticities of GDP growth with respect to other variables; and ε is the error term.

5.1.1 Fixed Effect and Cross-Sectional Time Series

To ensure that there exists a single true effect underlying all the estimates in the analysis and that any variations in the observed effects are solely due to sampling error, the regression is studied with fixed effect amendment. To address outliers in the regression analysis, the iteratively reweighted least squares method (IRLS) is utilized to assign weights to each data point (Borenstein et al., 2010). The data is also modified for cross-sectional time series by following the approach by De Hoyos and Sarafidis (2006).

5.1.2 Normality Test

Testing for normal distribution helps determine measures of central tendency, dispersion, and the selection of parametric or non-parametric tests based on the normality status. Therefore, the skewness-kurtosis test is made, showing that the data is normally distributed and thus, that the mean is an appropriate representative value of the data (Joanes et. al., 1998). Joanes and Gill (1998) estimate sample skewness and sample excess kurtosis using the following formulas respectively:

$$G_1 = \frac{\sqrt{n(n-1)}}{n-2} g_1$$

Where; n = sample size; and g_1= the average value of z-score in the power of three.

$$G_2 = \frac{n-1}{(n-2)(n-3)} \left[(n + 1) g_2 + 6 \right]$$

Where; n = sample size; and g_2 = the average value of z-score in the power of three.

5.1.3 Multicollinearity

It is essential to ensure that the independent variables are not correlated with each other. To identify the possible presence of a high correlation between two or more independent variables in the regression model and assure full rank assumption, the Variance Inflation Factor (VIF) test is employed (Kutner, 2005). The test serves to quantify the severity of multicollinearity, which indicates the increase in the variance of a regression coefficient as a result of collinearity. Cuthbert Daniel (1963) suggests the following equation (Snee, 1981):

$$VIF = \frac{1}{(1-R_j^2)} = \frac{1}{Tolerance}$$

Where; $R_j^2 = R^2$ of the model of one individual predictor against all the other predictors.

VIFs use a multiple regression model to calculate the degree of multicollinearity. Each model will produce an R^2 value indicating the percentage of the variance in the individual predictor that the set of other predictors explains. A value of $R_j^2 = 0$, suggests that the variation in the remaining independent variables cannot be accounted for by the i^{th} independent variable (Snee, 1981).

5.1.4 Cross-Sectional Dependence Test (CSD)

The CSD test utilizes the coefficient of correlation among the time series for each country present in the panel data to examine the presence of cross-sectional dependence within the panel variables (Pesaran, 2007). In order to address the issue of mutual interactions between variables, the CSD test is addressed using Pesaran's (2004) suggested equation:

$$CSD = \sqrt{\frac{2t}{z(z-1)}}\left(\sum_{i=0}^{z-1}\sum_{j=i+1}^{z-1} pij\right)$$

Where; CSD = cross-sectional dependence; z = cross-sections in the panel data; t = time horizon; and pij= cross-sections correlation of error between i and j. The equation to study the CSD is the following:

$$y_{it} = \alpha_{it} + \beta_i x_{it} + \varepsilon_{it} \qquad \text{with } i = 1,\ldots, N \text{ and } t = 1,\ldots, T$$

Where; t=time horizon and i= the cross-section in the panel. The null hypothesis states that cross-sectional dependence does not exist among the variables. The alternate hypothesis remark that cross-sectional dependence does exist among the variables.

5.1.5 First-Generation Unit Root Test

When high cross-sectional dependence is present, the null hypothesis for the study tends to be over-rejected by all tests. This leads to potential bias in the standard panel unit root test, which does not account for cross-sectional dependence (Pesaran, 2007). To test for stationarity, the first generation unit root test is made using the IPS test proposed by Im, Pesaran, and Shin (1997). The test accounts for individual effects, time trends, and common time effects, and assumes that all series in the panel are non-stationary under the null hypothesis based on the mean of the individual Dickey-Fuller t-statistics (Im et. al., 2003). According to Pesaran (2007), the unit-root test can be depicted as follows:

$$x_t = \alpha_{it} + \beta_i x_{it-1} + \rho_i t + \sum_{j=1}^{n} \theta_{ij} \Delta x_{i.t-j} + \varepsilon_{it} \qquad \text{with } i = 1,\dots,N \text{ and } t = 1,\dots,T$$

Where; α_{it}= intercept; t = time horizon; Δ = the difference operator; x_{it}= variables under study; and ε_{it}= error term. The null hypothesis states that the series under study are non-stationary. The alternate hypothesis remarks that the series under study are stationary.

5.1.6 Durbin-Watson Test for Autocorrelation

The presence of autocorrelation in the residuals of the regression model is assessed using the Durbin-Watson statistic. This widely used diagnostic tool helps evaluate the regression model's quality and identify any unmodeled effects of time trends that might impact the outcome. The Durbin-Watson statistic ranges from 0 to 4, where a value of DW = 0 implies no autocorrelation, DW < 2 indicates positive autocorrelation and DW > 2 implies negative serial correlation (Durbin and Watson, 1951:159-179). The mathematical formula for the Durbin-Watson statistic can be interpreted as follows:

$$d = \frac{\sum_{t=2}^{T} (e_t - e_{t-1})^2}{\sum_{t=1}^{T} e_t^2}$$

Where; e_t = residuals; and T = number of observations.

5.1.7 Heterogeneous Panel Causality Test

Granger non-causality test is utilized to establish the direction of causality, assuming that all coefficients vary across cross-sections. The test has been further developed by Dumitrescu and Hurlin (2012) who introduced the Heterogeneous panel causality test, accounting for heterogeneity across units when identifying causal relationships between variables in panel data models where dynamics across individuals and time may have different dynamics (Dumitrescu and Hurlin, 2012). However, this test is applicable only if the variables are stationary. Therefore, the first difference of the series was used to apply the test (Baltagi, 2013). Dumitrescu and Hurlin (2012) proposed an underlying regression equation which is expressed as follows:

$$y_{it} = \alpha_{it} + \sum_{k=1}^{K} \beta_{ik} y_{i,t-k} + \sum_{k=1}^{K} \gamma_{ik} x_{i,t-k} + \varepsilon_{it} \qquad \text{with } i = 1,\dots,N \text{ and } t = 1,\dots,T$$

Where the assumed lag of order K is identical for all individuals and the panel data must be balanced. The null hypothesis states that there is no causality between the selected variables under study. The alternate hypothesis remarks that there is causality for at least one panel variable.

5.2 Methodology Concerns

When applying the econometric methodology, it is essential to address and consider limitations. Firstly, the Durbin-Watson test can only indicate the adequacy of the model, and further analysis of residuals is necessary to determine the cause and seriousness of any detected autocorrelation. Thus, the test cannot provide evidence to exclude autocorrelation for this study, but rather an estimation (Durbin and Watson, 1951). Secondly, we did not use cointegration tests as they are unnecessary for relatively stable economies (Wooldridge, 2010). Thirdly, the Granger causality only indicates the forecasting ability of variables, not their true causal relationship (Dumitrescu and Hurlin, 2012). Finally, it is important to note that heterogeneity can impact generalizability. Therefore, to address this concern, randomized controlled trials and multivariate analysis are essential. The former helps to reduce bias and increase generalizability, while the latter emphasizes the need to report relevant information about the sample group and the methods used to handle causality (Angrist and Pischke, 2009).

6. Results

6.1 Main results

In this section, the main estimations and results obtained from the previously stated econometric methodology are presented.

6.1.1 Multicollinearity

VIF results for the independent variables are under 5, the model can be concluded to obtain moderate, almost no, correlation between the explanatory variables as the given data are relatively far below 5, see Table 3 (O'Brien, 2007). However, both POP_{it} and $LABOR_{it}$ exhibit high values, indicating high multicollinearity. According to Kutner (2005), the control variables do not affect how our independent variables affect each other or the dependent variable. Thus, the variance of the i^{th} regression coefficient is not inflated and does not correlate to the remaining ones, meaning multicollinearity does not exist in the model, as VIF and tolerance are not equal to 1. Accordingly, further adjustment is not needed and we conclude that the explanatory variables are not correlated and do not decrease the statistical significance of the independent variables (Kutner, 2005).

Table 3. Multicollinearity.

Variable	$BASIC_{it}$	$CONMAN_{it}$	$EQUEMP_{it}$	GOV_{it}	$INFINN_{it}$	$LABOR_{it}$	POP_{it}
VIF	1.77	1.32	3.40	1.81	2.64	212.55	220.66

6.1.2 Cross-Sectional Dependence Test

The null hypothesis for Pesaran's test of cross-sectional dependence is rejected at 99 % level of significance for the model as a whole and for all independent variables, excluding the two control variables, shown in Table 4. We can not reject the hypothesis of cross-section independence for LABOR and POP. For the majority of independent variables, there is significant cross-sectional dependence in the data (Pesaran, 2015). This suggests that the test statistic is substantial relative to its sampling distribution under the null hypothesis, which provides strong evidence against the null hypothesis of cross-sectional independence among our panel variables (De Hoyos and Sarafidis, 2006:3f). The average absolute value of the off-diagonal elements of the matrix of spatial correlations is reported as 0.545, where higher values suggest stronger cross-sectional dependence, and notes a significantly positive average absolute correlation. A strong correlation does not necessarily mean a causal relationship.

Table 4. Cross-Sectional dependence.

Variable	CSD	$BASIC_{it}$	$CONMAN_{it}$	$EQUEMP_{it}$	GOV_{t-1}	$INFINN_{it}$	LABOR	POP
IPS	16.59***	5.75***	17.74***	27.42***	8.51***	66.74***	1.05	0.92

Note: '*', '**', '***' signify 90 %, 95 % and 99 % level of statistical significance, respectively.

6.1.3 First-Generation Unit Root Test

The outcomes of the first-generation unit root test when accounting for time trend, demonstrate that all variables exhibit stationarity at a 99 % level of significance under the Im-Pesaran-Shin test. Concluding the findings in Table 5, most variables in the study are stationary, except for POP, which is non-stationary. This implies that the time series exhibits a stationary behavior, characterized by the absence of a deterministic trend or drift and the persistence of its statistical properties over time.

Table 5. First-generation unit root test.

Variable	$GROWTH_{t-1}$	$BASIC_{it}$	$CONMAN_{it}$	$EQUEMP_{it}$	GOV_{it}	$INFINN_{it}$	LABOR	POP
IPS	-20.52***	-21.45***	-20.80***	-21.48***	-20.77***	-21.82***	-23.56***	-23.58***

Note: '*', '**', '***' signify 90 %, 95 % and 99 % level of statistical significance, respectively.

6.1.4 Durbin Watson Test for Autocorrelation

Durbin Watson's test for autocorrelation reports a value of DW = 1.8302, which signifies there is no autocorrelation in the regression model (Durbin and Watson, 1951:159-179). The DW-value is within the area of the critical numbers, see Figure 7. Thus the null hypothesis that there is no autocorrelation cannot be rejected, as the model does not show autocorrelation.

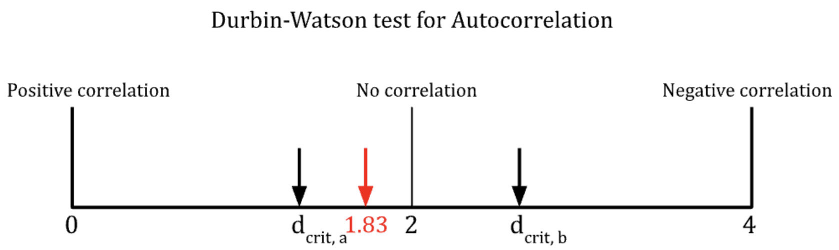


Figure 7. Autocorrelation.

Where; $d_{crit,\,a} > 0$ = severe positive autocorrelation; $d_{crit,\,a} < 2 < d_{crit,\,b}$ = no autocorrelation; and $d_{crit,\,b} > 4$ = severe negative autocorrelation.

6.1.5 Heterogeneous Panel Causality Test

Table 6 should be interpreted as a signal that the estimations suffer from small sample biases, as asymptotic p-values are underestimated (Dumitrescu and Hurlin, 2012). The null hypothesis of non-causality is rejected at the conventional significance level for all independent variables, except BASIC. We do not have enough evidence to ascertain that BASIC granger-cause the dependent variable, and therefore fail to granger-cause where it is not helpful for forecasting the dependent variable.

Table 6. Heterogeneous panel causality.

Variable	W-bar	Z-bar
$BASIC_{it}$ ≠> $GROWTH_{t-1}$	1.0207	0.0904
$CONMAN_{it}$ ≠> $GROWTH_{t-1}$	2.0509	4.5808***
$EQUEMP_{it}$ ≠> $GROWTH_{t-1}$	2.5335	6.6846***
$INFINN_{it}$ ≠> $GROWTH_{t-1}$	2.1417	4.9765***
GOV_{it} ≠> $GROWTH_{t-1}$	1.6136	2.6745***
$LABOR_{it}$ ≠> $GROWTH_{t-1}$	2.1422	4.9785***
POP_{it} ≠> $GROWTH_{t-1}$	2.8867	8.2238***

Note: '*', '**', '***' signify 90 %, 95 % and 99 % level of statistical significance, respectively.

6.1.6 Estimation results

The results of our analysis, as presented in Table 7, indicate that two of our variables are significant at a 99 % level of significance. Specifically, a 1 % increase in EQUEMP leads to a 1.88 % increase in GROWTH, while a 1 % rise in INFINN leads to a 1.03 % increase in GROWTH, thereby rejecting H_{0c} and H_{0e}. Furthermore, our findings suggest that, at a 95 % confidence interval, a 1 % increase in BASIC and GOV would positively impact GROWTH by 1.08 % and 0.65 %, respectively, leading to the rejection of H_{0a} and H_{0d}.

With regard to CONMAN, the output shows that the sign is not as expected. However, our data do not provide sufficient evidence to reject the null hypothesis H_{0b}, suggesting that environmental conservation and management may not have a negative impact on economic growth.

Overall, the results suggest that policymakers should focus on improving social equality and equity, while also investing in infrastructure and R&D to enhance sustainable economic growth. Notably, the coefficients for EQUEMP and INFINN are largest at a 99 % level of significance, highlighting the importance of investing in these areas to promote sustainable economic growth (Dasgupta and Ray, 1986). Our findings are consistent with those of Dasgupta (2021), which suggest that technology development has a positive impact on economic growth in the long run.

Table 7. OLS (GDP growth as dependent variable).

Independent variables	**Fixed effects, first difference OLS**	
	Coef	Std. Err.
$BASIC_{it}$	1.0809**	0.8578
$CONMAN_{it}$	-0.4608	0.3716
$EQUEMP_{it}$	1.8803***	0.3595
GOV_{it}	0.6527**	0.3257
$INFINN_{it}$	1.0282***	0.4694
$LABOR_{it}$	0.2617*	0.4894
POP_{it}	-0.2625*	0.47815
F-test	41.52***	
Adjusted R^2	0 .7454	
DF	37	
SSE	5.0252	
N	835	

Note: '*', '**', '***' signify 90 %, 95 % and 99 % level of statistical significance, respectively.

6.2 Result Limitation

When using explanatory variables in a regression model, it's crucial to consider their limitations, such as omitted variable bias, multicollinearity, endogeneity, measurement error, and sample selection bias. These limitations can lead to biased and inconsistent estimates of regression coefficients, affecting the model's validity and reliability. Hence, it's essential to carefully evaluate the model's assumptions and potential limitations and use appropriate techniques to address them when necessary. Doing so can help mitigate the risks of bias and enhance the model's robustness (Nandy, 2015).

Multicollinearity, if not addressed, can undermine the accuracy and validity of a regression model. However, high levels of multicollinearity among control variables may be acceptable, as control variables are important in achieving a comprehensive analysis of the relationship between variables of interest. Including control variables in models can also reduce the risk of misinterpretations when examining effects (Bremmer et al., 2021).

While the two control variables in this study do not violate the assumption of independent observations across different units in the sample, cross-sectional dependence among the variables cannot be ruled out. This may introduce bias in the regression model, requiring further analysis to draw conclusive insights. The cross-sectional dependence test may also fail to reject the null hypothesis, even if significant cross-sectional dependence in the errors exists (Hill et al., 2018).

The non-significant variable CONMAN in the regression model should not be excluded outright, as it may still have a theoretical basis or high correlation with other variables that have a significant effect on the dependent variable. The heterogeneous panel causality test supports the theoretical foundation for CONMAN to affect the dependent variable, and its high correlation with another significant variable may explain the variation in the dependent variable. Thus, excluding the non-significant variable may lead to an incomplete explanation (Moser et al., 2018).

7. Discussion

A relationship between sustainable development and economic growth can be ascertained according to the result. The study establishes a significant positive relationship between economic growth and both the social- and economic development factors, see Appendix B. This conclusion is consistent with our expected results.

Given the variations observed in the regression output across different cross-sections, the issue of causality warrants further examination. The heterogeneous panel causality test confirms that advancements in social well-being, such as improved education, healthcare, and quality of life, act as catalysts for economic growth. Similarly, economic development factors, including technological innovation, infrastructure investment, and productive employment, exert a profound influence on the expansion and flourishing of the economy

(Tupy and Pooley 2021). But, the Granger non-causality test was employed to ascertain the direction of causality, revealing that only BASIC is ineffective in forecasting the dependent variable (Dumitrescu and Hurlin, 2012). Statistically, there is no evidence to suggest that the provision of essential goods and services for well-being and sustainable development directly causes economic growth. It may depend on whether OECD countries generally exhibit a high standard of living and a high SDG index pertaining to basic needs. It is possible that the findings could differ if compared to developing countries where the prominence of basic needs is less apparent.

Furthermore, in the absence of sufficient statistical evidence, we refrain from concluding a relationship between the environmental factor, variable CONMAN, and economic growth. This finding presents a contrasting perspective to the DHSS theory which states that preserving and sustainably managing natural resources and ecosystems to promote biodiversity, mitigate climate change, and ensure availability for future generations will ensure economic growth. (Dasgupta 2021). Thus, our results oppose Dasgupta (2021), who expects such environmental efforts to contribute significantly to economic growth by fostering sustainable development and unlocking economic opportunities. As it can not be confirmed with a significant relationship between the two variables, the DHSS theory gives us a previous statistical basis for further discussion.

The UN development goal performance for the OECD countries does have a positive impact on economic growth for social and economic dimensions. This study reveals that progress towards these goals is associated with increased economic growth. For instance, when a country enhances its provision of basic needs (SDG 1, 2, 6, and 7) by 1 %, it generates a significant positive impact on its GDP per capita growth, increasing it by 1.08 %. This confirms previous research by Singh et al. (2022).

Again, the data provided in this study resulted in a negative, however not statistically significant, impact of the environment on economic growth. This contradicts our expected results. Even if the negative sign disagrees with Dasgupta's review (2021), a reasonable explanation is the limits to growth theory (Meadows et al., 2004). The negative sign implies that the environment has a finite capacity to absorb the impacts of economic activity, where environmental damages by economic growth act as a limit or constraint on further economic growth (Arrow et al., 1996:104-110). The OECD countries with high consumption rates may reach a limit of natural resources, but the environment will eventually force societies to address the issue of environmental degradation and promote sustainable development, see Figure 5 (3.4.1) on page 14.

The control variable POP exhibits a statistically significant negative correlation, which also contradicts the framework proposed in the DHSS model (Dasgupta, 2021). The result suggests that a growing population is associated with declining GDP growth per capita, indicating potential inefficiency within the country. Seen from the DHSS model, an increased population can negatively impact production factors by exceeding available capital leading to resource strain and inefficiency, straining the job market resulting in unemployment or low wages, overexploitation and environmental degradation, and providing sufficient education for quick solutions and infrastructure.

The positive relationship between economic-, and social development and economic growth is insightful for policymakers, as they provide a clear roadmap for fostering sustainable economic growth. Governments that prioritize investments in education, healthcare, and social infrastructure alongside measures to stimulate economic productivity will reap the rewards of accelerated economic growth. By achieving the United Nations' sustainable development goals and increasing its SDG Index score, states can foster human capital development, reduce poverty, and improve overall societal well-being, thereby positively contributing to economic growth and shifting the focus and craving for consumption.

Striking a balance between immediate economic priorities and long-term sustainability is a challenge. While some measures may yield short-term benefits, they can have negative long-term effects on the environment and social well-being. Achieving equilibrium across these dimensions requires careful planning and focus on sustainable strategies that provide both immediate and long-term advantages. But, economic competitiveness remains a significant concern and policymakers must navigate the trade-off between economic competitiveness and sustainability. While certain industries or practices may contribute to economic growth, they may also have negative environmental or social impacts in the long run, see New Toxic and Davidson in Figure 5 (3.4.2) on page 14. They need to carefully consider regulations, incentives, and support mechanisms that encourage sustainable practices without compromising economic competitiveness.

The opportunity cost can be a potential trade-off and challenges associated with achieving balance. With the limited amount of non-renewable resources, the opportunity cost of producing additional consumption goods increases (Yandle et al., 2004). Countries with higher GDP per capita and greater access to basic necessities may be more willing to allocate resources to environmental protection (Kubiszewski et al., 2013). An allocation inside the PPF is productively inefficient, see Figure 3 on page 12. Connected to the trade-off model it can be interpreted as, see Figure 2 on page 6, a country as Türkey with a high GDP that still focuses on economic output, is productively inefficient and should be investing in environmental protection. Investments in the environment promote economic growth and human well-being in the long run, which shows the importance to policymakers concerning the trade-off (Costanza et al., 2017).

The external cost of economic growth results in larger externalities in society (Yandle et al., 2004). In the context where economic growth causes external costs, policymakers need to incorporate these costs into the pricing framework, such as through the implementation of taxonomy. If the magnitude of the tax aligns with the complete extent of the external cost, it will culminate in a socially efficient outcome while concurrently instilling a potent incentive to foster growth strategies that mitigate external costs, see Figure 4 on page 13 (McCoy, 2003).

If policymakers consider the environment as a public good, the implementation of environmental policies addressing external costs can foster economic growth while protecting natural resources. The theory known as the Race to the Bottom suggests that in the early stages, environmental concerns are often overlooked in favor of prioritizing economic growth, see Figure 5 (3.4.3) on page 14. However, as awareness of the negative impacts of environmental degradation increases, countries are compelled to mitigate these effects, leading to a slower rate of degradation. Although a complete reversal of past trends may be impractical, it remains essential to strike a balance between economic growth and environmental protection to avoid unsustainable practices that detrimentally affect both the economy and the environment (Davidson, 2010).

Policymakers must exercise caution in discerning causality, particularly when utilizing GDP growth as a metric, as numerous factors influence it, and the direction of their effects must be considered. In this study, we examined causality from the independent variable to the dependent variable but do not disregard the possibility of reverse causality. Determining the true causal effect becomes more challenging in such cases. However, in this context, the causality from the opposite direction could potentially heighten incentives to invest in sustainability, to contribute to both GDP growth and sustainable progress. For instance, considering Ireland as an exemplar, see Figure 2 on page 6, it exhibits remarkable characteristics with substantial GDP growth and a high SDG index. Based on the observed causality, it implies that sustainability and economic growth mutually reinforce each other positively. Consequently, the potential trade-off between the two may not be as intricate, as evidenced by Ireland's success in achieving a harmonious combination of the two objectives.

This brings us to the issue of using GDP as a comprehensive measure, and if policymakers incorporate these considerations along with another measurement encompassing economic and sustainable costs, the trade-off could diminish, reducing associated opportunity costs. Equivalent to what Professor Sir Dasgupta established in the Dasgupta-Heal-Solow-Stiglitz model when taking account for natural capital, to provide a fairer balance. It should not be a binary dilemma between these two objectives but rather an implicit integration of both. Rather than solely focusing on GDP, policymakers should aim for a broader range of indicators encompassing living standards and environmental factors by incorporating quality of life and environmental metrics into economic statistics.

8. Conclusion

The aim of this study is to investigate the relationship between economic growth and sustainable development, and how the United Nations' sustainable development goals influence economic growth. The study also aims to examine the potential challenges and trade-offs in designing effective policies for promoting sustainable economic growth. Based on the literature review, the following hypothesis has been tested: H_0: *SDG index does not impact economic growth.* H_a: *SDG index does impact economic growth*, where the expected direction of each SDG's relationship consists of a positive sign that suggests a positive relationship. This was investigated by studying the effects of the OECD countries during a time series from 2000–2021.

The results in this study show that there is a significant positive relationship between economic growth and sustainable development, and the United Nations sustainable development goals explained by explanatory variables, see Table 2, have a significant positive impact on economic growth except for the variable CONMAN. These results reject the null hypothesis, however the variable CONMAN with a negative sign did not have statistical significance within the regression, but the DHSS model and Limits to Growth provided the discussion with empirical reasoning for the results in the context of this study.

Policymakers must strike a balance between immediate economic priorities and long-term sustainability. The provided result argues that sustainable development has a positive impact on economic growth, and therefore a worthy investment generating financial growth in the long run. From a policymakers' point of view, they can design effective policies to promote sustainable economic growth by focusing on social- and economic development, natural preservation, innovation, and international cooperation. However, they must also navigate trade-offs and challenges related to short-term versus long-term goals. A short-term focus on basic needs and services, effective governance, social equality and empowerment, robust infrastructure, and transformative innovation will build path dependence for economic growth in the long term.

It is important to emphasize that the model is a simplification of reality and a risk of sources of error in the study. It is a reasonable assumption that there are factors within the countries, beyond what is controlled for in the study, that influence the degree of GDP growth and SDG index, thus contributing to an omitted variable bias, despite the application of fixed effects in the analysis. The availability of data has contributed to several limitations for the selection of control variables, like technology and innovation expenditures, which are likely to impact the result. Moreover, the time series for GDP growth per capita spans from 2000 to 2021, while the data on the SDG index was introduced in 2015. As a result, much of the GDP growth time series falls outside the period when the SDG goals were implemented. While this presents an interesting topic for discussion, it falls outside the scope of this study's framework.

The study provides valuable insights into the positive relationship between the UN's sustainability goals and economic growth, but further research is needed to understand the specific channels and causal mechanisms involved. The next step could involve investigating if there is a breakpoint after implementing the SDG using the econometric difference in difference approach and comparing time periods to assess differences in outcomes before and after implementation. In-depth analysis can utilize milestones instead of explanatory variables, allowing for more specific regressions within each category as outlined in

Appendix B. Comparing the effects of the SDGs on economic growth in developing countries and developed countries may yield an explanation for contradictions disclosed in this study.

In conclusion, this study contributes to the understanding of the complex relationship between economic growth and sustainable development, and it provides a foundation for further investigation in this field.

References

Adrangi, B., Dhanda, K.K. and Hill, R.P., 2004. A Model of Consumption and Environmental

Degradation: Making the case for sustainable consumer behaviour. Journal of Human Development, 5(3), pp.417–432. https://doi.org/10.1080/1464988042000277279.

Alden, D.L., Steenkamp, J.-B.E.M. and Batra, R., 1999. Brand Positioning through Advertising in Asia, North America, and Europe: The Role of Global Consumer Culture. Journal of Marketing, 63(1), pp.75–87. https://doi.org/10.1177/002224299906300106.

Angrist, J.D. and Pischke, J.-S., 2009. *Mostly harmless econometrics: an empiricist's companion*. Princeton: Princeton University Press.

Arrow, K., Bolin, B., Costanza, R., Dasgupta, P., Folke, C., Holling, C.S., Jansson, B.-O., Levin, S., Maler, KaR.L.-G., Perrings, C. and Pimentel, D., 1996. Economic Growth, Carrying Capacity, and the Environment. Ecological Applications, 6(1), pp.13–15. https://doi.org/10.2307/2269539.

Azam, M., 2019. Relationship between energy, investment, human capital, environment, and economic growth in four BRICS countries. *Environmental Science and Pollution Research*, 26(33), pp.34388–34400. https://doi.org/10.1007/s11356-019-06533-9.

Baltagi, B.H., 2013. *Econometric analysis of panel data*. Fifth Edition ed. Chichester, West Sussex: John Wiley & Sons, Inc.

Bassanini, A. and Scarpetta, S., 2001. Does Human Capital Matter For in OECD Countries? Evidence From Pooled Mean-Group Estimates. *OECD Economics Department. Working Papers*, 282, pp.1–30.

Baumol, W.J. and Blinder, A.S., 2016. *Microeconomics: principles and policy*. Thirteenth edition ed. Boston, MA, USA: Cengage Learning.

Bremmer, J., Hurlin, C., & Popoff, N. (2021). *Is Multicollinearity Really a Problem in Economics? The Impact of High Levels of Multicollinearity among Control Variables in Regression Analysis.* Journal of Business and Economic Statistics, 39(3), 641-657. doi: 10.1080/07350015.2019.1657787

Costanza, R., Fioramonti, L. and Kubiszewski, I., 2016. The UN Sustainable Development Goals and the dynamics of well-being. *Frontiers in Ecology and the Environment*, 14(2), pp.59–59. https://doi.org/10.1002/fee.1231.

Daly, H.E. and Farley, J.C., 2011. *Ecological economics: principles and applications*. 2nd ed ed. Washington, DC: Island Press.

Daniels, L. and Minot, N., 2020. *An introduction to statistics and data analysis using Stata: from research design to final report*. First edition ed. Los Angeles: SAGE.

Dasgupta, P., 2021. *The economics of biodiversity: the Dasgupta review: full report*. Updated: 18 February 2021 ed. London: HM Treasury.

Dasgupta, P. and Heal, G., 2001. *Economic theory and exhaustible resources*. Repr. ed. The Cambridge economic handbooks. Cambridge: Cambridge Univ. Pr.

Davidson, C., 2010. Economic Growth and the Environment: Alternatives to the Limits Paradigm. *BioScience*, 50(5), p.433. https://doi.org/10.1641/0006-3568(2000)050[0433:EGATEA]2.0.CO;2.

Dumitrescu, E.-I. and Hurlin, C., 2012. Testing for Granger non-causality in heterogeneous panels. *Economic Modelling*, 29(4), pp.1450–1460. https://doi.org/10.1016/j.econmod.2012.02.014.

Durbin, J. and Watson, G.S., 1951. Testing for Serial Correlation in Least Squares Regression. II. Biometrika, 38(1/2), p.159. https://doi.org/10.2307/2332325.

Ger, G., 1997. Human Development and Humane Consumption: Weil-Being beyond the “Good Life”. Journal of Public Policy & Marketing, 16(1), pp.110–125. https://doi.org/10.1177/074391569701600110.

Grossman, G.M. and Krueger, A.B., 1995. Economic Growth and the Environment. The Quarterly Journal of Economics, 110(2), pp.353–377. https://doi.org/10.2307/2118443.

Helman, U., 1995. Sustainable development: Strategies for reconciling environment and economy in the developing world. The Washington Quarterly, 18(4), pp.187–207. https://doi.org/10.1080/01636609509550178.

Hill, R.C., Griffiths, W.E. and Lim, G.C., 2018. *Principles of econometrics*. 4th ed ed. Hoboken, NJ: Wiley.

Im, K.S., Pesaran, M.H. and Shin, Y., 2003. Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115(1), pp.53–74. https://doi.org/10.1016/S0304-4076(03)00092-7.

Jackson, T., 2009. Prosperity without Growth. 0 ed. [online] Routledge. https://doi.org/10.4324/9781849774338.

Joanes, D. N., and C. A. Gill. 1998. “Comparing Measures of Sample Skewness and Kurtosis”. The Statistician 47(1): 183–189.

Khan, M.A. and Ozturk, I., 2020. Examining foreign direct investment and environmental pollution linkage in Asia. *Environmental Science and Pollution Research*, 27(7), pp.7244–7255. https://doi.org/10.1007/s11356-019-07387-x.

Korhonen, J., Honkasalo, A. and Seppälä, J., 2018. Circular Economy: The Concept and its Limitations. *Ecological Economics*, 143, pp.37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041.

Kubiszewski, I., Costanza, R., Franco, C., Lawn, P., Talberth, J., Jackson, T. and Aylmer, C., 2013. Beyond GDP: Measuring and achieving global genuine progress. *Ecological Economics*, 93, pp.57–68. https://doi.org/10.1016/j.ecolecon.2013.04.019.

Kutner, M.H. ed., 2005. *Applied linear statistical models*. 5th ed ed. The McGraw-Hill/Irwin series operations and decision sciences. Boston: McGraw-Hill Irwin.

Neema Li., 2019. *Is There a Trade-Off Between Economic Development and Environmental Sustainability?*, Múnich, GRIN Verlag, pp.5.

Levy, J., C. Brandon, and R. Studart. 2020. *Designing the COVID-19 Recovery for a Safer and More Resilient World.* WRI Commentary. Washington, DC: World Resources Institute.

Lomborg, B., 2020. Welfare in the 21st century: Increasing development, reducing inequality, the impact of climate change, and the cost of climate policies. *Technological Forecasting and Social Change*, 156, p.119981. https://doi.org/10.1016/j.techfore.2020.119981.

Mankiw, N.G., 2015. *Principles of microeconomics*. Seventh edition ed. Australia ; Stamford, CT: Cengage Learning.

Meadows, D.H., Randers, J. and Meadows, D.L., 2004. *The limits to growth: the 30-year update*. White River Junction, Vt: Chelsea Green Publishing Company.

Moser, G., Windsperger, K., Pollheimer, J., De Sousa Lopes, S.C. and Huppertz, B., 2018. Human trophoblast invasion: new and unexpected routes and functions. Histochemistry and Cell Biology, 150(4), pp.361–370. https://doi.org/10.1007/s00418-018-1699-0.

Nandy, D. 2015. *Limitations of Regression Analysis.* International Journal of Educational Science and Research (IJESR), Vol. 5, Issue 2, sid. 117-123.

Narayan, P.K. and Smyth, R., 2008. Energy consumption and real GDP in G7 countries: New evidence from panel cointegration with structural breaks. *Energy Economics*, 30(5), pp.2331–2341. https://doi.org/10.1016/j.eneco.2007.10.006.

Nilsson, M., Griggs, D. and Visbeck, M., 2016. Policy: Map the interactions between Sustainable Development Goals. Nature, 534(7607), pp.320–322. https://doi.org/10.1038/534320a.

O'brien, R.M., 2007. A Caution Regarding Rules of Thumb for Variance Inflation Factors. *Quality & Quantity*, 41(5), pp.673–690. https://doi.org/10.1007/s11135-006-9018-6.

Pesaran, M.H., 2007. A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, 22(2), pp.265–312. https://doi.org/10.1002/jae.951.

Plumper, T., Troeger, V.E. and Manow, P., 2005. Panel data analysis in comparative politics: Linking method to theory. European Journal of Political Research, 44(2), pp.327–354. https://doi.org/10.1111/j.1475-6765.2005.00230.x.

Rahman, M.M., Rana, R.H. and Barua, S., 2019. The drivers of economic growth in South Asia: evidence from a dynamic system GMM approach. Journal of Economic Studies, 46(3), pp.564–577. https://doi.org/10.1108/JES-01-2018-0013.

Sachs, J., Kroll, C., Lafortune, G., Fuller, G. and Woelm, F., 2022. *Sustainable Development Report 2022*. 1st ed. [online] Cambridge University Press. https://doi.org/10.1017/9781009210058.

SDSN, S.D.S.N., 2022. *Sustainable Development Report*. [online] Available at: <https://www.sustainabledevelopment.report> [Accessed 23 March 2023].

Singh, H.P., Singh, A., Alam, F. and Agrawal, V., 2022. Impact of Sustainable Development Goals on Economic Growth in Saudi Arabia: Role of Education and Training. Sustainability, 14(21), p.14119. https://doi.org/10.3390/su142114119.

Snee, R., 1981. Who Invented the Variance Inflation Factor? [online] https://doi.org/10.13140/RG.2.1.3274.8562.

Stern, D.I., 2004. The Rise and Fall of the Environmental Kuznets Curve. *World Development*, 32(8), pp.1419–1439. https://doi.org/10.1016/j.worlddev.2004.03.004.

Sustainable Development Report, 2023. *Sustainable Development Report 2022*. [online] Available at: <https://dashboards.sdgindex.org/> [Accessed 11 April 2023].

Stern, N., 2007. The Economics of Climate Change: The Stern Review. 1st ed. [online] Cambridge University Press. https://doi.org/10.1017/CBO9780511817434.

The World Bank, 2023a. *GDP growth (annual %) | Data*. [online] Available at: <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG> [Accessed 11 April 2023].

The World Bank, 2023. *GDP, PPP (constant 2017 international $)*. [online] World Bank Open Data. Available at: <https://data.worldbank.org> [Accessed 2 May 2023].

The World Bank, 2023b. *Labor force, total*. [online] World Bank Open Data. Available at: <https://data.worldbank.org> [Accessed 23 April 2023].

The World Bank, 2023c. *Population, total*. [online] World Bank Open Data. Available at: <https://data.worldbank.org> [Accessed 23 April 2023].

Tupy, M.L. and Pooley, G.L., 2022. Superabundance: the story of population growth, innovation, and human flourishing on an infinitely bountiful planet. Washington, D.C: Cato Institute.

UN SDG, 2023. *THE 17 GOALS | Sustainable Development*. [online] Available at: <https://sdgs.un.org/goals> [Accessed 23 March 2023].

UNDP ed., 1999. *Globalization with a human face*. Human development report / publ. for the United Nations Development Programme (UNDP). New York: Oxford Univ. Press.

Wang, Q. and Wang, L., 2020. Renewable energy consumption and economic growth in OECD countries: A nonlinear panel data analysis. Energy, 207, p.118200. https://doi.org/10.1016/j.energy.2020.118200.

Wooldridge, J.M., 2010. *Econometric analysis of cross section and panel data*. 2nd ed ed. Cambridge, Mass: MIT Press.

Yandle, B., Bhattarai, M. and Vijayaraghavan, M., 2004. *Environmental Kuznets Curve - A Review of Findings, Methods, and Policy Implications*. [online] Available at: <https://www.sciencedirect.com/topics/earth-and-planetary-sciences/environmental-kuznets-curve> [Accessed 23 March 2023].

Appendix

Appendix A - SDG Subgoals

SDG		Description	Subgoal measurement
1	No poverty	End poverty in all its forms everywhere	1.1 Poverty headcount ratio at $1.90/day (%) 1.2 Poverty headcount ratio at $3.20/day (%) 1.3 Poverty rate after taxes and transfers (%)
2	Zero hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture	2.1 Prevalence of undernourishment (%) 2.2 Prevalence of stunting in children under 5 years of age (%) 2.3 Prevalence of wasting in children under 5 years of age (%) 2.4 Prevalence of obesity, BMI ≥ 30 (% of adult population) 2.5 Human Trophic Level (best 2-3 worst) 2.6 Cereal yield (tonnes per hectare of harvested land) 2.7 Sustainable Nitrogen Management Index (best 0-1.41 worst) 2.8 Yield gap closure (% of potential yield) 2.9 Exports of hazardous pesticides (tonnes per million population)
3	Good health and well-being	Ensure healthy lives and promote well-being for all at all ages	3.0 Maternal mortality rate (per 100,000 live births) 3.1 Neonatal mortality rate (per 1,000 live births) 3.2 Mortality rate, under-5 (per 1,000 live births) 3.3 Incidence of tuberculosis (per 100,000 population) 3.4 New HIV infections (per 1,000 uninfected population) 3.5 Age-standardized death rate due to cardiovascular 3.6 disease, cancer, diabetes, or chronic respiratory disease in adults aged 30–70 years (%) 3.7 Age-standardized death rate attributable to household air pollution and ambient air pollution (per 100,000 population) 3.8 Traffic deaths (per 100,000 population) 3.9 Life expectancy at birth (years)

			3.10 Adolescent fertility rate (births per 1,000 females aged 15 to 19) 3.11 Births attended by skilled health personnel (%) 3.12 Surviving infants who received 2 WHO-recommended vaccines (%) 3.13 Universal health coverage (UHC) index of service coverage (worst 0-100 best) 3.14 Subjective well-being (average ladder score, worst 0-10 best) 3.15 Gap in life expectancy at birth among regions (years) 3.16 Gap in self-reported health status by income (percentage points) 3.17 Daily smokers (% of population aged 15 and over)
4	Quality education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	4.1 Participation rate in pre-primary organized learning (% of children aged 4 to 6) 4.2 Net primary enrollment rate (%) 4.3 Lower secondary completion rate (%) 4.4 Literacy rate (% of population aged 15 to 24) 4.5 Tertiary educational attainment (% of population aged 25 to 34) 4.6 PISA score (worst 0-600 best) 4.7 Variation in science performance explained by socio-economic status (%) 4.8 Underachievers in science (% of 15-year-olds)
5	Gender equality	Achieve gender equality and empower all women and girls	5.1 Demand for family planning satisfied by modern methods (% of females aged 15 to 49) 5.2 Ratio of female-to-male mean years of education received (%) 5.3 Ratio of female-to-male labor force participation rate (%) 5.4 Seats held by women in national parliament (%) 5.5 Gender wage gap (% of male median wage)
6	Clean water and sanitation	Ensure availability and sustainable management of water and sanitation	6.1 Population using at least basic drinking water services (%) 6.2 Population using at least basic sanitation services (%)

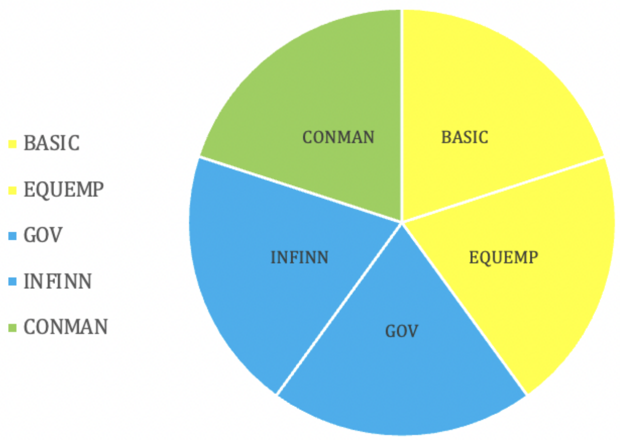
		for all	6.3 Freshwater withdrawal (% of available freshwater resources) 6.4 Anthropogenic wastewater that receives treatment (%) 6.5 Scarce water consumption embodied in imports (m3 H2O eq/capita) 6.6 Population using safely managed water services (%) 6.7 Population using safely managed sanitation services (%)
7	Affordable and clean energy	Ensure access to affordable, reliable, sustainable and modern energy for all	7.1 Population with access to electricity (%) 7.2 Population with access to clean fuels and technology for cooking (%) 7.3 CO_2 emissions from fuel combustion per total electricity output ($MtCO_2$/TWh) 7.4 Share of renewable energy in total primary energy supply (%)
8	Decent work and economic growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	8.1 Adjusted GDP growth (%) 8.2 Victims of modern slavery (per 1,000 population) 8.3 Adults with an account at a bank or other financial institution or with a mobile-money-service provider (% of population aged 15 or over) 8.4 Fundamental labor rights are effectively guaranteed (worst 0–1 best) 8.5 Fatal work-related accidents embodied in imports (per 100,000 population) 8.6 Employment-to-population ratio (%) 8.7 Youth not in employment, education or training (NEET) (% of population aged 15 to 29)
9	Industry, innovation and infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	9.1 Population using the internet (%) 9.2 Mobile broadband subscriptions (per 100 population) 9.3 Logistics Performance Index: Quality of trade and transport-related infrastructure (worst 1-5 best) 9.4 The Times Higher Education Universities Ranking: Average score of top 3 universities (worst 0-100 best) 9.4 Articles published in academic journals (per 1,000

			population) 9.5 Expenditure on research and development (% of GDP) 9.6 Researchers (per 1,000 employed population) 9.7 Triadic patent families filed (per million population) 9.8 Gap in internet access by income (percentage points) 9.9 Female share of graduates from STEM fields at the tertiary level (%)
10	Reduced inequalitites	Reduce inequality within and among countries	10.1 Gini coefficient 10.2 Palma ratio 10.3 Elderly poverty rate (% of population aged 66 or over)
11	Sustainable cities and communities	Make cities and human settlements inclusive, safe, resilient and sustainable	11.1 Proportion of urban population living in slums (%) 11.2 Annual mean concentration of particulate matter of less than 2.5 microns in diameter (PM2.5) ($\mu g/m^3$) 11.3 Access to improved water source, piped (% of urban population) 11.4 Satisfaction with public transport (%) 11.5 Population with rent overburden (%)
12	Responsible consumption and production	Ensure sustainable consumption and production patterns	12.1 Electronic waste (kg/capita) 12.2 Production-based SO_2 emissions (kg/capita) 12.3 SO_2 emissions embodied in imports (kg/capita) 12.4 Production-based nitrogen emissions (kg/capita) 12.5 Nitrogen emissions embodied in imports (kg/capita) 12.6 Exports of plastic waste (kg/capita) 12.7 Non-recycled municipal solid waste (kg/capita/day)
13	Climate action	Take urgent action to combat climate change and its impacts	13.1 CO_2 emissions from fossil fuel combustion and cement production (tCO2/capita) 13.2 CO_2 emissions embodied in imports (tCO_2/capita) 13.3 CO_2 emissions embodied in fossil fuel exports (kg/capita) 13.4 Carbon Pricing Score at EUR60/tCO_2 (%, worst 0-100 best)

14	Life below water:	Conserve and sustainably use the oceans, seas and marine resources for sustainable development	14.1 Mean area that is protected in marine sites important to biodiversity (%) 14.2 Ocean Health Index: Clean Waters score (worst 0-100 best) 14.3 Fish caught from overexploited or collapsed stocks (% of total catch) 14.4 Fish caught by trawling or dredging (%) 14.5 Fish caught that are then discarded (%) 14.6 Marine biodiversity threats embodied in imports (per million population)
15	Life on land	Protect, restore and promote sustainable use of terrestrial ecosystems, and halt biodiversity loss, sustainably manage forests, combat desertification, and halt and reverse land degradation	15.1 Mean area that is protected in terrestrial sites important to biodiversity (%) 15.2 Mean area that is protected in freshwater sites important to biodiversity (%) 15.3 Red List Index of species survival (worst 0-1 best) 15.4 Permanent deforestation (% of forest area, 3-year average) 15.5 Terrestrial and freshwater biodiversity threats embodied in imports (per million population)
16	Peace, justice and strong institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	16.1 Homicides (per 100,000 population) 16.2 Unsentenced detainees (% of prison population) 16.3 Population who feel safe walking alone at night in the city or area where they live (%) 16.4 Property Rights (worst 1-7 best) 16.5 Birth registrations with civil authority (% of children under age 5) 16.6 Corruption Perceptions Index (worst 0-100 best) 16.7 Children involved in child labor (% of population aged 5 to 14) 16.8 Exports of major conventional weapons (TIV constant million USD per 100,000 population) 16.9 Press Freedom Index (best 0-100 worst) 16.10 Access to and affordability of justice (worst 0–1 best)

			16.11 Persons held in prison (per 100,000 population)
17	Partnerships for the goals	Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	17.1 Government spending on health and education (% of GDP) 17.2 For high-income and all OECD DAC countries: International concessional public finance, including official development assistance (% of GNI) 17.3 Other countries: Government revenue excluding grants (% of GDP) 17.4 Corporate Tax Haven Score (best 0-100 worst) 17.5 Financial Secrecy Score (best 0-100 worst) 17.6 Shifted profits of multinationals (US$ billion) 17.7 Statistical Performance Index (worst 0-100 best)

Appendix B - Dimensions of Sustainability



Where; yellow is social; blue is ecconomic; and green is environmental