FROM GROWTH TO BUILDING PATHWAYS FOR GREEN GROWTH IN PAKISTAN IN THE LIGHT OF SUSTAINABLE DEVELOPMENT GOALS

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DEDICATION

to my beloved parents

and

my husband Syed Mohsin Ali,

my children Taha and Murtaza

who are a constant source of inspiration to me

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All praise and gratitude are to Almighty Allah, the Lord and the Creator of heavens and earth, who gave me the potential and patience to complete this work. All respect goes to the Holy Prophet Hazrat Muhammad (PBUH), who enlightened our conscience with the essence of faith in Allah, converging all the kindness upon him.

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Asma Jabeen

ABSTRACT

The Fifth Ministerial Conference on Environment and Development provided a regional implementation plan to pursue economic development in Asia-Pacific in 2005. In the ministerial declaration, green growth is defined as the strategy of sustaining economic growth and job creation, necessary for poverty reduction while coping with natural resource constraints and climate crisis. Based on the importance of green growth, the study investigates the likelihood of the simultaneous existence of three fundamental pillars of sustainability in Pakistan from 1990 to 2019. The constituents of sustainable development are selected from the Seoul Initiative Network on Green Growth (SINGG) presented in MCED-5. The first objective of the study employs Structural Equation Modeling (SEM) to determine the direct effects and indirect effects of the variables from the green growth model adopted in the MCED-5. The results indicate the importance of employment as the key link between sustained growth and poverty alleviation. The growth of the net national income of the country drives resource-efficient technologies that reduce the carbon intensity of production, but it does not save the natural resources from depletion. The study also reveals that natural resources are being exploited in the quest for higher living standards and sustainable economic growth. An increase in net national income with the increase in natural capital degradation indicates that Pakistan is on the path of weak sustainability. Thus, it is needed to improve the stock of natural capital to transform the economy from the path of weak sustainability to strong sustainability.

In order to successfully implement mitigation policies, it is also necessary to identify the contributing factors to carbon emissions. The second objective of the study investigate the driving forces of energy-related carbon emissions in Pakistan from 1990 to 2019 using the Logarithmic Mean Divisia Method 1 (LMDI-I) decomposition technique based on extended Kaya identity. The decomposition results reveal that the population size effect and affluence contributed significantly to accelerating carbon emissions from energy consumption throughout the period of analysis. The effect of fuel quality used and energy intensity effect is relatively minor (as the index value is less than 1) for most of the time period. The renewable energy penetration effect also contributed

positively to increasing carbon emissions in many periods (with effect values greater than 1). The cumulative effect of renewable energy penetration in total primary energy consumption on carbon emissions has increased from 0.998 in 1990 to 1.034 in 2019 due to Pakistan's less mature renewable energy technologies. Fuel switching is a factor that reduces carbon emissions as the index value decreased from 0.945 in 1990 to 0.918 in 2019.

The analysis of the third research question based on Tapio's decoupling status of economic growth and energy-related carbon emissions indicates that Pakistan has experienced four decoupling states from 1990 to 2019. However, the most prominent state is expensive negative decoupling, which points towards much faster growth of carbon emissions than the country's economic growth. In a few years, expensive coupling, weak decoupling, and strong decoupling are also observed. The prominent status of expansive negative decoupling among the other decoupling states highlights the need for measures of specific policy action that will cut carbon emissions and foster economic growth that is sustainable. The results of the study contain helpful information for lowering carbon emissions.

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LIST OF ABBREVIATIONS

Seoul Initiative Network on Green Growth	SINGG
Structural Equation Modeling	SEM
Fifth Ministerial Conference on Environment and Development in Asia and the Pacific	MCED-5
Logarithmic Mean Divisia Method-1	LMDI-I
Triple Bottom Line	TBL
Seoul Initiative Network on Green Growth	SINGG
Sustainable Development Goals	SDGs
Intergovernmental Panel on Climate Change	IPCC
Total Primary Energy Consumption	TPEC
Employment to population ratio (age 15+)	Empl
Share of the population below the poverty line of $3.20 per day	Pvty
Natural resources depletion	Res.Depl
Adjusted net national income	Adj.NI
CO_2 emissions per unit of GDP	CO2.Int
Index Decomposition Analysis	IDA
Gross domestic product	GDP
Carbon emissions	C
Total energy consumption	E

Total population	P
Total index of carbon emissions	D_{tot}
Fuel quality effect	D_F
Fossil fuel substitution effect	$D_{S_{ff}}$
Renewable energy penetration in total primary energy consumption effect	D_{S_E}
Energy intensity effect	D_I
Affluent effect	D_A
Population effect	D_P
Share of carbon intensity	F
Share of fossil fuel in total fossil fuels consumption	S_{ff}
Share of total fossil fuels in total primary energy consumption	S_e
Share of energy intensity of the economy	I
Share of economic activity	A
Decoupling index	ŋ
Growth rate of GDP	βC
Growth rate of carbon emissions	βG

CHAPTER 1

INTRODUCTION

The progression of mankind over the course of the last several decades has resulted in increasingly adverse climate changes and natural calamities. The actions of people have had a harmful impact on the environment, putting both the survival of the current generation on the planet and the lives of future generations in danger. Because of these circumstances, there has been a clear indication of a change in behavior with the intention of managing all resources more rationally and effectively, which will ensure less stress and negative impact on the environment. This kind of responsible conduct is what could secure the long-term utilization of available resources without putting the well-being of current and future generations in jeopardy. The notion of sustainable development is built on three principles: (1) growth (socio-economic advancement in accordance with environmental conditions), (2) basic requirements (distribution of resources to maintain a decent quality of life for everyone), and (3) future generations (potential utilization of resources, in the long run, to guarantee to maintain standards of living for future generations). The spirit of the term sustainable development is deduced from the concept of the Triple Bottom Line (TBL), which entails the balance between three pillars of sustainability; (1) economic sustainability needed to preserve the natural, man-made, and human capital essential for providing income opportunities to people; (2) social sustainability is required to maintain human rights, equality, and distinct cultural identities, which is required to preserve respect for gender, race, and religion; (3) environmental sustainability, which emphasizes the need of protecting the quality of the environment for the smooth conduct of economic activity in each sector of the economy. By achieving a balance between all of these three pillars, complete sustainable development is attained. To avoid creating an imbalance between them, each pillar should respect the interests of the others in order to achieve the goals of sustainable development.

Since the introduction of the term sustainable development, different organizations have held many conferences and summits to point out the activities to achieve the underlying pillars of sustainable development. In this context, the most important is the 5th Ministerial Conference on Environment and Development in Asia and the Pacific (MCED-5), which highlights that the economic growth of Asia-Pacific is creating pressure on environmental sustainability and a substantial delay in achieving development goals (ESCAP, 2005). The meeting adopted the Seoul Initiative Network on Green Growth relating to poverty reduction and environmental sustainability in this world region. The panel of experts who participated in the conference agreed upon the urgent need to merge social, economic, and ecological dimensions of sustainability to develop the Asia-Pacific region. The ministerial declaration defines sustainable development as green growth that needs to sustain economic growth and job creation necessary for reducing poverty while controlling natural resource constraints and climate crisis.

In parallel lines, ten years later, in 2015, sustainable development was supported, but at this time globally, as the top priority in the United Nations Conference on Sustainable Development in Rio de Janeiro. The 17 Sustainable Development Goals were set up at the Rio +20 conference. These goals are compatible with the philosophy and roadmap of development provided by the Seoul Initiative Network on Green Growth that emerged from MCED-5. The 17 SDGs emphasize that there is a need to shift the economic objectives toward growing well-being in society rather than simply seeking to maximize GDP. The countries of the world that have already achieved high levels of GDP per capita are required to achieve sustainable production and consumption patterns. Similarly, sustainable production and consumption are also crucial for developing countries where businesses and various other sectors are making progress by consuming excessive amounts of primary resources. The developing countries are coping with employment and economic growth but avoiding climate risks and resource-based risks. In the same way, the declaration of MCED-5 raised awareness about the plan of action for sustainability in production and consumption to achieve economic growth without compromising the natural environment. The ministerial declaration emphasized limiting inequity to rectify social problems. Seoul Initiative Network on Green Growth, presented in MCED-5, focuses on the need to reduce poverty to increase the economic resilience of the most vulnerable members of society. It stresses a better quality of life and environmentally sustainable economic growth, which is necessary for tackling economic inclusion in society. By providing a framework of green growth for Asia and the Pacific, the ministerial declaration focuses on the need to achieve economic growth without overburdening the ecological and biophysical resources.

Pakistan has embraced this socio-ecological and economic vision of sustainability. Pakistan has demonstrated how nature-based initiatives can help realize the ultimate objectives, such as ensuring sustainable livelihoods and reducing poverty (Perring et al., 2018). The Ten Billion Tree Tsunami Program (TBTTP), launched by the Government of Pakistan, is a four-year (2019-2023) project. This program is the 4th largest afforestation and restoration program initiated globally. The TBTTP has positively influenced employment in Pakistan, with an estimated 85,000 new jobs created. Additionally, as part of the green stimulus strategy, the government has also planned to cover over 2800 square miles of land within 15 national parks to improve environmental conditions and create 5,000 new jobs (Farand, 2021). Pakistan's mangrove restoration initiatives are also progressing. Pakistan's mangrove cover has grown from 477.22 Km^2 in 1990 to 1463.59 Km^2 in 2020. Since 1990, the area covered by mangroves has increased significantly by about 986.36 Km^2 (Gilani et al., 2021). Pakistan had started a marine conservation plan with Astola Island. Astola Island is a significant offshore island of Pakistan covering 400 square Km and was declared the first Marine Protected Area in 2017. The island supports maintaining marine biodiversity and raising revenue via eco-tourism. Additionally, Pakistan is a signatory to the Kyoto Protocol, and thereby the country is subjected to emissions mitigation obligations. Pakistan is also a party to the Vienna Convention and its Montreal Protocol to protect the Ozone Layer. Following the county's climate change policy, the Ministry of Climate Change (MoCC) has taken numerous steps towards a cleaner and more sustainable future in an effort to reduce emissions and ensure climate-resilient economic growth. The Ministry of Climate Change has established a dedicated National Ozone Unit (NOU) to guarantee effective compliance with the Vienna Convention and its Protocol. Trade restrictions on ozone-depleting substances, raising awareness, capacity-building campaigns, and technology transfer have helped Pakistan meet its commitments under the Montreal Protocol and have eliminated 10% of Hydrochlorofluorocarbons (HCFCs) by January 2015. The country has promised to decrease its carbon emissions by 50% by 2050 to reduce total emissions with 15% from its own resources and 35% subject to the availability of financial assistance from the world (Government of Pakistan, 2021b).

According to the report of the Ministry of Planning Development and Special Initiatives (2021), Pakistan's SDGs score in 2021 was 57.7 which is 26.2% higher than the score of 2016 and it was ranked 129^{th} out of 165 countries in year 2021. The findings of the report reveal that

Pakistan's SDGs progress from 2015 to 2020 for short-run (33.6%), medium-run (14.6%) and long-run (7.3%) goals. It is revealed that Pakistan has made significant progress since 2015 in short-run goals that include: zero hunger, good health and well-being, quality education and promoting peace, access to justice, and strong institutions. However, performance in terms of cheap and clean energy, as well as decent work for all, remains unsatisfactory. On the other hand, according to the Sustainable Development Report (2022), which marks the annual progress of all UN member states, the overall SDGs score of Pakistan has shown a steady increase from 57.7% in 2021 to 59.3 in the year 2022 and the country is ranked 125th out of 163 countries in the year 2022 (Sachs et al., 2022a). It shows that regardless of the government's commitments and efforts for sustainable development, according to the Sustainable Development Report (2022), the global ranking of Pakistan has declined due to its low performance in the year 2022. The low SGDs commitment is reflected by the scores of SDGs ranging from 40 to 50.

With its recent surge, poverty has become an endemic issue in Pakistan, and it has become a severe social menace. According to the Asian Development Bank (2019), the figures on the proportion of people living below the national poverty line increased from 22.3% in 2010 to 24.3% in 2017. Food poverty, which is on the rise in the country, is one of the most harmful types of poverty that poses a social hazard. According to von Grebmer et al. (2016), 22% of the population is under-nourished. A decade ago, 22.2% of Pakistan was extremely vulnerable to hunger. These trends show that the attention paid to eradicating poverty is not yielding the desired results. Similarly, the Global Climate Risk Index 2021 indicates that Pakistan is rated 8th among the list of ten countries most affected by climate change (Eckstein et al., 2021). The report mentions that Pakistan has suffered about 0.3 fatalities per 100,000 inhabitants, lost 0.52% per unit of its GDP, and witnessed 173 extreme weather events between the period 2000 to 2019. Major calamities include floods, droughts, heatwaves, cyclone activity, the steady melting of most glaciers, and the disruption of day-to-day human activities. Similarly, the mean temperature of Pakistan has increased by 0.6°C during the past century. The mean annual precipitation has also risen across the country. The rise is higher in summer than in winter with June and September exhibiting a significant increase. The IPCC-AR5 RCPs scenarios predicted that Pakistan would experience about 1°C higher average temperature than the global average by the end of the current century. This temperature rise, in particular, would be associated with extreme weather events, such as climate change and erratic weather patterns, having a considerable effect on nearly all sectors of the economy with a significant impact on agricultural productivity. Although, globally, Pakistan is a relatively small contributor to the total GHG emissions; however, its share in global carbon emissions has increased from 0.3% per annum in 1990 to 0.67% in 2020 (Ritchie et al., 2020). The experts argue that this is the use of fossil fuels in production activities that have resulted in the emission of GHG, which in turn leads to detrimental impacts on sustaining the quality of life and the environment. The seminal study of the Intergovernmental Panel on Climate Change, 2000 directed that future emissions depend upon how human civilizations grow in terms of demographics, which energy sources are preferred, and how economies are structured. The Kaya identity model proposed by Kaya (1990), was used as the basic framework for this study. The Fourth Assessment Report (AR4) of the IPCC also states that anthropogenic (human-caused) activities are responsible for most of the increase in global temperature since the mid-20th (IPCC, 2007). A by-product of a planned production process is a negative unintended detrimental impact on others by contributing to environmental degradation.

Humans emit emissions as a consequence of production activities such as burning fossil fuels to generate energy. Emitting large quantities of carbon into the atmosphere has serious environmental repercussions such as climate change and so imposes indirect costs on all people across the world and future generations. Individuals' carbon-emitting activities just take their private costs and benefits into account, neglecting the additional costs they impose on others. As a result, carbon emissions are negative externalities, and everyone uses the atmosphere as an open-access resource to dump excessive quantities. According to the first welfare theorem of neoclassical economic theory, markets allocate resources in a Pareto-efficient way. Two assumptions underlying producing a Pareto optimal situation are: 1) all goods have to be private goods, and 2) there must be no externalities. The atmosphere is an open-access resource in terms of its function as a repository of carbon emissions. Any person or organization does not own the open-access resource, nor it can be fully controlled. This leads to a situation in which no individual or company has an incentive to reduce its dumping actions and save the environment. Thus, in this regard the atmosphere differs from the private good. Secondly, carbon emissions are an example of a negative externality. Because there is no monetary penalty for generating negative effects, agents are not sufficiently discouraged from producing them. Consequently, markets produce too much amount of negative externality, thereby exacerbating the negative external influence. The two assumptions of the first welfare theorem are violated. Thus, the first welfare theorem no longer holds due to human-induced climate change. Therefore, rather than just expanding overall production, human welfare is best served by enhancing the quality and distribution of desired commodities provided by the economy. In the case of Pakistan, energy demand is rising due to the increasing population and growing consumption and production activities. Such a rise in demand has resulted in an exponential increase in total primary energy requirement (TPER), as shown in Figure 1.1, and at the same time, a large increase in carbon emissions. According to Butt et al. (2021), carbon emissions in Pakistan have climbed from 66.34 MT in 1990-91 to 202.71 MT in 2018-19. Energy-related carbon emissions increased to 234.75Mt in 2020, 29% higher than in 1990 (Ritchie et al., 2020); representing the significance of increasing the penetration of renewable energy in emission mitigation plans of the country.

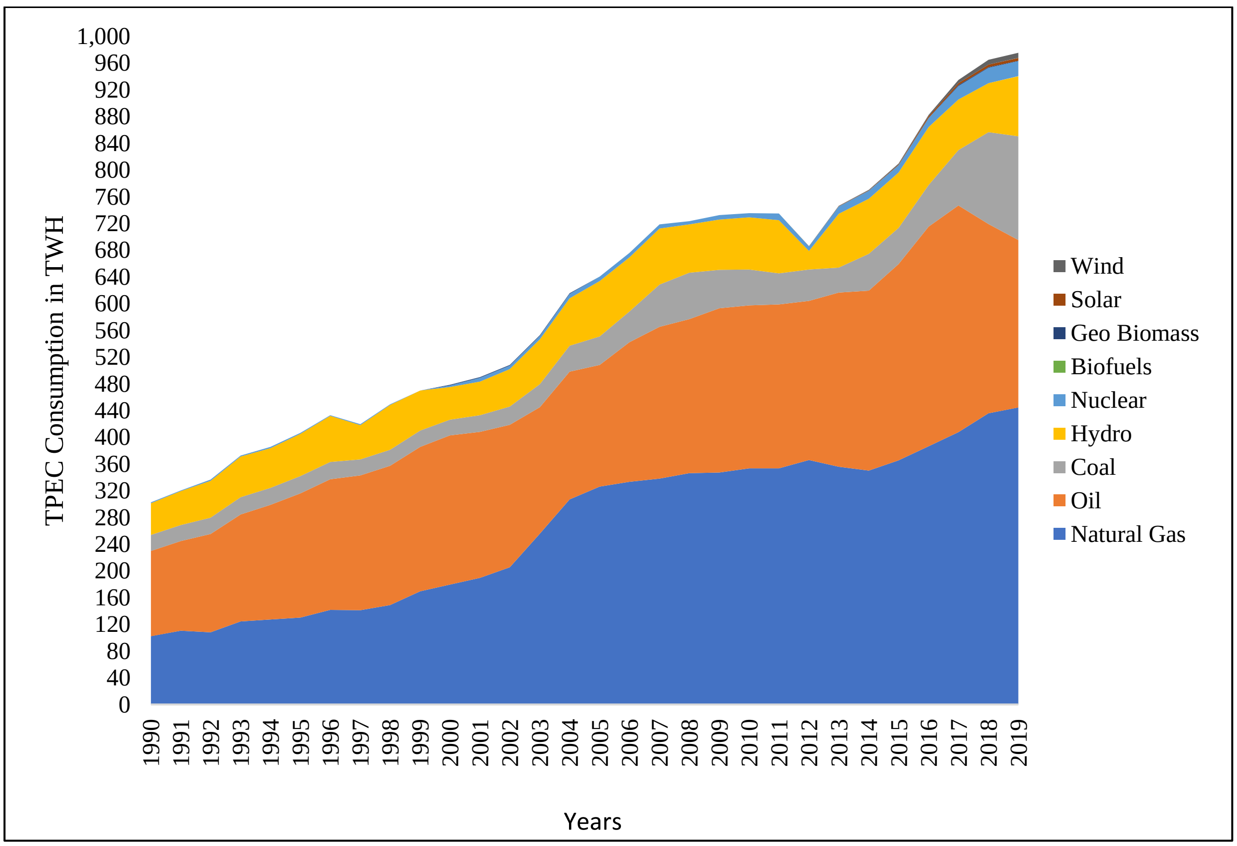

Figure 1. 1 Total Primary Energy Consumption (TPEC) of Pakistan from 1990 to 2019

Source: Authors' own representation using data from OWID, Global Change Data Lab

According to the Government of Pakistan (2019b), fossil fuel consumption and the economic growth of Pakistan are tightly bonded with each other. The government is focused on ensuring accessibility and security of energy supply with affordability through the development of renewable resources. However, Pakistan has a large potential for wind, solar, and hydro energy production. However, such large-scale projects cannot be initiated without the financial aid of foreign development agencies, due to this such projects of renewable energy production remain less mature. The share of renewables was 0.3% in 2015, which has steadily increased to 1.1% in 2018. Due to this reason, thermal accounts for the largest proportion of energy production. Pakistan depends primarily on gas and oil resources to meet its energy needs. Pakistan is endowed with enormous coal and gas reserves. The indigenous reserves of only coal are estimated to be over 186 BT, which is sufficient enough to satisfy the country's long-term energy requirements but remains unexplored. Therefore, Pakistan imports a large quantity of petroleum and petroleum-based products from the Middle East, particularly Saudi Arabia. The transport and power sectors are the two main consumers of oil. On the other hand, Pakistan's reliance on natural gas was 50.4% of its total energy mix in 2006, the highest percentage ever. Since then, gas production has steadily gone down because no major gas fields have been added. After 2015, imported LNG consumption represented a magnanimous increase of this fuel in the energy mix. In 2017–18, nearly 35% of the total primary energy supply was derived from the indigenous gas supply. In addition, Pakistan Atomic Energy Commission is the only department in the country using nuclear technology for power generation. Five nuclear power plants are functioning at two different locations: Chashma Nuclear power plants (C-1, C-2, C-3, C-4) in the Mainwali district of Punjab province and Karachi Nuclear Power Plant (KANUPP) in Karachi. Nuclear energy has steadily increased to 2.7% in 2018 from 0.2% in 1997 (Government of Pakistan, 2019b).

Energy consumption is the basic requirement for a modern lifestyle, economic activity, and human development in Pakistan. However, from the evidence presented above, it is clear that the total energy consumption of Pakistan is heavily dependent on the use of fossil fuels, which in turn is the main cause of carbon emissions in the country. As carbon emission is a strong indicator of environmental and ecological sustainability, it is important to quantify the contribution and role of influencing variables that are responsible for the rise in energy-related carbon emissions. This analysis would help to set sustainable development targets for reducing total carbon emissions from an ecological sustainability perspective. Additionally, it is also important to calculate the nature of the relationship between energy-related carbon emissions and economic growth to assess the environmental pressure of economic growth in Pakistan.

Moreover, ensuring the sustainability of total natural capital and its capacity to serve human welfare is also essential to secure a sustainable present and future (UNEP, 2021). Therefore, investment in natural capital is required for the smooth provision of ecological services for the nation, such as water cycle, air purification, oxygen generation, carbon sequestration, medicine, raw materials, etc. In this sense, the study also focuses on the sustainable consumption of the total stock of natural resources from the environmental sustainability aspect. From the perspective of natural resource sustainability, there is a great debate over the conservation of natural capital that has resulted in two different schools of thought: 1) weak sustainability and 2) strong sustainability.

On one side, advocates of weak sustainability emphasize that the natural and human capital stock together make up the total capital stock. The value of the total stock of capital should be at least maintained or preferably increased for future generations (R. Solow, 1993). In addition, technology is assumed to continually progress to provide solutions to the environmental problems resulting from the increased production of goods and services (Ekins et al., 2003). This school of thought is strongly disagreed and challenged by the strong sustainability school of thought. This school of thought holds that substitution between natural and man-made capital is constrained (Brand, 2009) – regardless of the amount of man-made capital that can be accumulated (Daly & Farley, 2004). Strong sustainability, in contrast to weak sustainability, presents the idea that conserving irreplaceable natural resources is essential for the benefit of future generations (Dedeurwaerdere, 2014). The concept of sustainable development has received a lot of attention in the notion of strong sustainability over the past few years because human development is decreasing the bearing capacity of the earth with the passage of time. Moreover, nature has the right to exist, and we have no right to damage it. We have borrowed it, and it should be passed on to the next generation in its original form (UNDP, 2011).

In light of the fact that nature offers central opportunities and constraints for development, the term sustainable development in theories is primarily described in terms of ecological sustainability which provides the essential conditions for life at a required level of wellbeing for the current and coming generations (Lélé, 1991). It means that this is an approach that considers sustainable development in conjunction with environmental preservation and places it in a global socio-economic, political, and ecological context (Ulhoi & Madsen, 1999) and (Sharpley, 2000). However, in addition, certain social circumstances must also be achieved in order to meet the essential environmental standards, while taking into consideration the influence of those conditions on ecological sustainability. From the social sustainability viewpoint, sustainable development offers an opportunity to fulfill human needs that are the outcomes of quantitative economic values (Ulhoi & Madsen, 1999) as well as specific social requirements, cultural traditions, and other social values etc.

1.1 Research Gap

The ingredients such as sustainable economic growth for protecting natural assets and climate change along with improving living standards by job creation and poverty eradication are accepted as necessary in the Fifth Ministerial Conference on Environment and Development in Asia and the Pacific, 2005 to achieve economic, social, and environmental sustainability simultaneously. Such a comprehensive framework remains to be investigated in the context of Pakistan. Similarly, to evaluate the correlation between economic growth and environmental outcomes, many conceptual and economic models have been developed. For example, Aqeel & Butt (2001), Muhammad et al. (2011), Nasir & Ur Rehman (2011), Ahmed & Long (2012), Shahbaz et al. (2012), Mahmood & Shahab (2014), Ahmed & Bashir (2016), Javaid & Zulfiqar (2017), Nisar (2017), Ota (2017), Nazir et al. (2018), Shujah-ur-Rahman et al. (2019) and Kong & Khan (2019) examined the relationship between economic growth, energy consumption, and environmental quality by analyzing Environmental Kuznets Curve (EKC), which shows pollution at first increasing and then decreasing as income increases. While the EKC explores the relationship between economic development and emissions, there are many economic, demographic, and environmental factors (such as technological effect, renewable energy, fossil fuel quality, fuel substitution, and population size) that can describe the environmental outcomes. These factors can impact emissions either positively or negatively. Greater economic activity per capita leads to higher energy consumption and carbon emissions. Population growth contributes to the emissions by demanding more from different productive sectors. In the same way, as an economy becomes more energy efficient and moves to renewable energy consumption, it transitions to lower carbon emissions and even can offset the emissions-increasing effect of income growth and population. Therefore, these factors are potential drivers of emission changes and can affect the possible shape of EKC. Many researchers have evaluated factors using Kaya identity that can affect total carbon emissions, e.g. Lin & Ahmad (2017) and Khan & Majeed (2019). However, the some areas of influence, such as fossil fuel substitution, and share of renewable energy penetration in total primary energy consumption, remained to be investigated. A conceptual framework is needed to estimate the potential impact of all these factors on emissions of carbon. Understanding the individual impacts of the influential factors is not only important for national climate policies but may be of much interest to other developing and transition economies like Pakistan.

Therefore, with the increasing proportion of natural capital as a major source of energy in the economic activities of the country, two major challenges have emerged: (1) increasing energy-related carbon emissions and (2) a rapid depletion of irreversible natural capital with huge consequences for future economic development. In this regard, the three primary research questions to be investigated are as follows:

1.2 Research Objectives

In light of the above discussion, the four primary research objectives of the study are as follows:

1. To build an understanding of the social, economic, and environmental sustainability in Pakistan, the study establishes a systematic relationship between the concepts that constitute sustainability by analyzing data from 1990 to 2019. The constituents of environmentally sustainable economic development are selected from the Seoul Initiative Network on Green Growth (SINGG) presented at the Fifth Ministerial Conference on Environment and Development in Asia and the Pacific (MCED-5). The variables that make up SINGG include sustainable economic growth, employment, poverty reduction, natural resource depletion, and climate change.

2. The study explores the quantitative relationship of carbon emissions with its driving forces as guided by the extended Kaya identity model using time series data from 1990 to 2019. The extended Kaya identity model includes variables namely fuel quality effect, fossil fuel substitution effect, renewable energy penetration effect, energy intensity effect, economic

activity per capita effect, and population size effect for describing environmental outcomes. The study decomposes the quantitative relationship of total carbon emissions with all these driving forces. Understanding the individual impacts of these influential factors of total carbon emissions is not only of concern for national climate programs but may be of much interest to other developing and transition economies like Pakistan. Moreover, the promotion of the clean energy sector is needed to be tied with international obligations of Intended Nationally Determined Contributions (INDs), under the Paris Agreement, and United Nations Sustainable Development Goals, therefore, understanding renewable energy penetration effects on carbon emissions is essential from a pure sustainability perspective.

3. The economic development of Pakistan is positively linked with carbon-intensive fossil fuel consumption. Therefore, the study explores different decoupling states, i.e., expansive coupling, expensive negative decoupling, recessive coupling, strong decoupling, weak decoupling, weak negative decoupling, recessive decoupling, and strong negative decoupling of economic growth from energy-related carbon emissions for every year from 1990 to 2019. The decoupling index will represent the scale of sustained economic growth. In this scenario, any reduction in the environmental effect per unit of economic activity will indicate that the economic system is progressing toward sustainable development.

4. The study also analyzes the contribution of various types of fossil fuels to the annual carbon emissions of Pakistan. In this context, the study uses the set of nine major types of fossil fuels namely bituminous coal, lignite, fuel oil, gas/diesel, other kerosene, motor gasoline, LPG, other oil products, and natural gas to estimate their emissions yearly based on 2006 IPCC guidelines from 1990 to 2019. This would be useful for policymakers to identify key energy sources that are accelerating carbon emissions in different periods.

1.3 Significance of the Study

In the long run, Pakistan should transition to a low-carbon economy. Therefore, it is essential for the economy to discover ways to decouple economic growth and emissions. For this purpose, analyzing the major driving forces of energy-related carbon emissions and decoupling the index of carbon emissions and economic growth can give theoretical knowledge for designing effective emission-cutting policies for Pakistan. Therefore, this research makes it possible by adding to the body of existing knowledge. This investigation differs from existing literature as it is based on two layers decomposition analysis. Firstly, quantifying the contribution of fuel quality, energy efficiency, technological effect, energy intensity, economic activity per person, and population size in total energy-related carbon emissions. Secondly, determining the decoupling among carbon emissions and economic growth at different economic development stages in the country. This study helps to grasp the overall trend of Pakistan's carbon emissions. The index of decoupling represents the scale of sustained economic growth. Any reduction in the environmental degradation per unit of economic activity will indicate that the economic system is progressing toward sustainable development.

Similarly, the declaration of the Fifth Ministerial Conference on Environment and Development in Asia and the Pacific, 2005, raised awareness about the plan of action for sustainability in economic development to achieve the overall well-being of the society without compromising the natural environment. No research for Pakistan has previously focused on investigating sustainable development in light of the Seoul Initiative Network on Green Growth that was adopted in the MCED-5. To the best of our knowledge, this study is the first to analyze the sustainability path that Pakistan is following through the MCED-5 green growth model. The study analyses the data for the period 1990-2019 to understand if the economic development of Pakistan is causing pressure on its natural resources and whether it is associated with employment generation and poverty reduction. Based on the analysis, the study provides policy implications to achieve the ultimate goals of strong and sustainable economic growth.

With these aims and objectives, the study is arranged in the following manner. Following Chapter 1, the next chapter reviews existing literature related to the study. Chapter 3 provides the history of policy responses to environmental problems and also provides some insights into economic theories about sustainable economic development. Chapter 4 presents the data and variables used in the study. The methodology and specifications of the model are included in Chapter 5. The empirical results are discussed in Chapter 6. Finally, chapter 7 provides the study's conclusion, including the important policy implications.

CHAPTER 2

LITERATURE REVIEW

The national income accounts were first published in 1942 in the United States. The conventional methods such as GDP and GNP for measuring the economic activity of a country can be misleading because they don't take into account some key concepts such as economic costs associated with environmental issues such as damages due to pollution, ecological degradation, natural resource base depletion, the depreciation of natural assets, all of which can impede the future growth and development. Therefore, we require some alternative measures from the standpoint of long-term growth. Despite these flaws, it turns out that GDP is used not only to gauge a country's economic success but also for cross-country comparisons. It is so because it is scientific, rule-based, and institutionally independent and capable of providing us with a picture of a complex economy. It is used as an accountability framework for policy goals and evaluation, but it, in fact, reflects the materialistic progress of an economy.

Motivated by these reasons, several economists have attempted to analyze economic growth by proposing alternative measures for environmentally adjusted GDP throughout history. An environmentally adjusted GDP would better provide an accurate picture of sustainable growth by measuring the cost of ecological and environmental deterioration so that it may be called a green GDP. Economic development improves life quality, but beyond a specific point, economic growth has a detrimental impact due to the "Threshold Effect". After a certain point, a further increase in economic growth deteriorates the quality of living due to the rising cost of environmental damage, increase in income inequality, and loss of leisure time. Conventional GDP is not a good indicator of social well-being. In traditional GDP, economic activities are evaluated at private rather than social costs. Alternatively, an index that attempts to measure the improvements to the standard of living neglecting the depletion of natural resources misleads economic incentives and distorts investment decisions. Ultimately, the economic path is unstable as well.

In order to forecast future development and policymaking, green GDP measures can accurately analyze national progress and well-being. It provides experts with important information for monitoring and policy analysis. Green GDP can be thought of as an augmented indicator that considers human-social-natural components. It actually evaluates the true impact of economic growth to determine the long-term sustainability of an economy. Green GDP can thus be used as a vital policy instrument. When countries face energy security challenges, sustainability standards become significantly important for enterprises, organizations, and economies. Similarly, the shadow economy is an additional factor that must be considered when using traditional GDP to assess development aspects. As a result, green GDP can be considered as an adjusted GDP measure that is corrected to reflect social and environmental costs.

2.1 Concepts, Methodologies and Tools for a Sustainable Economy

The empirical literature reveals no single standpoint for measuring green growth as different economists have considered different lines of inquiry for monitoring green GDP. The development of a green economy may go in a number of different directions.

According to Yusuf et al. (1989), the existing natural capital of geological (nonrenewable), biological (renewable), and flow resources (i.e., air and water) are vital for agro-industrial production and manufacturing processes. Recycling and conservation efforts as well as new geological discoveries don't reverse known stocks from depleting. They are derived from a limited supply of resources and only prolong the period during which the depletion process takes place. Depletion of renewable natural resources has indirect consequences as it reduces the sustainable income flow for industrial inputs and ecosystem services. The study presents two important conceptual methods for dealing with the deterioration of natural resources: the user cost approach and the depreciation approach. According to the study, since geological and biological depletion is measured in physical units, this must be valued so that adjustments can be made to GDP to get a true net product. A valuation can be based on the method of replacement cost concept, if replacement is possible, or on the willingness to pay method.

The following formula developed by Yusuf et al. (1989) is used to calculate true income (X) to net receipts, R, (exclusive of extraction costs) ratio.

$$\frac{X}{R} = 1 - \frac{1}{(1+r)^{n+1}}$$

Where n is the length of the period over which the resource is depleted. r is the discount rate. X stands for true income or sustainable income. R is the net receipts (exclusive of extraction costs). R-X will be the user cost (depletion component) that should be allocated to capital investment and should be subtracted from GDP.

Man-made assets, such as plants and equipment, are considered productive capital and their cost of depreciation is excluded from the amount of national production (Repetto & Magrath, 1989). However, natural resource depletion is not treated the same way as physical capital under national income accounting. Repetto and his co-authors referred to this outcome to as Dangerous Asymmetry. By ignoring the loss of natural resources such as forest thinning, soil erosions, air pollution, animal and fish hunting to their extinction, and the services they supply, the signal provided by development policies could be misleading. According to Repetto et al., failure to account for natural resource depreciation substantially distorts economic performance and estimation of macroeconomic relationships in resource-based economies. The study provided an example from Indonesia of how the updated accounts work and what signals the new findings would convey to those who make the policies for economic progress. Indonesia has relied heavily on the country's rich endowment of natural resources to fund its development projects over the past 20 years. Throughout the study period, the primary goods industry contributed more than 43% of GDP, 83% of exports, and employed 55% of total employment. The annual GDP per capita growth was 4.6% from 1965 to 1986. Gross domestic investment increased from 8% of GDP to 26%, from 1965 to 1986. In this study, the GDP growth (at constant prices) is compared with net domestic product growth (calculated by excluding net natural resource depreciation for three sectors: timber, petroleum, and soils. The findings revealed that the traditionally measured GDP and growth overstated net income after accounting for natural resource consumption. GDP increased on average at 7.1% per year from 1971 to 1984, but the estimates of the net domestic product rose at a rate of only 4.0% per year. If 1971 (a year of a considerable increase in petroleum reserves) is eliminated from the analysis, the annual growth rates of GDP and NDP from 1972 to 1984 are 6.9% and 5.4%, respectively. The results suggested that Indonesia, which is highly dependent on the limited stock of natural resources, should diversify its asset base to maintain a sustainable path of development.

United Nations et al. (1993) have provided guidelines for integrating economic and environmental data through the System of Integrated Environmental and Economic Accounting (SEEA). There are three primary methodologies for environmental-economic accounting. The first approach (physical resource accounting) is in physical terms and is referred to as natural resource accounting. The second approach, known as monetary satellite accounting, is related to national accounts and focuses on accounts in monetary terms. This approach incorporates the genuine cost of treating environmental deterioration caused by production activities in calculating net product. The second approach is rather limited in considering environmental concerns than the first. The third approach is welfare-based. It addresses the environmental issues created by producers and consumers rather than the producers who are the cause of these problems. The SEEA makes no distinction between the natural assets that are economic assets and those that are not as considered by SNA. Similarly, SEEA focuses on a wider variety of land and natural resources regardless of institutional ownership and control. SNA considers land as a natural resource that benefits the current population economically. SEEA views land and natural resources as assets that benefit both current and future generations. As a result, under SEEA, the possible sub-land reserves will be treated as assets, but only proven sub-oil reserves will be treated as assets under SNA. Secondly, the SEEA approach differs from SNA because the SEEA also incorporates the ecosystem, land, and natural resources. Ecosystems are essential to include as they indirectly provide a range of services to mankind, such as air and water purification.

According to Kellenberg (1996), a capital asset is any stock of value that has the ability to generate an income stream. Machines, factories, and buildings are examples of fixed capital infrastructure used in production to produce goods and services. In the same way, natural resource reserves such as petroleum deposits, forests, and minerals yield important benefits to the country. Policymakers must recognize that economic output cannot be measured without considering the natural capital depletion. If the economic value of these natural assets depreciates, it should be deducted from gross income calculations for a better reflection of economic performance. Kellenberg examined natural capital exploitation in Ecuador from the period 1971 to 1990; due to the depletion of enormous petroleum reserves in the Oriente region in 1967 and the construction of 500 pipelines across the Andes Mountains to the Pacific Ocean, Ecuador experienced an oil boom which acted as an engine for economic growth. For calculating the economic value of natural capital depletion, the study employed Natural Resource Accounting techniques for the petroleum sector. The depreciation method, developed by the World Resources Institute, adjusts national income to reflect economic value changes of natural capital during the accounting period. The User Cost Method proposed by the World Bank disaggregates the revenue generated from the sale of an exhaustible asset into "user cost" and a "value-added" component, which depicts true income. Ecuador's economy experienced a robust growth rate of 8.7% per annum during the 1970s, with significant contributions from the petroleum and mining sectors. The economic development slowed down during the 1980s, and GDP increased by 1.6% annually.

Likewise, GDP fails to take into account many economically valuable inputs and outputs that are not purchased and sold in the market, such as the broad variety of ecosystem services that are linked with conserved natural areas (Talberth & Bohara, 2006). Green GDP accounting methods are primarily concerned with providing the most accurate welfare measures and monitoring of sustainable path of the economy. Although theoretical and computational issues make any green GDP difficult to accept universally, they provide a source of time-series data to re-examine the links between green GDP and factors commonly included in traditional economic growth models. The study found that trade openness caused a significant slowdown in green GDP and GDP growth rates. There is a significant and positive correlation between trade openness and the growth of the GDP and the green GDP gap. The GDP and green GDP gap are significantly influenced by the growth of the livestock production index. On the other side, CO_2 emissions have a negative correlation with the GDP and green GDP gap.

According to Abdallah et al. (2012), the Happy Planet Index (HPI) quantifies well-being from the environmental security approach. It claims a society's goal is to ensure that its members live happy lives in the long term. To reflect these notions, the HPI includes three variables: 1) Life expectancy/ It determines whether or not the members of a society are capable of living long lives. 2) Well-being: This refers to an individual's sense of belonging to society. 3) Ecological footprint: This metric estimates the overall ecological effects of the society by measuring the amount of land that is necessary to provide society with resources that it consumes and dispose of the waste the society produces. It measures the quantity of land that is needed to maintain the consumption patterns of a nation. It includes the land required to provide the renewable resources that people need (most importantly food and wood products) and the area that is occupied by infrastructure required to absorb carbon emissions.

The study of Veklich & Shlapak (2012) revealed that the growing threat of natural resource degradation has heightened the interest in the connection between the economic development of a country and the environmental condition globally. The study provides a methodology for calculating an environmentally adjusted indicator to determine the real national income in light of depleting natural resources. The adjusted indicator for green net domestic product (NDP) is calculated as follows:

Green NDP = GDP – CFC – CNR – EEP – DE

where GDP stands for conventional gross domestic product. CFC represents fixed capital consumption. CNR is the consumption of natural resources (a decrease in natural resource reserves). EEP is the environmental protection expenditures, and DE is the estimate of the environmental damage due to economic activity. Three factors for the ecological adjustment are subtracted from conventional GDP to estimate green NDP. According to the study, it is practically valuable and important to calculate the environmentally adjusted NDP for countries whose economies are heavily dependent on natural resource consumption. Ukraine is among these economies. The study provided Ukraine’s green GDP estimations for the post-Soviet region from 2001 to 2007. The estimations took into consideration the losses caused by natural resource depletion due to the extractive industry’s activities, air pollution from thermal power plants, and government expenditures on environmental protection. The findings reveal the significance of the environmental cost for Ukraine's economy. The gap between the conventional GDP and green GDP is, on average, 4.6%. In other words, the green GDP is almost 95.4% of traditional GDP. According to the study, the green GDP of the country represents its economic growth potential. The discrepancy between the traditional GDP and the green GDP showed that the country’s economic development is dependent on its natural capital, and it requires management regulations.

According to Stjepanović et al. (2017), although there are statistical, methodological, and practical concerns with calculating a more equitable and sustainable growth indicator, they should be seen as challenges rather than constraints. The authors of this study have created a green GDP measure that is comparable to conventional GDP. The green GDP is calculated as a conventional

GDP less the cost of natural resource depletion and environmental degradation. The methodology was applied to a sample of 44 developed and developing nations. The study presents the gap between the yearly growth rates of traditional GDP and computed green GDP for 2014. According to the results, in 2014, the growth rates of traditional GDP, overall, ranged from -6.99 for Australia to 10.79 for Iceland. The green GDP value was ranging from -14.83 for Chile to 9.94 for Iceland. The results reveal that economic growth in these countries was not satisfactory in 2014. When the countries are categorized into three standard groups, the traditional GDP and green GDP growth rates are 1.85 and 0.92 for developed nations, while 1.78 and -1.15 for the developing ones, and 4.03 and -3.98 for the low developing economies. This suggests that economic growth and the quality of the environment increase with an increase in development. According to Sharif et al. (2017a), electricity is the primary driver of long-run economic development in Singapore, one of ASEAN's major economies. The relationship between electricity generation and economic growth by using co-integration approaches confirmed that the attainment of swift economic growth is possible by investing in electricity generation technology and infrastructure. A couple of experts reported that the development of the tourism industry could be beneficial for long-run economic growth. Sharif et al. (2017b) explored the causal association between tourism development and economic growth (measured through the industrial production index) in the United States using monthly observations from 1996(1) to 2015(8). Sharif et al. (2020a) analyzed the effect of tourism on Malaysia's environmental deterioration for the period 1965Q1 to 2017Q4. The results of the study confirmed that the nature of tourism development negatively affects emissions. Therefore, green technology can be used in the tourism sector to improve the quality of the environment. According to Khan et al. (2019), most developing countries in Asia have inadequate logistics, trade, and transportation infrastructure. The absence of eco-friendly practices in the supply chain and logistics operations can be a major source of environmental and social issues. Similarly, to attain green growth in the long run, policies should be directed to increase the magnitude of social and political globalization by giving attention to regional integration and greater participation in economic processes, e.g., by improving energy efficiency through clean energy projects, diversification of energy sources and reduction of fossil fuel usage (Suki et al., 2020). The study explored the presence of the EKC with different proxies of globalization by taking quarterly data from 1970 to 2018 for the Malaysian economy.

Similarly, in another study by Vimochana (2017), natural resource accounting is an integral part of economic accounting, resulting in an environmentally adjusted GDP. The accounting of natural resources analyzes the inclusion of costs associated with resource depletion and environmental degradation, which in this way adjusts the conventional GDP. In order to calculate environmentally adjusted GDP, the study subtracts the value of environmental damage from GDP. According to the System of National Accounts (SNA) published by the United Nations Statistical Office (United Nations 1968), the environmentally adjusted Domestic Product can be expressed as:

$$EDP = \Sigma\, EVA_i - \Sigma\, EC_h = NDP - EC = C + CF + X - M - CC - EC$$

Where EDP is the net domestic product adjusted for the environment. ΣEVA_i is the sum of environmentally adjusted value assets of industries, and ΣEC_h is the total deduction of environmental cost imposed by households. EDP is the sum of final consumption (C), environmentally adjusted net capital (CF-CC-EC), and net exports (X-M). The SNA provided a comprehensive accounting framework not only for a country's economic activities but also for its productive assets and the wealth of its citizens at a particular time. SNA also considers the external account of a country. The central framework of SNA is incapable of incorporating the natural assets that lie outside its asset boundaries. The SNA only takes into account such natural assets that provide benefit to its owner economically via control of an institutional unit. That is, explicit ownership is subject to government laws as well as market price availability. The SNA does not cover environmental services i.e., clean air, natural filtration, and decontamination of soil, water, and air.

According to Chelli et al. (2013), the Index of Sustainable Economic Welfare (ISEW) gives a realistic representation of a society's well-being. This is because the ISEW includes variables that are not included in GDP (such as costs of social and environmental issues). The most important contribution of the ISEW is that it proposes adjustments to the GDP: like, it adjusts personal consumption to tackle inequalities. ISEW includes health and education to the public expenditures. It also takes into account both domestic labor and volunteer. In addition, the ISEW deducts environmental emission costs, defense expenditures, the costs of commuting, car accidents, individual pollution control expenses, social costs (such as family breakdown), and natural capital depreciation. Lastly, it also incorporates the long-run cost of climate change. The following equation serves as a definition of the ISEW:

$$\mathrm{ISEW} = \mathrm{C}^* + \mathrm{G}^* + \mathrm{I}^* + \mathrm{W} - \mathrm{D} - \mathrm{E} - \mathrm{N}$$

Where C^* is the personal consumption spending (as measured by the GDP) adjusted for income inequality. In fact, personal consumption expenditure is not reflective of the degree of economic well-being since any rise in income should boost welfare more for an impoverished family than for a rich one. G^* represents the non-defensive public expenditure. I^* consists of consumer durable goods, net capital growth, and net foreign investment changes.

Centre for Bhutan Studies & GNH Research (2016) conducted a study using the concept of Gross National Happiness (GNH). King Jigme Wangchuck in 1972 proposed Gross National Happiness (GNH) to provide a philosophy that would maximize economic progress. The GNH focused initially on four policy goals: equitable economic development, environmental conservation, cultural resilience, and good governance. In recent years the Centre for Bhutan Studies (CBS) has described GNH as consisting of nine domains: [1] Psychological well-being, [2] Living standard, [3] Good governance, [4] Health, [5] Education, [6] Community vitality, [7] Cultural diversity, [8] Time usage, [9] Ecological diversity. The Centre conducted a comprehensive survey of over 7,000 households to evaluate the GNH of Bhutan for 2015. Multiple questions were asked to study each domain. The responses determined the sufficiency of each household in each of these nine areas. According to the results, 43.4% of families in Bhutan have sufficiency in at least six categories and are regarded as extensively happy. This is an improvement over a similar kind of survey conducted in 2010 when the figure was 40.9%. Bhutanese have more sufficiency in their health, followed by their ecological and community vitality. The results proposed that sufficiency is more prevalent in urban areas and among the young people having formal education.

According to Curran (2017), it's time to look beyond GDP. The author investigates the concept of the Index of Sustainable Economic Growth which strikes a balance between social, economic, and environmental systems. Three economic strategy elements, namely the growth of the economy, unemployment rate, and the low carbon economy are well suited to create a single and straightforward measure of sustainable economic growth, which is a product of economic efficiency (GDP per capita), social inefficiency (the unemployment rate) and environmental inefficiency (CO_2 emissions per head). Therefore:

$$\text{Index of sustainable economic growth} = \text{GDP per capita divided by unemployment rate} / \text{carbon dioxide emissions per capita}$$

These three index components are widely available for nearly every country, making it easy to calculate the index annually for various countries. Given that sustainable development itself is often described as a journey or a process, it sounds reasonable to normalize the index values such that all countries begin with a value of one in the first year of measurement. This seems to be a helpful and quite informative index since it focuses on the factors that are politically significant not just in one country but across the globe.

According to Harris & Roach (2017), traditional national accounting estimates the saving and investment rates of a country. This measure provides meaningful insight into the nation's savings for its future. Net saving is obtained after excluding fixed capital depreciation from gross savings. The study revealed that net saving in the United States was negative from 2008 to 2011, positively turning positive in 2012. The study proposed that the natural resource management of a country reveals information about whether the nation is saving for the future or causing resource depletion that may reduce future consumption. Productivity and the well-being of a nation rely upon natural assets. The World Bank introduced a measure called Adjusted net saving, incorporating natural and human capital assets. Depletion of a non-renewable resource and over-exploitation of a renewable one reduces the value of that resource stock as an asset. Such activity represents dissaving and ultimate reduction in future productivity and well-being. Sharif et al. (2019) unveiled the need to adopt green technology in collaboration between two countries or within a country. The results for the top 74 carbon emission countries according to the KOP globalization index concluded that a 1% increase in non-renewable energy increases CO_2 by 1.123%. While, a 1% increase in renewable energy and financial development decreases CO_2 by 0.924% and 0.174%, respectively. The results showed that countries aiming for economic development through renewable energy consumption are inclined to partner with countries that choose green infrastructure. Likewise, continued reliance on natural resource pools leads to long-term environmental unsustainability while providing short-term economic benefits to the country (Sharif, Baris Tuzemen, et al., 2020). The outcomes of QARDL estimates found that renewable energy in Turkey decreases ecological footprint after the second quantile. Economic growth and non-renewable energy have a positive impact on the ecological footprint. In addition, the turning points of the environmental Kuznets curve (EKC) start rising between 0.05-0.80 quantiles, indicating that the growth path being attained by Turkey is unsustainable. The low penetration of renewable energy programs has a minimal impact on the ecological footprint in Turkey. In line with this, the influence of innovations in addressing key climate and sustainable development challenges is important. Godil et al. (2021) examined the impact of technology and renewable energy in mitigating emissions in China's transport sector. The application of the QARDL approach has shown that the impact of technological innovation is highly significant and negative in all quantiles. Renewable energy is significant and negative in all the quantiles except for 0.10.

OECD (2017) conducted a comprehensive attempt by collecting data on well-being from a number of nations and calculating the Better Life Index. According to the report, in 2016, the typical OECD home had 1.8 rooms per head, but 2.1% of individuals live in houses that lack basic sanitary services (i.e., access to an indoor flushing toilet for the sole use of their household). From the health status, the average newborn in OECD nations can now expect to live until they are just over 80 years old, but only 69% of individuals reported feeling in good health. People who live in OECD countries are, on average, exposed to outdoor air pollution which is about 40% higher than the threshold level suggested by the WHO, which is 10 micrograms per cubic meter. Around 80% of OECD citizens are satisfied with the quality of water provided by their communities. Table 2.1 below presents the review of the literature on socio-economic and environmental framework in the context of Pakistan.

Table 2.1: Review of Past Literature in Pakistan on Socio-Economic and Environmental Framework

Author	Factors to measure sustainable development framework	Context	Findings
Baloch et al. (2018)	CO_2 emissions per capita, Per capita real income, Gini coefficient, Industry value added share of GDP, Population density	Nexus between income inequality, economic growth, and environmental degradation	According to the results, carbon emissions in Pakistan grow as the income differences widen. Aside from the negative influence of industrial share and population density on emissions, the findings show that Pakistan's GDP growth results in increased emissions.
Faridi, Chaudhry, and Azam (2018)	Headcount ratio, CO_2 emissions per capita, GDP per capita, Trade openness, Urbanization, Industrial production share in GDP	Economic growth, urbanization, and poverty impact on environmental degradation	According to the study, CO_2 emissions are the primary cause of the greenhouse impact caused by fossil fuel consumption. According to the study, energy is the primary source of pollution in the environment.
Naeem Nawaz and Alvi (2018)	Energy security risk, International country risk index, CO_2 emissions	Energy security to achieve sustainability	The findings of the study reported that energy insecurity is harmful to the environment and socioeconomic conditions. Policymakers should prioritize long-term energy security in order

			to achieve environmental and socioeconomic sustainability in the country.
Awais et al. (2019)	Infrastructure, Energy, Industry, Gwadar city development projects, Fiber optics cable development project	Inclusive viewpoint of CPEC towards sustainable development	The CPEC is expected to be a win-win initiative. Pakistan and China will both gain for a long time from investment in the energy, construction, and infrastructure sectors. CPEC building and investment projects benefit individuals, communities, and societal development in multiple ways.
Rashid Khan et al. (2019)	Headcount index, Gini coefficient, GDP per capita, GNI, Forest depletion, Mineral depletion, Fisheries production, Livestock production, Mortality rate under age 5, Govt. education expenditures, CO2 emissions, Fossil fuel energy consumption, Foreign direct investment, Trade openness, Population density	Socio-economic and environmental sustainability framework	Higher economic growth reduces poverty incidence, but deforestation, under-5 mortality, trade openness, carbon emissions, and FDI inflows raise poverty. Due to the strong involvement of dirty polluting businesses in the country's economic transition process, the "pollution haven hypothesis" has been proven. Carbon emissions are increased by the use of fossil fuels and the high population density.

Sadaf and Jabbar (2020)	Total waste consumption, Energy consumption, Construction land area, Investment in fixed assets, Number of employed persons, CO2 emission, Total suspended particulates, Solid waste emissions, Wastewater, Prosperity score	Imbalanced urban social and economic development and environmental degradation	The main causes of environmental deterioration in Pakistan include unbalanced and unplanned social and economic development, as well as urbanization. Karachi has the lowest eco-efficiency rating of any city. When compared to Karachi, Lahore has a higher level of prosperity. The disparities in eco-efficiency between cities are significantly greater than the disparities in prosperity rankings.
Khan and Yahong (2021)	Population below $1.9 a day, Gini index. Population density, GDP, Inflation, Industry value added to GDP, Sanitation	Impact of poverty, income inequality, population, and economic growth on carbon emissions	According to the study's findings, poverty, population density, and GDP per capita all raise carbon emissions in the short and long term, whereas income inequality has no effect on carbon emissions in the short run. While the findings suggest that income disparity reduces environmental degradation in terms of carbon emissions in the long run.
Rizwanullah et al. (2022)	Education, Health expenditure, GDP, Financial development	Socio-economic development and environmental quality of the country	The findings confirm that education and health expenditures have a detrimental impact on emissions; nevertheless, GDP has a long-term favourable impact on carbon emissions.

Khan, Yahong, and Zeeshan (2022)	Gini index, GDP, Foreign direct investment, Population growth, Access to electricity, Forest area, Inflation, Manufacturing value added	Poverty, inequality, and environmental degradation relationship for sustainable development	The study's empirical findings proved that the poverty headcount contributes to environmental degradation. Growing income disparity has a negative impact on the environment.
Diwakar 2023)	Headcount ratio, Inequality in the bottom half, GHG emissions per capita, Material footprint per capital. Labor productivity, Diversification index, Govt. effectiveness.	Capturing degrees of inclusive and sustainable economic transformation	The study discovered varying degrees of inclusive, sustainable economic transformation in the country. It is difficult to observe the country constantly functioning well across the three criteria of sustainability. Volatility exists in both inclusion and growth trajectories.

After reviewing several studies above at the national level, our analysis differs on the following basis.

1. The literature reveals that Pakistan is less likely to reduce poverty rates when considering carbon emissions that mainly come from economic growth. Therefore, a potential solution to poverty could be a climate-resilient economic path. According to the MCED-5 (2005), such a path helps promote sustainable economic growth in Asia-Pacific countries which ultimately conditions the prosperity of future generations. Moreover, in many studies mentioned above, the manufacturing industry is viewed as a proxy for economic growth; however, this industry of Pakistan is heavily dependent on imported fuel products and low diversity, which is a compromise over sustainability. For these reasons, the present study has used World Bank estimates of Adjusted Net National Income (NNI*) as a proxy for sustainable economic development. This measure is built on methods presented in the World Bank's book "The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium" (World Bank 2011). According to the definition, sustainable development requires that the total capital stock should not decrease, and the accurate measure of sustainable national income is the quantity that can be consumed without depleting the total capital stock (i.e., fixed capital stock and natural resource stock).
2. Based on the literature mentioned above it is concluded that extreme poverty (US$ 1.90 a day) reduction and economic growth have a significantly positive relationship in Pakistan. In the socio-economic scenario, it is also important to estimate whether the poverty in the country would decrease when higher poverty lines are considered. In this continuation, the World Bank has provided new standards for the international poverty line. For a low-middle-income country, the poverty line is $3.20 a day. According to the World Bank classification, Pakistan is considered a low-middle-income country. As a result, the World Bank's higher poverty line of $3.20 a day is used to measure the incidence of poverty in this study. The findings of the study would suggest some important lessons to learn e.g., the trends based on the higher poverty line will show whether poverty in all forms can be eradicated with significant real social change to the economy. As a result, the $3.20 per day poverty level can be utilized to create programs and economic strategies for Pakistan.

3. Thirdly, our empirical approach involves regressing carbon intensity as a measure of Carbon emissions emitted per US dollar of GDP. Previous studies have focused on either total carbon emissions or carbon emissions per capita. Examining carbon emissions per unit of GDP fairly represents the country's responsibilities towards climate change. It measures how much CO_2 we generate when we produce one dollar in our economy. A declining trend in carbon intensity is a good sign for the environment and economy. Decreasing carbon intensity means that energy consumption has become efficient and does not require burning more fossil fuels.
4. Fourthly, it is assessed that there is no general agreement or consensus in the literature about a uniform measure for assigning monitoring value to natural asset degradation. However, this study has used the environmental asset accounting approach introduced by the World Bank. According to the definition, the high depreciation of natural resources as a percentage of GNI implies that the country is becoming poorer by leaving very little natural wealth for future generations. The World Bank defines the value of natural resource depletion as equal to the sum of the net depletion of forest, natural gas, hard and soft coal, tin, gold, lead, iron, zinc, nickel, copper, nickel, phosphate, silver, and bauxite.

2.2 Carbon Emissions and Economic Growth

Ang & Choi (1997) refined the Divisia index method of index decomposition analysis using a logarithmic weight function and used the method to compute the aggregate CO_2 intensity index for the Korean industry. Four energy types were considered, i.e., coal, gas, oil, and electricity. The study considered CO_2 emissions arising from all these four types. Korean energy and industrial production data for 1981 and 1993 were collected. The aggregate CO_2 intensity index is decomposed into structural effect (due to resource shift toward relatively high productivity sectors of the economy, intensity effect (total industrial energy consumption divided by total industrial production), emission coefficient effect (changes associated with CO_2 emission coefficients) and fuel share effect (changes in sectoral fuel shares). The results of the study using the refined Divisia index method revealed that the fuel share effect contribution is 1.014, the structural effect is 0.914, the emission coefficient effect is 0.901, and the intensity effect is 0.772 in total CO_2 intensity. The aggregate CO_2 intensity index for the Korean industry for the period 1981 and 1993 is 0.648. The results revealed that the fuel share effect causes mainly aggregate CO_2 intensity. Similarly, Tapio (2005) found a substantial correlation between road traffic volumes and gross domestic product. The study provided a comprehensive system of various economic growth and environmental challenges decoupling states. According to the findings of the EU-15 nations from 1970 to 2001, transport volume growth followed the GDP growth pattern in the 1970s while surpassing the GDP growth rate in the 1980s and increased slightly sluggish than GDP in the 1990s. There was expansive coupling in the 1970s. In the 1980s, economic development resulted in expansive negative decoupling, and the 1990s, there was expansive coupling again. The study argued that the potentially growing maritime and international air travel partially explains the disparity.

According to UN & ECLAC (2009), the economy of Latin America and the Caribbean will face the challenges of climate change in the 21st century. The nations will also need to simultaneously address other challenges, such as sustainable economic development, employment creation, and poverty reduction. Climate change will adversely affect economic activities, including agriculture and tourism, biodiversity, and the quality of human life. There will be a loss in the forested land area an increase in temperature, a change in precipitation patterns, and a decline in the cryosphere (ice and snow deposits. Consequently, it will impact the well-being of future generations. Climate change is characterized by dry spells, farmland flooding, and a considerable drop in forestry. These also include the proliferation of pests, soil deterioration, and irrigation water shortages. This would significantly increase the number of people who will face a shortage of clean water availability by 2025 and seriously stress hydroelectric power production. Malaria, dengue, cholera, and respiratory ailments are associated with changes in precipitation, poor water and air quality, and increased UV radiation will be the primary health effects of climate change. The number of patients with nonmelanoma skin cancer will increase. The rise in sea level will result in the displacement of many people, and the amount of land lost due to floods and severe degradation of the jungles that are home to the greatest biodiversity. The combustion of fossil fuels and cement manufacturing accounts for 60% of global emissions, followed by land-use-change and the agricultural sector. Urbanization, industrialization, modern lifestyles, and means of transportation are significant contributors to carbon emissions. If this problem is not addressed, it will constrain economic progress.

According to Lamb & Rao (2015), in a world of chronic poverty, it is necessary to measure the effects of GHG emissions on lifting all individuals to an adequate standard of living. The study defines basic needs as a combination of six components: food, shelter, basic health, sanitation, and education. Using historical elasticities of economic growth and energy consumption for Africa, centrally planned Asia, and South Asia, the study projected the impact of GHG emissions from development as usual on acquiring higher life expectancy, access to necessities, and continuous economic growth to the mid-century. GHG emissions were computed for each of these regions by adding the carbon dioxide equivalents of CO2, CH4, N2O, and F-gases. Longer life expectancy and more access to basic services were found to be achievable at lower emissions levels than current economic development but would need a significant amount of the global budget to achieve the 2^0C climate objective.

Loiseau et al. (2016) consider green growth essential for achieving climate mitigation goals. Therefore, it is necessary to investigate the linkages between the green economy and climate mitigation. Green growth is related to the specific terms "sustainable development" or "sustainability" in 35% of scientific publications. This relationship demonstrates that a green economy is often regarded as a means to sustainability. Green growth reduces pressure on natural resources and climate change, thus promoting economic growth and employment. Cleaner production with resource efficiency is a paradigm shift since it asserts that it is more suitable to avoid pollution than remedy it. By focusing on enterprises and their behavior, resource efficiency strives to improve the use of natural resources across the value chain of production by focusing on lowering emissions via technological advancements.

Schandl et al. (2016) established a detailed analysis for future material efficiency, carbon footprints, and energy for thirteen world regions for the four decades to 2050. The findings indicated that although relative decoupling could be achieved, none of the nations advanced to an absolute decrease in material footprint or energy. However, in absolute terms, the carbon footprint might be reduced. Robust carbon abatement strategies with a worldwide carbon price commencing at $50/ton and increasing to $236/ton in 2050 and gaining a significant increase in material efficiency globally would have a minor impact on global GDP growth. However, in absolute terms, the carbon impact might be lowered. Stringent carbon-cutting measures, with a worldwide carbon price beginning at $50 per ton and increasing to $236 per ton in 2050 and acquiring highly significant increases in material efficiency worldwide, would not affect global GDP growth. Strong emissions abatement regulations and significant investment in resource efficient technology would lead global income to grow by US$3 trillion less than it could grow otherwise, resulting in a loss of only 1.6% over four decades. Imposing a carbon price globally would raise the cost of energy use and impede energy-intensive activities due to sluggish demand. However, this would provide incentives to invest in renewable energy sources. Therefore, to a larger extent, the increase in investment in renewable energy industries would counterbalance the negative consequences of carbon pricing on traditional industries, resulting in relatively low overall GDP loss. The results indicated that carbon footprint reductions are primarily driven by worldwide improvements in renewable energy supply and other sources with reduced carbon contents. Material efficiency also has a far higher impact in lowering carbon footprint than energy efficiency. Improvements in material efficiency lowered carbon due to a declining need for transportation services and energy saving in energy-intensive heavy industries.

Chen et al. (2017) estimated decoupling rates of Macao's economic development with energy embodied GHG emissions (EEGE), total energy consumption (TEC), and total embodied GHG emissions (TEGE) for the period 2000 to 2013. According to the study, transportation and fugitive emissions, physical or chemical processing, and local electricity production account for most direct greenhouse gas emissions. According to the results, EEGE, in most accounting years, is in the weak decoupling state with decoupling indices values in the range of 0.07 and 0.78. The total energy consumption depicted expansive negative decoupling, with 4.41 and 1.41 decoupling indicator values for 2001 and 2009, respectively. In 2002, expansive coupling was found with a 0.85 value of the decoupling indicator. For the remaining years, weak or strong decoupling was observed. According to the decoupling statistics for TEGE, the country is steadily approaching sustainable economic development. The results indicated that the regulations and laws implemented to reduce emissions are beginning to impact them.

Lin & Ahmad (2017) investigated that GDP per head and population growth are the primary causes of carbon emissions in Pakistan by applying the extended Kaya identity and LMDI technique. Carbon intensity leads to emission reduction in all sub-periods except 1995-1999. The impact of energy intensity and fuel substitution on the reduction of emissions are mixed and unstable across all sub-periods. During the period 2000-04 and 2010-14, energy intensity, carbon intensity, and fuel mix effect contributed negatively to the change in CO_2 emissions. The study also predicted that the carbon emissions of Pakistan are likely to reach 251.5Mt CO_2 in 2025 based on the business-as-usual scenario. The forecasting scenarios suggest that the CO_2 emissions reduction potential is equivalent to 28.94Mt and 55.02Mt in 2025, as per medium and high emission reduction scenarios.

Mahony (2013) investigated the influence of various driving factors of energy-related carbon emissions in Ireland using the LMDI approach on the extended Kaya identity model. The study focused on eleven consumption sectors of Ireland from 1990 to 2017. The sub-fuel types included oil, coal, gas, peat, and renewable energy sources. The accumulated effects over time illustrated that the most dominant positive factor for carbon emissions is GDP per capita. Population and carbon intensity effects also have positive but relatively minimal effects. The energy intensity is the most significant factor that inhibited the total emissions throughout the analysis. Renewable energy and fossil fuel substitution effects decreased carbon emissions, but their effects are relatively minor. The total negative impact of inhibiting factors was significantly surpassed by the total positive effect of contributing factors resulting in a substantial rise in the aggregate energy-related carbon emissions.

York & McGee (2017) evaluated whether the changes in the proportion of electricity produced by renewable energy sources and combustible biomass and wastes affect the link between economic growth and CO_2 emissions per capita for the electrical sector. There were 128 countries to analyze. The data covered the period 1960 to 2012. The results indicated that for every 1% rise in GDP per capita emissions increased by around 0.50%. The relationship between renewable and GDP per capita is positive and statistically significant. Renewable power production growth in wealthy nations cuts emissions but less than in poorer nations. The results also suggested that economic development raises emissions more in countries with a high proportion of renewable energy than in nations with a low utility-scale of renewable energy in electricity generation. The estimated elasticity for GDP per capita is higher in years when a considerable share of electricity is generated from renewable sources. This suggests that a greater percentage of electricity derived from renewable sources results in a closer coupling between GDP and emissions. This paradoxical result appeared because electricity production from renewable sources is likely to suppress nuclear power production rather than fossil fuel use in wealthy countries.

Engo (2018) investigated Cameroon's tertiary (service) and industrial sectors to analyze the decoupling status. Using the extended Kaya identity, the study employed LMDI and the Tapio elasticity model to examine the impact of economic activity, carbon emission, demographic factors, economic structure, and energy intensity. According to the findings, the value of the cumulative decoupling index is 0.00013. Carbon emissions grew by 4.705tCO_2, representing a 103% growth of Cameroon's total carbon emissions (in absolute terms) from 1990 to 2015. Due to demographic factors, carbon emissions significantly increased by 96.8% in the tertiary sector and 29.64% in the industrial sector. This was the effect of population growth which increased energy requirements and, ultimately, carbon emissions. In addition to this, the economic output caused an increase of 9.57% in CO_2 emissions. Likewise, the results found that the energy intensity contributed to a 32.64% rise in carbon emissions. The results showed that the economic structure and carbon emissions lowered CO_2 emissions in the industrial sector. However, the emission factor was the only contributory factor for the tertiary sector. The study believed this might be attributed to the improvement in productivity and technology.

Wu & Zhu (2018) evaluated the significance of numerous influencing factors for determining the degree of decoupling. The decoupling index was calculated for the change in total energy requirement per GDP and the GDP growth rate for Russia, Brazil, China, India, USA, France, UK, and Germany from 1965 to 2015. The results indicated that for most countries, the decoupling index ranges from 0 to 1, indicating that these nations have been nearly in a relative decoupling state for the past five decades. The growth of technology has a minimal effect on the decoupling index. Technological advancement significantly influences developed nations, followed by industrial structure and economic growth patterns. The comparison between developed and developing countries discovered that the total energy consumption, although large in developed countries, but their energy efficiency is very high, resulting in a decoupling score much higher than that of developing nations.

Khan et al. (2019) analyzed the key determinants of carbon emissions in Pakistan from 1990 to 2017. The study investigated the five main factors responsible for emissions, including economic activity, structural effect, fuel mix, intensity effect, and emission effect, by using the LMDI method. The study confirmed the rising trend of CO_2 emissions. Among all factors, the economic activity effect was the single most important contributor to the CO_2 emissions in

Pakistan. During 1990-2000, the effect of economic activity was relatively stagnant. The structural effect positively impacts carbon emissions, reflecting a shift of the economy towards highly energy-intensive industries. The contribution of structural effect was rather more significant in total CO_2 emissions change from 2000 to 2017, with the rise in the comparatively more energy-intensive sector. Likewise, the intensity effect negatively correlates with emissions, indicating improvement in energy efficiency in three sectors of the country.

The fuel mix lowered the emissions from 2000 to 2017 due to the rise in the proportion of gas in the total energy mix, while it was sufficiently high during the 1990s. In another study for Pakistan, Anser et al. (2020) analyzed the proportion of carbon-fossil-GHG (CFG) in the country's Water-Energy-Food (WEF) resources using five data sets: 1970-1980, 1981-1990, 1991-2000, 2001-2010, and 2011-2016. The findings revealed strong decoupling among WEF resources and CFG from 1970-1980 and 2011-2016, but expansive negative decoupling from the 1980s to 2000s. The share of carbon in water resources decoupled weakly in the 1970s and 2011-2016, while expensive negative decoupling was found in the 1980s and strong decoupling in the 1990s and 2000s. The fossil share in water resources strongly decoupled from the 1970s to the 2000s but weakly decoupled in the period 2011 to 2016. From 2011 to 2016, the results revealed that fossil shares in food resources exhibited expensive negative decoupling and weak decoupling in energy. The results concluded that CFG emissions in WEF resources significantly affect Pakistan's economy and hence the country's sustainability agenda. The following Table 2.2 represents the review of literature on energy decomposition analysis in Pakistan.

Table 2.2: List of Studies on Energy Decomposition Analysis in Pakistan

Study	Data	Index Decomposition Methodology	Decoupling Approach	Effects
Ullah, Khan, and Akhtar (2014)	1972-2011	Fisher's Ideal Index	×	Economic activity effect Energy efficiency effect
Mirza and Fatima (2016)	1980-2009	Fisher's Ideal Index	×	Energy intensity effect Energy efficiency effect Structural change effect
Lin & Ahmad (2017)	1990-2014	Additive LMDI	×	GDP per capita effect Energy intensity effect Fuel substitution effect Population effect Carbon intensity effect
Jamil and Shahzad (2017)	1990-2013	Additive LMDI	×	Energy activity effect Energy structure effect Energy intensity effect
Akram et al. (2019)	1990-2016	Additive LMDI	×	Emission factor effect Energy structure effect Energy intensity effect Economic structure effect Economic activity effect Population effect
Khan & Majeed, (2019)	1990-2014	Additive LMDI	Tapio's elasticity	Population size effect Economic activity effect Energy structure effect

				Carbon intensity effect Energy intensity effect
Khan et al. (2019)	1990-2017	Additive LMDI	×	Energy intensity effect Fuel substitution effect Activity effect Structural effect Carbon emission effect
Anser et al. (2020)	1970-2016	×	Tapio's elasticity	Decoupling of Water-energy-food- resource and carbon fossil-GHG emissions
Rasheed et al. (2022)	2005-2020	Additive LMDI	×	Energy structure effect Energy intensity effect Carbon intensity effect Labor productivity effect
Raza, Chen, and Tang (2022)	1993-2017	Additive LMDI	×	Activity effect Energy intensity effect Energy mix effect Carbon intensity effect Research and development effect Research and development efficiency effect
Xiuhui and Raza (2022)	1990-2019	Additive LMDI	Tapio's elasticity	Carbon intensity effect Energy structure effect Energy intensity of industrial value-added effect Employee's value-added effect Intensity scale effect
Khan and Majeed (2023)	1980-2018	×	Tapio's elasticity	Decoupling index. Johansen cointegration to assess the relationship between decoupling index, industrialization, carbon intensity, urbanization, and economic growth

From the literature mentioned above, it is found that many researchers have analyzed the decoupling index and the impact of several factors on energy-related carbon emissions in Pakistan. There still exists a gap in the previous studies for further research to enhance understanding of carbon emissions accounting. As a result, this study intends to add to the existing knowledge in four distinct ways:

1) The studies mentioned above have sought to improve knowledge of the driving forces of carbon emissions in Pakistan using the Kaya identity framework by providing different sets of factors. In this regard, Lin & Ahmad (2017) used extended Kaya identity by incorporating various factors and fuel substitution effect. Khan et al. (2019) further decomposed Kaya identity by adding carbon emission factor and structural effect for Pakistan along with fuel substitution effect and other factors. Raza, Chen, and Tang (2022) analyzed the research and development effect and the research and development efficiency effect along with the fuel substitution effect. This study extends further such index decomposition literature to Pakistan by splitting fuel substitution into two effects: [1] fossil fuel substitution effect (the share of i^{th} fossil fuel in total fossil fuels consumption) and [2] renewable energy penetration effect (share of total fossil fuels consumption in total primary energy consumption).
2) Lin & Ahmad (2017) provide a period-wise analysis based on national economic planning of five years. Jamil and Shahzad (2017) conducted such analysis based on aggregate energy used while Akram et al. (2019) analyzed decomposition analysis just based on 5-year intervals. However, this study provides period wise analysis of carbon emissions based on development trends in Pakistan over five distinct periods based on economic growth. [1] 1990-1998 (Boom Period and Increase in Carbon Emissions): This period saw significant privatization and economic liberalization in Pakistan, which have contributed to economic growth. However, this growth was accompanied by a notable increase in carbon emissions [2] 1998-2001 (Macroeconomic Deterioration and Decrease in Carbon Emissions): During this time, Pakistan faced challenges due to sanctions resulting from nuclear tests and suspension of the IMF program. These factors contributed to a decline in economic growth. Moreover, carbon emissions decreased during this period. [3] 2001-2008 (Post-9/11 Economic Benefits and Increased Carbon Emissions): The aftermath of the 9/11 attacks led to Pakistan receiving favorable terms and aid. This period has seen economic growth as a result. Simultaneously, carbon emissions increased at a higher rate [4] 2008-2015 (Global Recession and Carbon

Emission Decline): The global economic recession that began in 2008 impacted economies worldwide. In Pakistan, this has led to a slight decrease in carbon emissions as economic activities slowed down. The recession's effects have contributed to this trend. [5] 2015-2019 (Post-SDG Era and Emission Decline): This period reflects Pakistan's recognition of sustainable consumption and production as vital for green development, likely aligning with the global Sustainable Development Goals (SDGs). This shift in perspective has contributed to a decline in carbon emissions as the country adopted more environmentally friendly practices.

3) All studies mentioned above have used the Kaya identity model by applying the Additive Log Mean Divixia Index-1 methodology. Contrary to this, our study has used the Kaya identity framework and multiplicative Log Mean Divisia Index-1 decomposition methodology. The additive LMDI approach gives changes in absolute terms while multiplicative LMDI provides changes in terms of ratio form (Ang 2015). The former presents the exact magnitude of change while the latter presents the comparative index (or index change) of carbon emission changes (Shao et al. 2016). Although the researcher has choices between these two approaches while using the LMDI methodology, it has been found that the additive form tends to be found more in Structural Decomposition Analysis (SDA) literature, whereas the multiplicative form is found more in "Classical" economics theory of index number (Olanrewaju 2019). The "Classical" economics theory of index number theory was developed by Staehle and others, with the later work of hicks and Samuelson (Allen 1949).

4) Moreover, this study further enhances the existing literature on decoupling states of Pakistan by providing long-term trends of the absolute contribution of the burning of fossil fuels (natural gas, bituminous coal, lignite, fuel oil, gas/diesel, kerosene, motor gasoline, LPG, and other oil products) to annual carbon emissions between 1990 and 2019. This perspective is particularly important because the share of these fuels to total energy consumption has changed during the period of analysis. However, in this scenario, Khan & Majeed (2019) have provided only a long-term perspective of total carbon emissions in Pakistan.

CHAPTER 3

FROM THE BEGINNING TO THE CONTEMPORARY ISSUES OF SUSTAINABLE DEVELOPMENT

3.1 HISTORY OF POLICY RESPONSES TO ENVIRONMENTAL PROBLEMS

The recognition of environmental-related challenges has varied in the history of Pakistan, and so have the policy responses. The historical policy responses to environmental issues can be divided into three distinct eras.

3.1.1 The First Phase from 1947 to 1972: Environmental Negligence

During the first decade of independence (1947-57), the Government of Pakistan remained occupied with the challenges of establishing a government, boundary distribution, rehabilitation of refugees, electricity and water issues, and division of military and financial assets with India. The government prepared its first six-year development program (1951-1957). Although several projects were outlined for the country's economic development, the program did not suggest any significant administrative changes concerned with sustainable development. In later years, the First five-year plan of Pakistan (1955-60) attempted economic advancement in the country. However, it was still limited to banking services of the economy, expanding government revenue and trade in particular. The period from 1960 to 1972 was marked by a considerable expansion in the manufacturing sector and the beginning of the green revolution in the agricultural sector. However, the emergence of environmental problems due to the exploitative use of resources and the growing population received only a little attention. Remedial actions were taken to solve the problem of soil pollution. Salinity Control and Reclamation Projects (SCARP), which started in 1961, recovered a large part of deteriorated land.

3.1.2 The Second Phase from 1972 to 2000: Acknowledgement of Environmental Problems

The era from 1972 to 2000 is marked as a period during which legislation and institutions evolved. Pakistan started paying attention, particularly to protecting the environment, soon after the Conference of Stockholm in June 1972. Stockholm Conference was the first UN major conference on global human impact on the environment.

The second part of the fifth principle of the Stockholm Conference: **"The non-renewable resources of the earth must be employed in such a way as to guard against the danger of their future exhaustion and to ensure that benefits from such employment are shared by all mankind."** was suggested by Pakistan. The idea of sharing benefits by all humanity stresses the social character of international law, which no longer protects the lucky few, but instead provides for more distributive justice.

In November 1972, the Ministry of Presidential Affairs organized a meeting concerning various environmental aspects. One of the important meeting outcomes was the formulation of the committee on the human environment. The committee submitted its first report in April 1973. It suggested both long-term preventive and short-term curative measures so that economic development would not produce climatic chaos and poor living conditions. Another significant positive development of 1973 was a constitutional mandate to preserve the environment. "Environmental Pollution and Ecology" was included in the existing legislative list of the 4th Schedule of the Constitution of Pakistan. Some provincial government departments perform very well. For example, the provincial forest departments established biannual tree-planting campaigns. Similarly, the Provincial Soil Conservation Department was also disseminating contour ploughing, terracing, and other soil conservation techniques.

The function of looking after general environmental matters was assigned to the Ministry of Production, Industries, Town Planning and Agrovilles in 1972. However, the Ministry of Science and Technology also looked after many issues dealing with the general environment. During the 80s, the Government of Pakistan took some preliminary steps to integrate the environment and development. Pakistan Environmental Protection Council and Environmental Protection Agency were established under the Pakistan environmental protection Ordinance in 1984. A significant task of the Agency was the formulation of National Environmental Quality Standards to be approved by the National Environmental Protection Council. The International Union of Conservation of Nature (IUCN) office was established in 1985. Programs of IUCN focus on biodiversity conservation; priority areas are the country's coastal and forest areas in the context of climate change impact. IUCN works at both policy and community levels, with a major thrust toward sustainable development.

Another major aspect of the 80s was the realization of a close relationship between environment and development. This led to the guidance of the Planning Commission in economic and social policies. The Planning Commission established an environment cell for the environmental monitoring of projects undertaken by the public sector at the federal level. In the sixth five-year plan, Integration of the environment and development acceleration through the 'rural transformation' strategy was emphasized to promote sustainable development. Similarly, the plan included substantial programs for exploiting forestry and fishery potential within the bounds of economic, technical, and ecological constraints.

Considerable progress was achieved in the 90s in terms of legislative and policy development. The Stockholm Conference, 1972, laid the foundations for the United Nations Conference on Environment and Development (UNCED), held in Rio in 1992, commonly called the Earth Summit. Pakistan played a leading role at UNCED. As head of the Group of 77, Pakistan represented the developing countries. The prime minister of Pakistan at that time presented the National Conservation Strategy (NCS) as an environmental policy at the Earth Summit in 1992. The purpose of NCS was to focus on the preservation of natural resources and the promotion of sustainable development. These objectives depend on three principles: the expansion of public participation in development and environmental management; integration of environmental and economics in decision-making and focusing on long-term improvements in people’s quality of life.

The post-Rio years witnessed important gains. In August 1993, National Environmental Quality Standards (NEQS) were developed. All newly established industries were required to meet the standards by July 1994, while existing industries had to comply till July 1996. The Pakistan Environmental Protection Act of 1997 (PEPA) replaced the Pakistan Environmental Protection Ordinance. PEPA established the general criteria, prohibitions, and enforcement requirements of the pollution control strategy and the promotion of sustainable development.

Sustainable Development Policy Institute (SDPI) was established in 1992 as a policy think tank of Pakistan on the recommendations of the National Conservation Strategy. SDPI is a center of excellence for sustainable development research, policy linkages and outreach, and capacity enhancement in Pakistan.

3.1.3 The Third Phase from 2000 – to Present: Environmental Sustainability

From 2000 – to the present, the third phase is marked as the beginning of an era during which the environmental institutions matured, and an environmental monitoring system was established. The twenty-first century witnessed the development of various new environmental projects and plans.

Pakistan signed Millennium Development Goals (MDGs) in September 2000. The MDGs include eight goals and 18 targets emphasizing extreme poverty and hunger, primary education, maternal health and child mortality, health, gender inequality and women empowerment, environmental degradation, and global partnership for development. National Sustainable Development Strategies (NSDS) preparation is a significant step in promoting sustainable development in Pakistan. Its draft was prepared with the assistance of the United Nations Environment Program (UNEP) in 2009. The NSDS has endeavored to address various pressing concerns of sustainable development in three dimensions: environment, social, and economic.

The National Environmental Action Plan (NEAP) was designed in 2001. The development objective of NEAP was to alleviate poverty through environmental projects. NEAP was approved by the Pakistan Environment Protection Council. It addressed many environmental issues facing Pakistan, particularly land, forestry, sanitation, water, air, and climate change. National Environmental Policy (NEP) was adopted in the year 2005. NEP provided guidelines to the federal, provincial, as well as local governments in addressing environmental issues.

On April 8, 2010, the 18 constitutional amendment was passed by the National Assembly of Pakistan. The 18 constitutional amendments eliminated the concurrent list leading to the abolition of the Ministry of Environment, and its related subjects were either devolved or assigned to other federal ministries. However, this process was initially amended by formulating a Federal Ministry of Disaster Management and then renaming it as the Federal Ministry of Climate Change, which was recently re-designated as the Climate Change Division. The primary government agency responsible for developing laws for resource preservation and environmental protection is the Climate Change Division. The Pakistan Environmental Protection Act's execution falls within its boundaries as well. In addition to serving as the secretariat for the Pakistan Environmental Protection Council, it supervises the work of other federal ministries. The Climate Change Division also handles environmental regulatory agreements with foreign nations. Additionally, the Climate Change Division has administrative supervision over the Pakistan Environmental Protection Agency.

Three major federal institutions, (1) the Pakistan Environmental Protection Council, (2) the Pakistan Environmental Protection Agency and (3) the Environmental Cell in the Planning Commission, handle environmental issues. In 2016 Pakistan joined the Paris Agreement to deal with GHG emissions and their mitigation. The Paris agreement is the first, legally binding global climate change agreement within the UNFCCC. The agreement aims to handle the global climate change risk by keeping the global temperature well below 2°C in this century.

Pakistan endorsed the Development Agenda 2030 in 2015. A unanimous resolution to this effect was passed by the National Assembly of Pakistan in 2016, and since then, the 17 SDGs have been incorporated into the national development agenda. At the national level, the SDGs Support Unit was established in the Federal ministries to provide coordination and support to ensure the early nationalization of SDGs. The Support Unit is actively undertaking coordination, monitoring progress, and reporting SDGs. It also provides research, policy, and management support to stakeholders for SDGs. In August 2016, the government of Pakistan actively contributed to an UN-sponsored roundtable on Sustainable Consumption and Production (SCP), where the minister for climate change of that time described (SCP) as a means of ensuring **"Efficient, appropriate and affordable use of our natural resources, which reduces our vulnerability to climate change and helps achieve food, water, and energy security"**. Pakistan recognized SCP as a framework for green development to decouple economic growth and development from environmental degradation, thus strengthening sustainable development. With the National Action Plan SDG12-SCP in 2017, Pakistan had given recognition to SDG 12 to mainstream other SDGs. In 2018 Pakistan launched a program of Billion Tree plantations over 350,000 hectares to fulfil its commitment to national resource conservation. This program is in accordance with the Bonn Challenge pledge, initiated by the Government of Germany and IUCN in 2011. This project has now been extended to Billion Tree Tsunami; a five-year tree plantation drive to restore depleted forests and reduce climate change. In addition, Clean and Green Pakistan programs have been launched to improve biodiversity.

3.2 Development of the Concept of Sustainability

The term "sustainable development" was first used in the realm of forestry. It featured methods of harvesting and afforestation of forests that do not impede the natural regeneration of forests (Črnjar & Črnjar, 2009). This term appeared for the first time in the Nature Conservation and Natural Resources Strategy (NCNRS) in 1980 (International Union for Conservation of Nature and Natural Resources et al., 1980). Though the study of sustainable development began from an environmental perspective, it rapidly extended to socio-economic aspects of the study. Economic growth-based development persisted till the end of the 20th century when it became evident that consumption and the business as usual is putting pressure on the environment owing to polluted environment, poverty, and diseases (Šimleša, 2003). During the same period, the excessive extraction of natural resources, specifically fossil fuels has stimulated the discussion on the requirements of next generations and establishing the conditions necessary for effective use of finite natural resources in the long run. The unbalanced economic progress and natural resource constraints figured out the escalating environmental concerns and potentially fatal disastrous consequences. Due to this reason, developed nations desired to improve the socioeconomic and ecological status of countries. The experts from 10 countries in 1968 met in Rome to debate the current and future generation challenges of humanity. These experts formed the Roman Club, an autonomous global organization, and released two key editions: 1) Limits of Growth, published in 1972 and 2) Mankind at the Turning Point, published in 1974, both contain the conclusions of this debate and inspired the rest of the world to rethink how it treats the planet. Additionally, sustainability was explained in the context of the modern notion of sustainable economic development (Drljača, 2012) (Meadows et al., 1972). The Roman Club expressed fear that the planet's ecological limits would soon be breached by fast industrialization and intense economic expansion.

During the 18th century, economic theorists like Adam Smith brought attention to problems associated with the process of development. Karl Marx, Thomas Malthus, David Ricardo, and John Stuart Mill all discussed certain aspects of sustainable development in the 19th century. However, in the 20th century, neoclassical economic theory placed a strong emphasis on the importance of natural resources, and the necessity of the role of government to tackle externalities (Willis, 2011). Understanding theories is important. Analysts need theory to shape their methodology and thus explore causes and solutions to the confronting problems. Likewise, economic theories are the ways by which economists can arrive at their conclusions about sustainability issues. The mainstream theory of economics, Neoclassical theory, stresses very significant entry points to start organizing its analysis for long-run economic growth. Neoclassical economic theory directs its attention to many distinctive objects for sustainability in economic growth. Efficient allocation in both consumption and production are the most prominent objects. Neoclassical theory starts with the entry points of (1) preferences of individuals (wants, taste, desires, etc.), (2) productive resources (land labor, machinery, etc.), and (3) technology of production (production function). Neoclassical theory demonstrates that an efficient economy is the aggregate effect of interacting individuals. The key notion for an efficient economy is that individuals pursue their self-interests freely by utilizing the available resources with the given technology to contribute to output (Rational Choice theory). The "Humanist determinism" of neoclassical theory makes human nature the "essential" entry point that causes sustainability. Neoclassical theory argues that wealth measures the economic progress of any society. If maximization of wealth is the social objective, then achieving this objective requires the full freedom of each rationally motivated individual to own, buy, or sell his or her productive resources or private property. In its view when markets perform properly, an economy is efficient. It produces maximum wealth with its scarce resources (Pareto efficiency). The theory follows that imperfections in the market like excessive exploitation of natural resources may prevent society from achieving maximum production and consumption of wealth. It means that the market imperfections impose the cost on the society. Market imperfections flow from the very nature of consumers and producers.

The neoclassical theory proposes a solution to compensate for this imperfection. The best solution is to protect the condition of private property from those who reform, regulate, or destroy it (Coase theorem). Given the initial resource endowments, an improvement in the initially given technology can increase society's potential output growth rate (Endogenous growth). Similarly, for the given technology by increasing the marginal productivity of resources output of the economy can be increased. Neoclassical theory goes further by saying that for any given technology, the higher income of the rich relative to the poor or any income inequality what he or she has contributed to the production of output (Marginal productivity) in labor market activities. So, equity in the income distribution process promotes economic growth and sustainable development. The neoclassical economic theory employs the logic or philosophy of "deduction". All subsequent concepts of sustainability are derived from its entry points. For instance, neoclassicals connect the starting points of human preferences, initial endowments, and technology in a deducible way to production. Similarly, marginal productivity determines the individual income and status in society. Likewise, in the case of externalities arising due to market imperfection the affected individuals privately negotiate to compensate for those externalities. This deductive way of connecting entry points to the subsequent concept of sustainability is also called "essentialism". To sum up, neoclassical theory debates the most important question ever confronted by economics: what determines the income and equitable distribution in the economy. Efficient production and consumption, climate change, unemployment, poverty resource constraint is among them too. The facets of sustainability are incorporated into the mainstream theory of economic development. According to (Lélé, 1991), sustainable development is the social transformation that accomplishes development objectives within the boundaries of ecological sustainability. This theory takes into account the present status of mankind, including the negative implications of ongoing environmental damage and pollution, together with widespread poverty and hunger in nations that are considered to be important in developing countries. It acknowledges the need to ensure that essential human needs will be met by both current and future generations. Therefore, the intergenerational equality viewpoint brought about by ecological restrictions is highlighted by this method. As a result, this theory incorporates an outlook that is focused on the growth of the future (Ulhoi & Madsen, 1999). If reshaping the behavior of producers and consumer behavior doesn't involve the conservation of natural resources and their appropriate usage, then the pressure of economic growth will progressively lead to a depletion of those resources. Because economic growth is impossible to accomplish without resources, future debate regarding sustainable development must focus on developing the pathways of sustainable development and the methods in which natural resources are used. This debate is essential to the idea of sustainability because there are numerous interpretations of the term sustainability. These interpretations range from "weak" to "strong" sustainability - the two extremes (Turner, 1993) and (Pelenc, Ballet and Dedeurwaerdere 2015).

In a similar manner, (Weaver & Lawton, 1999) links sustainable development to spending versus saving it. Accordingly, their perspective ranges from unsustainable development through business as usual to development that is sustainable and enhanced by the use of renewable resources. According to (Turner, 1993) a technology-optimistic or technology-centric viewpoint is considered to be an example of weak sustainability, whereas an ecological-centric perspective of sustainability is considered to be an example of strong sustainability. Natural and man-made capital are interchangeable, which means some resources decrease because of a growth in the quantity of other resources, specifically, the decrease in the quantity of natural resources should aways be replaced by an increased quantity of man-made resources. Weak sustainability refers to a situation, in which the overall amount of stock of total capital (including all types of capital) remains constant throughout time, although natural and man-made capitals are substitutable (Neumayer, 2003). This approach reflects the neoclassical notion of sustainability, which aims for the optimum exploitation of limited natural resources. It also points to the implementation of cutting-edge technologies, that have unquestionably boosted the capacity of nature and ought to accommodate the unfavorable influence on the environment.

This kind of sustainability provides support to free markets, the over-exploitation of resources, and development that focuses on man-made capital as manufactured capital is more significant as compared to natural capital (Davies, 2013). Strong sustainability, on the other side, is directed toward the green economy as well as stringent environmental preservation (Davies, 2013). It emphasizes the fact that just the preservation of total capital stock is not enough, while the conservation of natural capital is especially crucial. This claim is built on the observation that irreversible characteristics of certain essential natural resources cannot be complemented or substituted with other types of resources. As a consequence of this, the loss of their capital has repercussions for all types of capital (Turner, 1993) and (Neumayer 2003).

In this particular scenario, (R. M. Solow, 1974) applied the Max-Min principle to the intertemporal problem of optimizing capital accumulation, recommending that consumption levels per person should remain constant across time. The term "Hartwick's rule" refers to the investment savings rule that was established after the findings of the study that was published in 1977 by Hartwick (Hartwick, 1977). To be more specific, Hartwick's rule for sustainable development mandates the reinvestment of resource rents while maintaining the net investment value equal to zero. Additionally, reinvestments may compensate for losses if the resources are managed in an efficient manner, which ensures that the stock of total capital does not decrease over time. According to this point of view, natural capital and manmade capital are interchangeable with one another. On the other hand, the rent obtained from the depletion of natural capital ought to be invested in the production of physical capital. In general, the weak sustainability model holds the belief that progress in technology can boost human well-being regardless of its adverse effects on the surrounding environment.

With the increasing proportion of natural capital as a major source of energy in the economic development of Pakistan, two major challenges have emerged: (1) increasing carbon emissions and (2) a rapid depletion of finite energy resources with huge implications for future economic development. In light of this, the current study intends to achieve the following research objectives.

1. Examine the sustainability of Pakistan's economy in view of both strong and weak sustainability indicators in order to understand the path of sustainability followed by the economy of Pakistan. To understand the country's path, we have used natural resource depletion as a %age GNI as a strong sustainability indicator. Weak environmental regulation can significantly facilitate a decrease in carbon intensity through industrial green transformation therefore carbon intensity has been taken as a weak sustainability indicator.
2. Total emissions of carbon are also a strong by product of economic development. Therefore, the study assesses the relationship between environmental pressures in terms of energy-related carbon emissions and economic performance from 1990–2019.
3. To set sustainable development targets for reducing carbon emissions, the study also examines the determinants of Pakistan's energy-related carbon emissions from 1990–2019.

In past years, as part of the transition process and the dominance of neoclassical philosophy, the linear economy has been turned into a circular economy, which has its origins in the idea of sustainable development. A circular economy refers to an economic system built on business models that replace the concept of the end of life with the goals of decreasing, recycling, and recovering resources in manufacturing consumption (Kirchherr et al., 2017). The return of collected waste and recycled as a useful raw material in the manufacturing cycle is the key to the circular economy. Despite the good consequences of the circular economy, (Kirchherr et al., 2017) reveal that the circular economy was primarily focused on economic growth rather than environmental quality and social equity. This is despite the fact that the circular economy has been shown to have positive effects. In general, the importance of making systemic changes was treated with a degree of carelessness. A lack of coordination, government monitoring, and enforcement, as well as the inability to adapt to a dynamic nature that was overshadowed by dominant neo-classical economic discourse, were among the factors that contributed to the constraints (Kammer & Christopherson, 2018). These shortcomings also contributed to the uncertainty of investment choices (both conservation and development), as well as the cost of bearing risk (Arrow and Lind 1970) and (K. J. Arrow & Fisher, 1974), as well as externalities (Foldes & Rees, 1977). When human development exceeds the earth's bearing capacity, depleted natural capital cannot be replaced with manmade capital. To put it another way, there is an ultimate natural constraint of economic development. As a result, it is important to monitor economic development in connection with the carrying capacity of the planet (Holden et al., 2014). Another argument in favor of strong sustainability is that there is a huge disparity in quality between natural resources and those that have been manufactured. Some natural resources cannot be changed or reproduced, yet people use natural resources to create other resources. These natural resources cannot be modified. In the end, any resource that is replaced at the current moment will ultimately have long term effects (Pelenc et al., 2015).

Over the past few years, the idea of sustainable development has placed a heavy emphasis on strong sustainability. This is because the degradation of the environment has not been stopped due to the fact that many essential natural resources are being depleted and harmful effects are being caused (Davies, 2013). Additionally, the concept has moved closer to ecological sustainability in some areas to fully respect the natural carrying capacity (Bell & Morse, 2008). In summary, economic theory suggests that addressing poverty, employment, sustainable economic growth, natural resource constraints, and the climate crisis requires a comprehensive sustainable development approach that recognizes their interconnectivity. Policies that promote sustainable economic growth, can lessen reliance on finite natural resources, and also mitigate the impacts of climate change that can help reduce poverty and promote more equitable and sustainable development. There are complex interactions between poverty, sustainable economic growth, carbon intensity, employment, and natural resource constraints. Table 3.1 provides some of the ways/ directions in which these variables are linked with each other.

Table 3.1: Hypothesis for the Sustainable Development (Based on the Economic Theory)

Relationship between variables of sustainable development		
	Logic	
Economic development ⇧	⇨	Natural resource depletion ⇩
Economic development ⇧	⇨	Climate change ⇩
Natural resource depletion ⇩	⇨	Climate change ⇩
Economic development ⇧	⇨	Employment ⇧
Economic development ⇧	⇨	Poverty ⇩
Employment ⇧	⇨	Poverty ⇩

The description of these relationships is as follows:

Economic growth and carbon intensity: Carbon intensity is the quantity of carbon emissions produced per unit of economic output. Sustainable economic growth requires a reduction in carbon intensity (M. K. Khan et al. 2022), as high levels of emissions contribute to climate change. Strategies of sustainable economic growth can reduce carbon intensity create new employment opportunities and help to address poverty by promoting environmentally friendly economic activities (Granoff et al. 2015). Sustainable economic growth means promoting growth that is socially and environmentally sustainable in the long term. However, natural resource constraints can limit economic growth (Maris and Holmes 2023). Therefore, sustainable economic growth needs a shift towards more efficient utilization of natural capital and finding alternative sources to reduce resource dependence.

Natural resource depletion and carbon intensity: Natural resource constraints can also contribute to high levels of carbon intensity, for example, when industries rely on non-renewable resources like coal or oil (SERI 2009). Strategies of sustainable economic growth reduce carbon intensity by finding alternative sources of energy that are less reliant on natural resources, such as wind or solar power (Toman 2012). The climate crisis is one of the most pressing environmental issues of our time, and it is closely linked to natural resource constraints. Climate change is caused by the excessive use of fossil fuels, which are finite resources. Therefore, tackling the climate catastrophe necessitates a move towards green growth in order to stimulate innovation in renewable energy sources while decreasing our reliance on fossil fuels (UNESCAP 2012).

Sustainable economic growth and employment: By establishing job opportunities and generating revenue, sustainable economic growth can assist in eliminating poverty (Kreinin and Aigner 2022). However, it is critical to guarantee that these possibilities are available to all sections of society, especially marginalized groups (United Nations 2019). Investing in education and training programs, for example, can assist in ensuring that individuals have the abilities and information required to participate in new job opportunities (Balakrishnan, Steinberg, and Syed 2013).

Employment and poverty: Poverty is caused by unequal resource distribution and a lack of economic opportunity (Ruesga-Benito, González-Laxe, and Picatoste 2018). Sustainable economic growth, on the other hand, is viewed as a means of alleviating poverty by providing jobs and improving income levels (Iqbal and Khan 2020). The level of employment is one of the most important factors in reducing poverty. In economic theory, a lack of employment opportunities is seen as a major cause of poverty. Policies that increase employment, such as investment in infrastructure or education, can help reduce poverty (Ali and Pernia 2003).

Overall, addressing poverty, sustainable economic growth, carbon intensity, employment, and natural resource constraints requires a coordinated approach that takes into account the complex relationships between these factors. Strategies that promote sustainable economic growth while addressing poverty and environmental concerns are essential for creating a more equitable and prosperous future.

3.3. Theoretical Framework for Factors Influencing Carbon Emission

Concerns related to sustainable development address the need to achieve maximum economic growth with the least possible effect on the environment. Carbon dioxide (CO2) emissions are one of the most important environmental issues. There is no doubt that the human effect on the environment is very strong- strong enough to exceed the resilience of the systems. As a result, it is critical to investigate the relationship between human population, resource consumption, and their influence on our ecology. This debate began in the late 18th century in England, with the writings of Thomas Robert Malthus (Malthus 1798). Malthus stated in his book "An Essay on the Principle of Population" that human population increase is exponential while natural resources (especially land) are fixed. He claimed that unless the human population was restrained in some way, it would outstrip resource availability, resulting in starvation, disease, and population catastrophe. Malthus blamed the majority of human population problems on the shoulders of people from least developing countries, condemning their ignorance and lack of moral discipline (Todaro and Smith 2020).

However, by the mid-twentieth century, a new group of thinkers had taken up the issue of unrestrained population growth and resource deficiency. These scholars are referred to as Neo-Malthusians since their beliefs represent an update to Malthus' work (Uddin, Alam, and Gow 2016) The key difference in Neo-Malthusian explanations is the recognition that human prosperity and technology consume natural resources (and thus environmental effect) in addition to total population (Ehrlich and Holdren 1971). In other words, richer countries are also contributing to the problem. Paul Ehrlich and John Holdren Paul are the well-known and most vocal Neo-Malthusian thinkers, and their work and activism have contributed to Neo-Malthusian ideas' dominance in environmental and sustainability circles. They pointed out that carbon emissions (with the view that the quality of the environment is required to be measured in order to support the human population and its prosperity) are the product of the interaction among economic, social, and technical systems. They presented the carrying capacity of our earth in the IPAT model as given below:

$$\text{Impact} = \text{Population} \times \text{Affluence} \times \text{Technology}$$

In the abovementioned equation, the impacts on the environment (I) are the product of population size (P), affluence (A), and technology (T) of the human population in question under the Malthusian framework.

The Kaya identity is a variation of the IPAT model (Kaya 1990), that has been used primarily in investigations of energy-related carbon emissions. This model was proposed by Yoichi Kaya to Intergovernmental Panel on Climate Change (IPCC) in 1990. Kaya identity defines carbon emissions as the product of four main factors, as shown in the equation below.

$$C = \frac{C}{E} \times \frac{E}{GDP} \times \frac{GDP}{P} \times P$$

In the Kaya identity, GDP, C, E, and P represent the gross domestic product, carbon emissions, total energy consumption, and total population. The first component in the equation ($\frac{C}{E}$) represents the carbon intensity of energy consumption, while ($\frac{E}{GDP}$) represents the energy intensity of economic growth. These two components relate to the Technology factor of the IPAT model. The last two variables ($\frac{GDP}{P}$ and P) relate to the Affluence and Population factors of the IPAT model.

The Kaya Identity framework has its significance in the context of green growth. It may guide policymakers and researchers in understanding the effects of a variety of variables on total carbon emissions. By analyzing these factors, the stakeholders can design strategies that boost economic development and minimize environmental damages simultaneously. In the same way, the Kaya Identity model can provide a framework for monitoring progress towards the goal of green growth. We see that Kaya Identity analyzes how much population expansion affects the use of finite resources and produces environmental harm, guiding green growth policies to initiate policies for sustainable population increase. Secondly, according to the Kaya identity model, rising income levels are associated with increased energy use. As a result, green growth policies should promote smart and green technologies to decouple economic growth from resource consumption and emissions. Thirdly, reduced energy intensity is critical for green growth. This can be accomplished using energy-efficient technologies. Lastly, carbon intensity is the amount of carbon emitted for each unit of energy utilized. Therefore, CO2 reduction should be prioritized in green growth programs.

3.4 Environmental Performance due to Economic Expansion

The Environmental Kuznets Curve (EKC) is a prominent method for analyzing environmental performance, implying that environmental degradation first worsens with economic expansion but begins to improve after a specific income threshold level (Stern 1998) and (Ang 2007). The EKC is built on Kuznets' inverted U-shaped curve, which was created in the mid-twentieth century. The relationship between economic growth and income disparity is shown as a Kuznets' inverted U-shaped curve (Kuznets 1955). However, the concept of decoupling economic growth and environmental deterioration gained popularity in the twenty-first century with the introduction of the decoupling index by the Organization of Economic Co-operation and Development (OECD 2002). These decoupling indices are built on the foundations of the EKC hypothesis. According to the OECD (2002), decoupling occurs when the rate of environmental deterioration is less than the rate of economic growth. According to OECD, decoupling can be of two types i.e., absolute decoupling or relative decoupling. When the environmental deterioration is declining or stable, it is called absolute decoupling. Contrary to this, relative decoupling refers to the situation when the growth rate of environmental deterioration is positive, and its rate of growth is smaller than the growth rate of its driving force.

Tapio (2005) later developed a more comprehensive framework for analyzing decoupling that became the most widely used approach. The Tapio decoupling index, named after Petri Tapio, is used to examine the decoupling relationship between economic growth and environmental harm, specifically carbon emissions. This theoretical framework is most frequently used to comprehend how changes in economic activity might affect environmental sustainability. The Tapio decoupling elasticity approach is constructed on the foundations of decoupling indices as proposed by OECD (2002), however, Tapio further disaggregated them into "strong" and "weak" decoupling. According to Tapio, strong decoupling means that economic growth can occur without any increase or with a decrease in environmental pressure. Contrary to this, weak decoupling implies that the environmental pressure still increases, but at a slower rate than economic growth. The

Tapio decoupling elasticity analysis helps quantify the type and degree of decoupling that occurs in different time periods.

Mathematically, the Tapio decoupling elastic indicator is calculated using the following formula:

$$\text{Tapio decoupling elastic index } (\text{ŋ}) = \frac{\text{Percentage change in environmental pressure}}{\text{Percentage change in economic activity}}$$

Where

$$\text{Percentage change in environmental pressure} = \frac{\text{Environmental pressure in period } t - \text{Environmental pressure in period } t-1}{\text{Environmental pressure in period } t-1}$$

and

$$\text{Percentage change in Economic activity} = \frac{\text{Economic activity in period } t - \text{Economic activity in period } t-1}{\text{Economic activity in period } t-1}$$

The Tapio decoupling elastic index can be expansive, weak, recessive, or strong, and each scenario provides insights into the relationship between economic activity and environmental outcome. If ŋ = 1.0, it means that both environmental pressure and economic activity grow at the same rate. To avoid misinterpreting, very small changes as evidence of decoupling in the analysis, a ±20% variation of the ŋ values around 1.0 is recognized as coupling, resulting in coupling being defined for elasticity values between 0.8 and 1.2. Rates of change between two variables might be positive, regarded as expansive coupling, or negative, regarded as recessive coupling. Decoupling is further classified into three types: weak, strong, and recessive decoupling.

In weak decoupling, economic activity and environmental pressure both increase however economic activity grows faster (0 ≤ ŋ ≤ 0.8).

In strong decoupling, economic activity increases, and environmental pressure decreases, thus ŋ < 0.

In recessive decoupling, economic activity and environmental pressure both decrease, but the environmental pressure decreases more than the economic activity (ŋ >1.2).

Negative decoupling is further divided into three subtypes.

In expansive negative decoupling, economic activity and environmental pressure both increase and the later increases more than the economic activity (ŋ >1.2).

In strong negative decoupling, economic activity decreases and environmental pressure increases, and ŋ < 0.

In weak negative decoupling, economic activity and environmental pressure, both decreases and $0 \leq ŋ \leq 0.8$

In our study, Tapio's decoupling elasticity framework provides a way to assess whether the strategies and policies implemented to address environmental concerns are effectively decoupling economic growth from environmental degradation, particularly in the context of carbon emissions. It helps policymakers, researchers, and stakeholders gauge the progress toward sustainable development goals and make informed decisions to promote a more environmentally friendly path of economic growth. The concept of decoupling economic growth from carbon emissions is highly relevant in the context of green growth and sustainable development. For instance, decoupling allows for economic growth without exacerbating the global climate crisis. This is also crucial in meeting international climate agreements and targets, such as those outlined in the Paris Agreement and the United Nations Sustainable Development Goals (SDGs). Decoupling leads to a resilient economy by encouraging green energy sources and less reliance on carbon-intensive fossil fuels.

CHAPTER 4

DATA AND VARIABLES

The research objectives of the study are explored by analyzing secondary data from valid and reliable data sources. The data is collected for the period 1990 to 2019. The significance of the time frame chosen is because, in 1992, Pakistan signed an agreement on Agenda 21 at the United Nations Conference on Environment and Development, held in Rio de Janeiro, Brazil.

4.1 Measurement of Sustainable Economic Development

The concept of green growth was brought under intergovernmental discussion in 2005 for the first time at the 5th Ministerial Conference on Environment and Development (MCED-5) in Asia and the Pacific, in 2005. The conference considered three main areas in advancing green growth performance: a) pursuing sustainable economic growth b) employment generation and poverty eradication and c) conserving natural capital and preventing climate change. The variables of sustainable economic development selected from the green growth model of MCED-5 are presented in Table 4.1 below.

Table 4.1 Variables and Data Source for Measuring Sustainable Economic Development

	Variables	**Data Source**
Sustainable Economic Growth	Adjusted net national income (annual % growth)	World Bank
Social Development and Equity	Employment to population (15_{+}) ratio	ILO
	Share of the population below the poverty line of $3.20 per day	World Bank
Environmental Protection	Natural resources depletion (% of GNI)	World Bank
	CO_2 intensity (CO_2 emission per US dollar of GDP)	OECD database

Detail regarding the selection of each variable is given below:

Economists use the poverty line to identify how many people in the country live in extreme poverty. The poverty line is a yardstick below which an individual's minimum of immediate basic needs cannot be met. A poverty line is set at a level that empowers individuals to accomplish a specific set of capabilities. A typical approach to moving towards approaching capabilities is in the first place measure an adequate amount of nutritional supply. Two common methods of making this functional are 1) Cost-of-Basic-Needs (CBN) method and 2) Food Energy Intake (FEI) approach. Under the FEI method, the objective is to find the income level that enables the household to purchase a sufficient amount of food to satisfy its energy needs. This method includes the consumption of food and other than food items such as clothing and shelter. The amount of calories needed per person per day in Pakistan is 2,350. The FEI method has some limitations. Food energy is typically shown in terms of calorie intake which is affected by other factors along with money. These factors include the tastes and preferences of a household, the relative prices of different food items, relative prices of food and other than food items, and availability of the goods. On the other hand, the CBN approach is to build a poverty line, ensuring that it covers the cost of both food and not food items in the consumption bundle. There is no single acceptable way to measure the non-food component to estimate the poverty line. Similarly, the issue of poverty remains unaddressed when poverty does not end even if a person crosses the poverty line per day whether calculated in terms of FEI or CBN. In addition to the food, shelter, and clothing as elements of basic deprivation, a long-run threat of climate change can also push people into poverty. Along with this in low-middle-income countries access to an adequate amount of education, public health care, provision of electricity, safe drinking water, sanitation, and clean environmental are critical for welfare and to fully participate in the society. As many of these items cannot be bought, therefore they are not included in the set of baskets that measure extreme poverty. Therefore, the World Bank has provided a high-value poverty line of $3.20 per day to cover multidimensional poverty aspects for low-middle-income countries.

Since 2008, the global poverty line has been $1.25. From October 2015, we have $1.90 as the new global poverty line using 2011 prices. World Bank constructed a global poverty line using the basic standards of low-income countries and adjusted to the country’s currency by using purchasing power parities. A poverty line of $1.90 a day shows the basic cost of food, shelter, and clothing expenditures only. However, access to education, clean water, sanitation, health, etc., are also extremely important dimensions of poverty. The global poverty line of $1.90 does not consider these multiple dimensions of poverty. Similarly, the World Bank updated the poverty line from $1.90 a day to an international poverty line of $2.15 a day (expressed in 2017 international-$). It represents that anyone living on less than $2.15 a day is considered to be living in extreme poverty globally. In this continuation, the World Bank further provided new standards for the international poverty line in terms of the goods and services that the citizens of a country can afford. For a low-middle-income country, the poverty line is $3.2 while for high-income countries it is $5.5 a day. According to the World Bank classification, Pakistan is considered a low-middle-income country. Therefore, the World Bank established the $3.20 ($ 2011 PPP) poverty line per day for Pakistan. A higher poverty line of $3.20 per day developed by the World Bank is the median average of the national poverty line of low-middle-income countries. Reducing poverty at $3.20 per day is more relevant as the lowest line, $1.90 per day, is not equivalent to eradicating poverty in all its forms. In addition, using the $3.20 per day poverty line and analyzing the trends based on this line may well portray that absolute poverty is eradicated or soon it will be in all forms with significant real change to the economy. Therefore, the poverty line at $3.20 a day ($2011 PPP) can be used to plan programs and economic policies. The data of the poverty line of $3.20 per day is collected from the World Bank.

The primary household survey data used to create the World Bank Data is sourced from national statistical offices and World Bank country offices. The Poverty and Inequality Platform (PIP) of the World Bank is an interactive computational tool that offers a thorough picture of regional, country, and global trends for more than 150 economies worldwide. The PIP data from the World Bank is a sizable collection of household surveys where the World Bank has taken steps to unify definitions and procedures throughout time and between countries. The World Bank uses the surveys for each nation that falls closest to the year is estimated to 'line-up' the data to the year being estimated by projecting it either forwards or backward because surveys are not done annually in every country. This lining-up is typically done under the presumption that household incomes or expenditures increase at a rate consistent with the growth rates detected in the national accounts data using interpolation techniques. The data is expressed in 2011 international dollars to take inflation and regional price variations into account. A hypothetical currency that results from price changes over time and space is the international dollar. It is described as having the same amount of purchasing power in a specific base year, in this case, 2011, as one US dollar would have in the US. No matter where or when it is spent, a single international dollar can be used to purchase exactly the same quantity of goods and services. A person's wellbeing is seen to depend less on his own absolute level of living than it does on how it compares to some reference group or on whether it allows him to participate in the social norms and customs of his society. This is the premise of evaluating poverty in relative terms. A monetary measure of poverty is what the Poverty and Inequality Platform (PIP) mostly uses. Monetary poverty can be calculated using either a household's aggregate income or the monetary value of its consumption. The World Bank collectively refers to these aggregates as welfare aggregates.

To maximize comparability, welfare aggregates are standardized across nations and over time, but country-specific choices regarding things like whether to use consumption or income, how to design the household survey's questionnaire, which components to be included in the welfare aggregate, and whether to account for price variations within a nation, suggest that full comparability is not possible. Integrating environmental sustainability principles into country policies and activities is needed to conserve ecological resources. Climate indicators capture the impacts of national activities on the weather. Countries that are parties to the Climate Change Convention (UNFCCC) are required to submit carbon emissions data regularly to the UNFCCC secretariat. CO_2 emissions per unit of GDP produced is a useful measure of climate change. Examining carbon emissions per unit of GDP fairly represents the country's responsibilities to climate change. Carbon intensity is the measure of CO_2 emitted per US dollar of GDP. It measures how much CO_2 we generate when we produce one dollar in our economy. A declining trend in carbon intensity is a good sign for the environment and economy. Decreasing carbon intensity means that energy consumption has become efficient and does not require burning more fossil fuels. The dataset of carbon intensity is obtained from the Organisation for Economic Cooperation and Development (OECD) green growth indicators database.

Employment generation is necessary to keep pace with the rapidly rising population, labor force, and ultimately for the whole economy. The capacity of a country to improve the living standards of its residents depends on its available resources, technological advances, and institutional strategies. In economics, productivity is considered the relationship between outputs and factors of production. Labor productivity is measured as the amount of GDP produced per unit of labor. Many economists point out that labor productivity depends on the availability and quality of labor resources, new technology, and investments in physical capital. The employment to population (+15) ratio is the proportion of the working-age population of a country that is actively participating in the labor force. It is considered a key measure to narrate whether a country is on track to achieve inclusive economic growth for eradicating poverty in all its forms. Data for this variable is collected from the International Labor Organization (ILO) database.

Sustainable development requires the management of natural resources**.** High economic growth can deplete natural capital. Countries like Pakistan, which are heavily dependent on exploiting natural resources, can only sustain their growth if they invest in natural assets. Sustainable economic growth is seen as wealth building and managing assets portfolio. Therefore, economic sustainability challenges are to manage the total volume and composition of natural assets just as the physical capital and human capital assets. It is so because the replenishment of natural resources is either slow or many of them can't be replaced at all. The World Bank estimates natural resource depletion to observe the natural resource sustainability of countries. Natural resource depletion measures the decline in a country's fixed assets, including net forest depletion and, energy and mineral depletion. It reflects the decline in asset values of natural resources due to extraction. The basic approach to environmental assets accounting is centered on the concept of assessing the interaction between the economy and the environment. The primary reason for environmental assets accounting is to determine the extent to which economic activity is linked to producing goods and services and environmental outputs. This approach requires collecting data on various types of natural capital and calculating the environmental assets accounting in many different ways.

The most important accounting measure is the valuation and metric calculation of any damage caused by the exhaustion of natural resources due to the economic process. There is no general agreement or consensus in the literature about a uniform measure for assigning value to the reduction of natural capital. The World Bank calculated the values of natural resource depletion as a % of GNI. On behalf of environmental quality assessment, natural resource depletion (% of GNI) calculates the environmental externalities per unit of GNI. An increase in the value of net natural resource depletion (% of GNI) of a country indicates that the environmental quality has been compromised due to economic growth or that a reduced amount of natural resources is available due to economic growth. In other words, decreasing the amount of natural resources left in order to gain a certain level of economic growth. Therefore, estimating the depletion of natural resources as a % of GNI is a reasonable way to extend traditional savings concepts. When addressing the natural resource damages in terms of costs, due to estimation issues and unavailability of data, this indicator is unable to account for all natural resource depletion costs, such as minerals, water, forests, biodiversity, ecosystems, etc.

The literature provides evidence that natural resources are generally transformed into energy sources (Diaz-Chavez et al., 2013). This explains that higher levels of affluence may lead to energy depletion by way of natural resources. As a country develops, there appears to be a trade-off between GDP growth and the quality of the environment. The high depreciation of natural resources as a percentage of GNI implies that the country is becoming poorer by leaving very little natural wealth for future generations. The World Bank measure net natural resource depletion as a percentage of GNI on an annual basis. The World Bank defines the value of the net depletion of natural resources depletion is equal to the sum of the net depletion of forest, energy, and mineral resources. The net forest depletion is estimated as the product of rents per unit of resource and the excess amount of roundwood extracted exceeding its natural growth. The proportion of the current value of energy resource stock to the amount of time that is still left in the reserve of these resources is the measure of energy depletion (capped at 25 years). It includes natural gas, hard and soft coal, and crude oil. Similarly, mineral depletion is defined as the proportion of the current value of mineral resource stock to the amount of time that is still left in the reserve for that resource (capped at 25 years). It includes tin, gold, lead, iron, zinc, nickel, copper, nickel, phosphate, silver, and bauxite.

The key to increasing future consumption and thus the population's living standard is embedded in growing the nation's wealth- including physical capital and natural capital. A broader measure of economic performance is adjusted net national income. Adjusted net national income is measured as Gross National Income (GNI) less consumption of fixed capital and natural resources. Adjusted net national income is suitable for monitoring the economic performance of resource-rich but developing economies like Pakistan. Such economies mostly face extensive natural resource depletion. By considering the consumption of fixed and natural capital, adjusted net national income better measures the income available for investment and future consumption. If a country's net adjusted national income is positive, economic theory suggests that the present value of social welfare is increasing, indicating that the economy is on a sustainable path of development. The adjusted net national income data is collected from the World Bank database.

4.2 Index Decomposition Analysis

The second objective of the study is to analyze for period from 1990 to 2019, for which valid and reliable time series data for energy, GDP, and population for Pakistan are available. We have taken 1990 as the base year for our analysis. Table 4.2 represents the data and variables considered in the LMDI decomposition analysis.

Table 4.2 Variables and Data Source for Index Decomposition Analysis

Variables	Unit	Data Source
Fossil fuel consumption by fuel type	Terajoules	International Energy Agency
Total fossil fuel consumption	Terawatt-hour	OWID (Global Change Data Lab)
Total primary energy consumption	Terawatt-hour	OWID (Global Change Data Lab)
GDP	Constant 2010 US$	OWID (Global Change Data Lab)
Population	Total	OWID (Global Change Data Lab)

The description of variables and data sources is given below.

Fossil fuel consumption by fuel types for natural gas, coal, and petroleum is collected from the International Energy Agency (IEA), an autonomous intergovernmental organization established in 1974 as part of the Organization for Economic Cooperation and Development (OECD) following the oil crisis of 1973. The database of world energy balances includes annual data for 1971-2019 for various non-OECD Asian countries, including Pakistan. The energy data used consists of nine fuel types including bituminous coal, lignite, fuel oil, gas/diesel, other kerosene, motor gasoline, LPG, oil products, and natural gas. This establishes the supply side profile.

Total fossil fuel consumption and total primary energy consumption data is collected from Our World in Data (OWID), a scientific data publishing online, using official statistics from the UN and other international organizations. Total fossil fuel consumption is the sum of energy from all sources of coal, oil, and gas. Total Primary Energy consumption includes oil, coal, gas, nuclear, hydropower, wind, solar, and other renewables. Other renewables include geothermal, biomass, and waste energy. The data in exajoules (EJ) has been converted to Terawatt-hour (TWh).

The economic data is measured by Gross Domestic Product (GDP) in constant 2010 prices and collected from OWID. Gross domestic product is measured in the international dollar using 2010 prices to adjust for price changes over time (inflation) and price differences between countries. Gross Domestic Product (GDP) at constant basic prices of 2010 includes the agriculture sector, industrial sector, and service sector.

Population estimates are collected from OWID based on the de facto definition of the population; it includes all residents regardless of their legal status or nationality. A de facto population census involves counting only those who are present physically at the time when the census is performed. OWID maintains a dataset of the population by country, region, and the world from the period 1950 onwards. The population data are adjusted for mid-year (July 1) by using a constant population growth rate between two data points. For the years for which census or national estimates are not available, the population figures are interpolated or extrapolated. The estimates refer to July 1 of a specified year. Time series population estimates the population in number.

4.3 Relationship Between Carbon Emissions and Economic Growth

The relationship between carbon emissions and the economic growth of Pakistan for the period 1990 to 2019 is assessed through the decoupling classification provided by Tapio (2005). This research objective of the study is explored by analyzing the data of total fossil fuel-related carbon emissions and GDP (at constant 2010 US$). The data for GDP is collected from Our World in Data (OWID). The IPCC National Guidelines on Greenhouse Gas Inventory (IPCC 2006) are used to calculate carbon emissions with the help of the following equation:

$$C_i^t = FF_i^t \times EF_i$$

$$C_{tot}^t = \sum_{i}^{n=9} FF_i^t \times EF_i$$

Where C_i^t stands for the total carbon emissions of the fuel i for the period (t), $FF_i^t \times EF_i$ represents the total quantity of fossil fuel of type “i” used in the period (t) times the quantity of carbon contained in that fossil fuel. Carbon emission factors from fuel type i are given in Table 4.3 below.

Table 4.3 Carbon Emission Factors from Fuel Type i9

Fossil Fuel	**Fuel (i)**	**Carbon Emissions (ton/GJ)**
Natural Gas	Natural Gas	0.0561
Coal	Other Bituminous coal	0.0946
	Lignite	0.1010
Petroleum	Fuel Oil	0.0774
	Gas/ Diesel	0.0741
	Other Kerosene	0.0719
	Motor Gasoline	0.0693
	LPG	0.0616
	Other Oil Products	0.0733

Source: Intergovernmental Panel on Climate Change (2006)

CHAPTER 5

METHODOLOGY

The first objective of our study is to investigate a balance between economic growth sustainability, social development, and raising environmental protection in achieving green growth by taking evidence from Pakistan. Green growth as defined by the Fifth Ministerial Declaration on Environment and Development in Asia and the Pacific (MECD-5) is a holistic approach to sustaining economic growth and job creation that is required for effectively reducing poverty while addressing challenges of natural resource depletion and climate crisis. The green growth model is depicted in Figure 5.1.

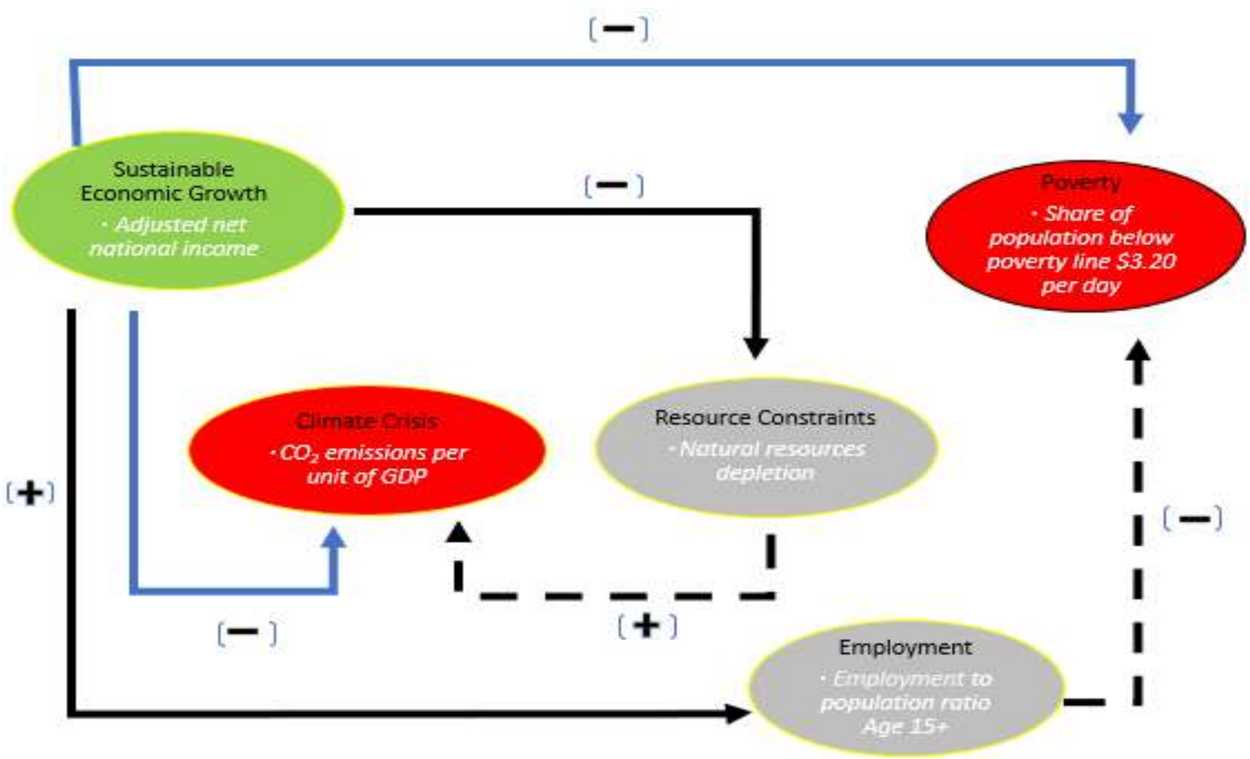

Figure 5. 1 Model Based on the Hypotheses Developed on the Concepts of SINGG for Asia and the Pacific

Source: Author's representation of conceptual model based on the Seoul Initiative Network on Green Growth

In Figure 5.1, blue lines indicate the direct relationships between sustainable economic growth on poverty and climate change. Dashed black lines indicate the mediation effects of natural resource constraints on climate sustainability and employment generation on poverty alleviation. Additionally, the solid black lines represent the impact of sustainable economic growth on mediators, i.e., natural resource constraints and employment. These relationships are deduced from the hypotheses developed on the concepts of the Seoul Initiative Network on Green Growth model adopted in MCED-5.

5.1 Structural Equation Modeling (SEM)

To answer the first research objective of the study, Structural Equation Modeling (SEM) is used to find whether there is an empirical possibility of strong economic sustainability in Pakistan during the period of analysis. SEM is a set of statistical methods that use path coefficients to observe the interactions between interacting variables (Hox and Bechger, 1999). For modeling a causal system, SEM is particularly well suited (Tremblay & Gardner, 1996) and (Hershberger, 2003). In contrast to single equation regression, SEM analysis uses a different estimating method. The single equation regression model has one exogenous variable and multiple endogenous variables. While in SEM, the endogenous variable in one equation might be an exogenous variable in another equation. SEM allows estimating not only the extent to which an endogenous variable is influenced directly due to the exogenous variable but also estimates how much of that endogenous variable is influenced indirectly (Bollen, 1989) and (Kline, 1998). Path dependency (direct effect or interaction of indirect effects) of variables with each other is analyzed in this study. Path coefficients can be useful in estimating several concepts in our research, for instance, while investigating the green growth model, poverty may be a function of sustainable economic growth or sustainable development-led employment. The inclusion of many dependent variables enables us to do multiple regression analyses and identify, for example, whether poverty is influenced by a single variable (direct effects) or by the interplay of several variables (indirect effects). SEM can be used in the analysis under certain conditions.

To begin with, SEM is performed on time-series data under the assumption that there is a linear relationship among the variables. Secondly, the variables selected must possess significant cross-correlations with each other. Thirdly, there should be a model present that predicts potential path dependence, which in our study is the Seoul Initiative Network on Green Growth (SINGG) that was presented in MCED-5. Fourthly, there is no correlation among error terms in the structural equation modeling method. Fifth the most significant assumption of the maximum likelihood estimation approach employed in SEM is the multivariate normal distribution of data. To assess whether the variables in the data set are normally distributed, the skewness and kurtosis values are checked. Moments are used to calculate the values. The variable is considered to be normally distributed if values lie between -2 and +2.

5.1.1 Mediation Effects (Using Bootstrapping)

To analyze the first objective of the study, we have employed bootstrapping with 2,000 subsamples to calculate the path coefficients of the model and p-values. Efron (1979) introduced the bootstrap sampling method. Bootstrapping is a nonparametric technique that does not assume any distributional assumptions about the data (Kwan & Chan, 2014). Using the bootstrapping technique, we have tested two models: 1) the direct effect model, which estimates the relationship between independent and dependent variables without any mediator, and 2) the indirect effect or mediation model by adding a mediator between the independent and its dependent variable. The total effect is the aggregate of direct and indirect effect. Additionally, the raw data is converted to Z scores to maintain uniformity in the interpretation of statistical results.

5.1.2 Green Growth SEM Model

Path dependency analysis will be useful while observing the green growth phenomenon because sustainable economic growth and employment driven by sustainable economic growth may have an impact on poverty simultaneously. Similarly, the inclusion of a moderator will allow us to investigate whether CO_2 productivity per unit of GDP is influenced by one variable (i.e., direct effect) or the interplay of many variables (i.e., indirect effects). The green growth model in SEM is depicted in Figure 5.2 with error terms on all endogenous variables. In this Figure, Empl represents employment to population ratio (age 15+), Pvty is the share of the population living on less than $3.20 per day, Res.Depl is natural resources depletion, Adj.NI is adjusted net national income and CO2.Int is CO_2 emissions per unit of GDP.

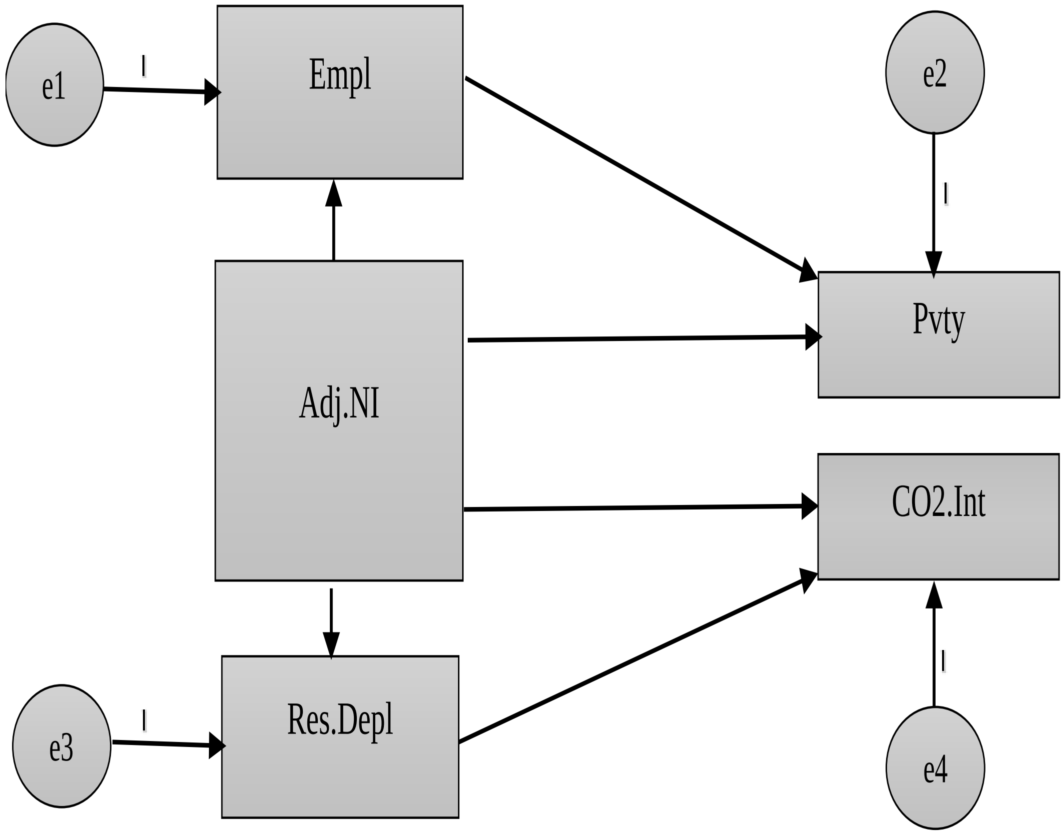

Figure 5. 2 Green Growth SEM Model

5.1.3 Methodological Framework for Green Growth Model

For the analysis of objective one, the following hypotheses are based on the interpretation of the conceptual framework for green growth as developed by the Fifth Ministerial Declaration on Environment and Development for Asia and the Pacific.

Hypotheses Developed on the Concepts of SINGG (Model for Asia and Pacific)

H_{01}: Sustainable economic growth does not foster low carbon emissions in the economy.

H_1: Sustainable economic growth fosters low carbon emissions in the economy.

H_{02}: Sustainable economic growth does not drive-up poverty alleviation.

H_2: Sustainable economic growth drives up poverty alleviation.

H_{03}: Sustainable use of natural resources does not mediate the negative relationship between sustainable economic growth and CO_2 productivity.

H_3: Sustainable use of natural resources mediates the negative relationship between sustainable economic growth and CO_2 productivity.

H_{04}: Employment availability does not mediate the positive relationship between sustainable economic growth and poverty reduction

H_4: Employment availability mediates the positive relationship between sustainable economic growth and poverty reduction.

5.1.4 Model Estimation in Structural Equation Modeling

In SEM, model estimation involves estimating standardized regression weights given that model fit indices are significant. The coefficient of the standardized regression weights tells us how much the dependent variable is expected to increase when an independent variable increases by one unit, holding all the other independent variables constant. In order to observe the presence of any non-significant values under the SEM model, the regression weights are examined as follows:

$$\mathrm{Empl}_t = \rho_{21}\mathrm{Adj.NI}_t + \epsilon_t \qquad \text{Eq. (1)}$$

$$\mathrm{Pvty}_t = \rho_{31}\mathrm{Adj.NI}_t + \varepsilon_t \qquad \text{Eq. (2)}$$

$$\mathrm{Pvty}_t = \rho_{32}\mathrm{Empl}_t + \omega_t \qquad \text{Eq. (3)}$$

5.1.5 Path Analysis Model

Once the mediating variable (Empl_t) is entered into the model, the Eq. (2) becomes

$$\mathrm{Pvty_t} = \rho_{31}\mathrm{Adj.NI_t} + \rho_{32}\mathrm{Empl_t} + \varepsilon_t \qquad \text{Eq. (4)}$$

Substitute Eq. (1) in Eq. (4), we get

$$\mathrm{Pvty_t} = \rho_{31}\mathrm{Adj.NI_t} + \rho_{32}(\rho_{21}\mathrm{Adj.NI_t} + \epsilon_t) + \varepsilon_t \qquad \text{Eq. (5)}$$

$$\mathrm{Pvty_t} = \rho_{31}\mathrm{Adj.NI_t} + \rho_{32}\,\rho_{21}\mathrm{Adj.NI_t} + \rho_{32}\epsilon_t + \varepsilon_t \qquad \text{Eq. (6)}$$

$$\mathrm{Pvty_t} = (\rho_{31} + \rho_{32}\,\rho_{21})\mathrm{Adj.NI_t} + \rho_{32}\epsilon_t + \varepsilon_t \qquad \text{Eq. (7)}$$

Where $t = 1,2, \ldots\ldots T$

The residual term $(\rho_{32}\epsilon_t + \varepsilon_t)$ is not involved in the effects from $\mathrm{Adj.NI_t}$ to $\mathrm{Pvty_t}$. The parameter $(\rho_{31} + \rho_{32}\,\rho_{21})$, in Eq. (7) is the total effect that $\mathrm{Adj.NI_t}$ has on $\mathrm{Pvty_t}$. Out of total effect, $\rho_{32}\,\rho_{21}$ is the indirect effect that $\mathrm{Adj.NI_t}$ has on $\mathrm{Pvty_t}$ after accounting for $\mathrm{Empl_t}$, and ρ_{31} is the direct effect of $\mathrm{Adj.NI_t}$ has on $\mathrm{Pvty_t}$.

Mediation is assessed for statistical significance through testing of the $\rho_{32}\,\rho_{21}$ effect.

The mediation paths are expressed as follows:

1) Total effect (TE) = $\rho_{31} + \rho_{32}\,\rho_{21}$

where

2) Direct effect (DE) $= \rho_{31}$
3) Indirect effect (IE) = TE $-$ DE = $(\rho_{31} + \rho_{32}\,\rho_{21}) - \rho_{31} = \rho_{32}\,\rho_{21}$

The path coefficients of the above-mentioned equations are calculated as follows:

$$\rho_{21} = r_{12} \qquad \text{Eq. (8)}$$

$$\rho_{31} = \frac{r_{13} - r_{12}r_{23}}{1 - r_{12}^2} \qquad \text{Eq. (9)}$$

$$\rho_{32} = \frac{r_{23} - r_{12}r_{13}}{1 - r_{12}^2} \qquad \text{Eq. (10)}$$

In Eq. (8), (9) and (10), r_{ij} are the coefficients of correlations. Hypotheses H2 and H4 are tested from the total effect of $\mathrm{Adj.NI}_t$ has on Pvty_t and indirect effect that $\mathrm{Adj.NI}_t$ has on Pvty_t after accounting for Empl_t, respectively.

Similarly, in order to observe the presence of non-significant values under the standardized regression weighths for $\mathrm{Adj.NI}$ on $\mathrm{CO2.Int}_t$, we proceed in a similar previous way:

$$\mathrm{Res.Depl}_t = \rho_{21}{}^{*}\mathrm{Adj.NI}_t + \epsilon_t \qquad \text{Eq. (11)}$$

$$\mathrm{CO2.Int}_t = \rho_{31}{}^{*}\mathrm{Adj.NI}_t + \varepsilon_t \qquad \text{Eq. (12)}$$

$$\mathrm{CO2.Int}_t = \rho_{32}\mathrm{Res.Depl}_t + \omega_t \qquad \text{Eq. (13)}$$

Once the mediating variable is entered into the model, the Eq. (12) becomes

$$\mathrm{CO2.Int}_t = \rho_{31}{}^{*}\,\mathrm{Adj.NI}_t + \rho_{32}{}^{*}\,\mathrm{Res.Depl}_t + \varepsilon_t \qquad \text{Eq. (14)}$$

Substitute Eq. (11) in Eq. (14), we get

$$\mathrm{CO2.Int}_t = \rho_{31}{}^{*}\mathrm{Adj.NI}_t + \rho_{32}{}^{*}(\rho_{21}{}^{*}\mathrm{Adj.NI}_t + \epsilon_t) + \varepsilon_t \qquad \text{Eq. (15)}$$

$$\mathrm{CO2.Int}_t = \rho_{31}{}^{*}\,\mathrm{Adj.NI}_t + \rho_{32}{}^{*}\rho_{21}{}^{*}\mathrm{Adj.NI}_t + \rho_{32}{}^{*}\epsilon_t + \varepsilon_t \qquad \text{Eq. (16)}$$

$$\mathrm{CO2.Int}_t = (\rho_{31}{}^{*} + \rho_{32}{}^{*}\rho_{21}{}^{*})\,\mathrm{Adj.NI}_t + \rho_{32}{}^{*}\epsilon_t + \varepsilon_t \qquad \text{Eq. (17)}$$

Where $t = 1,2, \dots . . T$

The residual term $(\rho_{32}{}^{*}\epsilon_t + \varepsilon_t)$ is not involved in the effects from $\mathrm{Adj.NI}_t$ to $\mathrm{CO2.Int}_t$. The parameter $(\rho_{31}{}^{*} + \rho_{32}{}^{*}\rho_{21}{}^{*})$, in Eq. (17) is the total effect that $\mathrm{Adj.NI}_t$ has on $\mathrm{CO2.Int}_t$. In Eq. (17), $\rho_{32}{}^{*}\rho_{21}{}^{*}$ is the indirect effect that $\mathrm{Adj.NI}_t$ has on $\mathrm{CO2.Int}_t$ after accounting for $\mathrm{Res.Depl}_t$ as a mediator, and $\rho_{31}{}^{*}$ is the direct effect of $\mathrm{Adj.NI}_t$ has on $\mathrm{CO2.Int}_t$.

Mediation is assessed for statistical significance through testing of the $\rho_{32}{}^{*}\rho_{21}{}^{*}$ effect.

The mediation paths are expressed as follows:

1) Total effect (TE) = $\rho_{31}{}^{*} + \rho_{32}{}^{*}\rho_{21}{}^{*}$

where

2) Direct effect (DE) $= \rho_{31}{}^{*}$
3) Indirect effect (IE) = TE − DE = $\rho_{32}{}^{*}\rho_{21}{}^{*} = (\rho_{31}{}^{*} + \rho_{32}{}^{*}\rho_{21}{}^{*}) - \rho_{31}{}^{*}$

$$\rho_{21}{}^{*} = r_{12} \qquad \text{Eq. (18)}$$

$$\rho_{31}{}^{*} = \frac{r_{13} - r_{12}r_{23}}{1 - r_{12}^2} \qquad \text{Eq. (19)}$$

$$\rho_{32}{}^{*} = \frac{r_{23} - r_{12}r_{13}}{1 - r_{12}^2} \qquad \text{Eq. (20)}$$

In Eq. (18), (19) and (20), r_{ij} are the coefficients of correlations among the variables. The Hypotheses H1 and H3 are tested from the total of $\mathrm{Adj.NI}_t$ has on $\mathrm{CO2.Int}_t$ and the indirect effect that $\mathrm{Adj.NI}_t$ has on $\mathrm{CO2.Int}_t$ after accounting for $\mathrm{Res.Depl}_t$, respectively.

5.1.6 Basics of Structural Equation Modeling

Structural Equation Modeling is a statistical technique of measuring and analyzing the linear relationship among the variables and simultaneously accounting for the measurement error.

How to Standardize the Parameters

Let X be a variable with such a distribution

$$X \sim D(\mu, \sigma^2)$$

Where $X^* = X - \mu$

$$E(X^*) = E(X - \mu)$$

$$E(X^*) = E(X) - E(\mu)$$

$$E(X^*) = 0$$

Let

$$x = \frac{X - \mu}{\sigma}$$

$$x = \frac{X^*}{\sigma}$$

$$x \sim D(0,1)$$

Now the center of x is "0" and variance is "1".

Let $$Y_t = \propto + \beta Z_t + \varepsilon_t$$

For the standardized "Y" and "Z", we have

$$y_t = \propto^* + \beta^* z_t + \epsilon_t \qquad \text{Eq. (i)}$$

In Eq. (i), $\propto^* = 0$, as the intercept is a mean value. Therefore Eq. (i) becomes

$$y_t = \beta^*{}_t z_t + \epsilon_t$$

How to Isolate Direct and Indirect Effects of the SEM Model

As depicted in Figure 5.3, to test mediation using the bootstrapping technique we need to test two models: 1) the direct effect model (ρ_{31}) means a direct relationship between A and B without any mediator and 2) the mediation model means adding a mediator (C) in the relationship between A and B so that we have an indirect effect ($\rho_{32}\,\rho_{21}$).

Total effect = Direct Effect + Indirect Effect

Total effect (TE) = $\rho_{31} + \rho_{32}\,\rho_{21}$

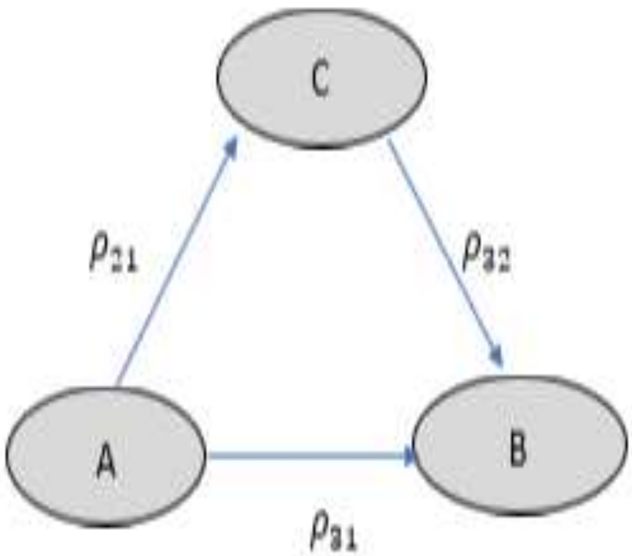

Figure 5. 3 Direct and Indirect Effects in SEM Model

In the case of the mediation model, the path coefficient will be different because part of the total effect from A to B will go through C. The rest of the effect will go through $\rho_{32}\,\rho_{21}$ in the mediation model.

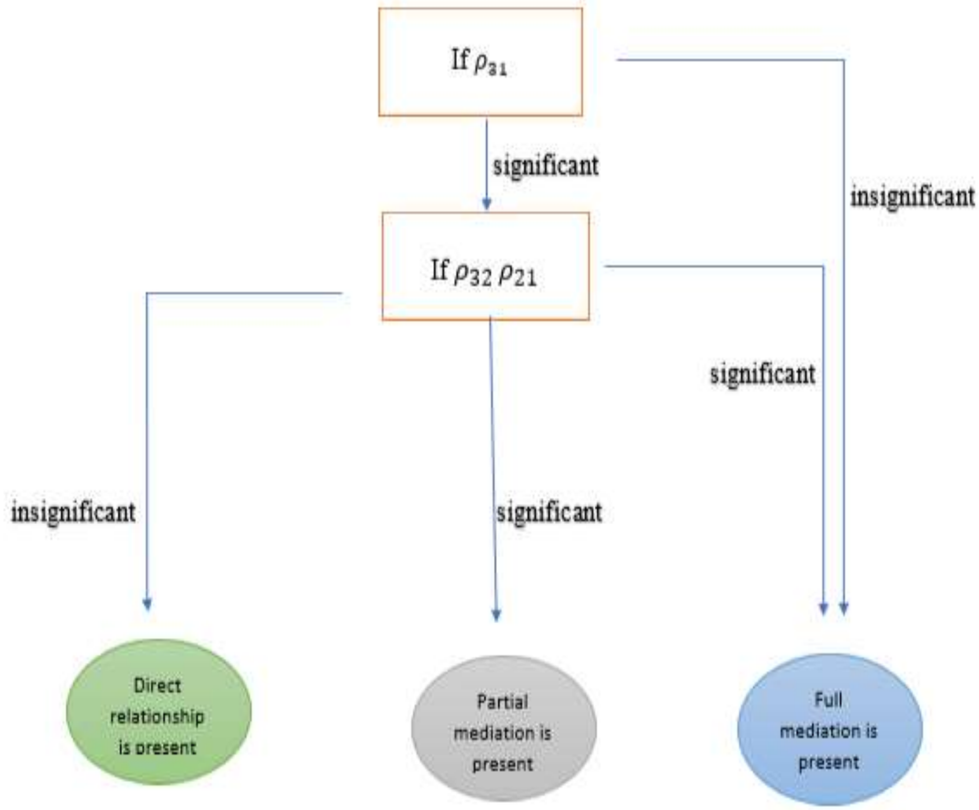

Figure 5. 4 Testing for Mediation (Using Bootstrapping)

As depicted in Figure 5.4, we observe if the indirect effect ($\rho_{32}\,\rho_{21}$) through the mediator is significant, if it is so this means that mediation is present.

As shown in Figure 5.4, we have two types of mediation: 1) partial mediation and 2) full mediation. If $\rho_{32}\,\rho_{21}$ is significant and ρ_{31} is also significant, this means we have partial mediation, as the direct effect still persists and a part of the total effect of A on B goes through the mediator, so it is called partial mediation. If ρ_{31} is not significant and only $\rho_{32}\,\rho_{21}$ is significant, in this case, we say that mediator is absorbing the full effect of A on B, so it is termed as full mediation. On the other hand, if $\rho_{32}\,\rho_{21}$ is not significant while ρ_{31} is only significant, then just a direct relationship is observed between A and B.

5.2 INDEX DECOMPOSITION ANALYSIS METHOD EVALUATION

To analyze the second objective of the study, we have applied Log Mean Divisia Index I to observe the contribution of the following effects: (1) carbon intensity, (2) renewable energy penetration, (3) fossil fuel substitution, (4) affluence, (5) energy intensity, and (6) population size in aggregate carbon emissions of the country.

An index number is a statistical value that measures the combined change in a set of related variables. The overall change in a group of variables can be measured concerning time, geographical location, characteristics, etc. (International Monetary Fund, 2009). In various studies, researchers have adopted various methods for Index Decomposition Analysis (IDA). The IDA allows to evaluation of the contribution of various driving factors responsible for the observed aggregate change in carbon emission over time. These contributing factors are related either in multiplicative or additive ways. When the aggregate is decomposed by the additive decomposition method, the results are obtained in physical units and are related to each other in an additive way. In multiplicative index decomposition, the values are in the form of an index and related to each other in a multiplicative way. The most applied IDAs are Laspeyres, Paasche, Logarithmic Mean Divisia Index-1, Logarithmic Mean Divisia Index-II, and Arithmetic Mean Divisia Index.

The IDA must satisfy some desirable theoretical properties. Ang et al. (2004) deliberated on this subject with a focus on the six properties of index number theory. Details of these properties are as follows:

i. Factor-reversal test

According to this test, the index decomposition method producing residuals equal to zero represents complete decomposition. In other words, this test requires that the product of estimations of the variables for the aggregate must be equal to the index value of aggregate change, regardless of the number of factors. If the residual term occurs, it affects the accuracy of results and leads to a problem in the interpretation (Ang and Choi, 1997). Hence, this test is often considered the most important.

ii. **Time-reversal test**

The test specifies that reversing the time periods gives the value of an index that is equal to the reciprocal of the original index. In other words, the test shows that the index calculated from the target year to the base year is absolutely reciprocal to the one computed from the base year to the target year. The fulfillment of this test demonstrates that the estimated results are symmetrical (Ang et al., 2004).

iii. **Proportionality test**

This test states that if all values of target year t of a factor are multiplied by a positive number ƛ, then the new index is ƛ times the old index. In other words, the index function is homogeneous of degree 1 in the components of the period t factor vector. If all values of a factor in the base year (t-1) are multiplied by the positive number ƛ, then the new index is 1/ ƛ times the old index. It means that the index function is homogeneous of degree -1 in the components of the base year (t-1) factor vector.

iv. **Aggregation test**

An index is considered to be stable in aggregation, if it has a similar value regardless of how it is computed either in one step or in more than one step (Vartia, 1976). According to Waziers (2005), consistency in aggregation can be classified into four types based on the powers of this property.

Type A1 (Exact consistency): The consistency in aggregation enables the analyst to get similar answers regardless the index is generated in one-step or several steps procedures. **Type A2:** The aggregate index may be calculated in two or more steps by first computing the indices for sub-aggregates and finally the aggregate. The functional formulae to calculate the index in one or multi-step calculation must be the same. **Type B (Partial consistency):** This method is partially consistent in aggregation with Type A_2 for each factor, i.e., a unique aggregator function linear and homogeneous which allows the results for each factor are consistent, but the results for the composite index are not consistent (means a residual term left). **Type C (Approximate numerical consistency):** This approach is consistent in aggregation numerically if the estimated results in one or multi-step procedures differ by not more than 1%.

v. Zero-value robustness

Zero-value robustness test refers to the approach that is capable of handling a data set that includes zero values.

vi. Negative-value robustness

This test means that no complication should arise if the data set contains negative values. This property deals with the ability to handle data sets with negative values. Table 6.1 compares the properties of the most widely used IDA methods in the literature:

Table 5.1 Properties of Indices ("√" means the index passes the test and "×" indicates the index fails the test)

Index	Factor-reversal test	Time-reversal test	Proportionality test	Aggregation test: Multiplicative	Zero value robustness	Negative value robustness
Laspeyres	×	×	√	B	√	√
Paasche	×	×	√	C	√	√
Generalized Fisher	√	√	√	C	√	√
ADMI	×	√	√	C	×	×
LMDI I	√	√	×	A_1	√	×
LMDI II	√	√	√	C	√	×

From Table 5.1, it can be seen that the Laspeyres, Paasche, and AMDI methods have obvious drawbacks. The AMDI decomposition approach does not satisfy the factor reversal test, which means that it is not applicable for complete decomposition as it leaves residual term. Similarly, Laspeyres and Paasche's decomposition methods do not pass the time-reversal test and factor reversal test. Both IDA methods induce the residual term, which is rather significant. This failure is a major shortcoming linked with the application of Laspeyres and Paasche decomposition methods. The generalized fisher index can be a better choice as it possesses more desirable properties as compared with other most widely used indices. However, the limitation of the generalized fisher index is that its formula becomes relatively complex when it is extended for "n" factors. The generalized fisher method suffers from its complicated formula, and due to this reason, when factors are more than two, its effectiveness drops. Ang et al. (2004) believed that even if a decomposition approach possesses most of the properties, it may not be quite effective in case the formula under consideration is too much complicated.

Our dataset contains no negative and zero values for the variables of population, GDP, fossil fuel consumption, and carbon emissions. In such a case, the Log Mean Divisia Index (LMDI) decomposition can be a good practical application. The LMDI decomposition method is subdivided into LMDI-I decomposition, and LMDI-II decomposition, each of them having their multiplicative and additive decomposition models. The multiplicative approach is used to assess absolute changes, whereas the additive method is used to study relative changes. Initially, the additive decomposition model of LMDI-I was proposed by Ang et al. (1998). Later on, Ang & Liu (2001) suggested the multiplicative decomposition model of LMDI-I. The LMDI-II decomposition was proposed by Ang & Choi (1997). The findings of LMDI-II are more similar to those obtained by LMDI-I, but the computation process of LMDI-II is more complicated. Moreover, LMDI II is inconsistent in aggregation in its multiplicative form. Due to this reason, this method has not been widely used in literature.

Given the research objective of the study to investigate the decoupling relationship between economic growth and carbon emissions in Pakistan, the Logarithmic Divisia Index Method I (LMD-I) as proposed by Ang & Choi (1997) and decoupling elasticity analysis developed by Tapio (2005) have been applied. The LMDI-I is used in its multiplicative with fixed base and chain-linked year by year. Tapio's (2005) technique determines the state of decoupling or coupling, while the contribution of numerous variables to carbon emission change is broken down and quantified by the LMDI-I method. In order to estimate carbon emissions for the country, the Kaya identity model is most extensively used. The Kaya identity approach is a conceptual framework to estimate potential carbon emissions due to human activities. This model was originally presented in 1990 in a working group of the United Nations' Intergovernmental Panel on Climate Change. In more detail, this model establishes a mathematical equation that relates various economic, demographic, and environmental factors to estimate carbon emissions resulting from energy consumption. According to Tavakoli (2017), Kaya identity can be used widely and reliably for the estimation of emissions and identification of effective factors. The Kaya identity links economic, demographic, and policy factors with the carbon emissions generated by anthropogenic activities. This model proposed by Yoichi Kaya to IPCC in 1990 defines carbon emissions as the product of four main factors, as shown in the equation below.

$$C = \frac{C}{E} \times \frac{E}{GDP} \times \frac{GDP}{P} \times P$$

Where GDP, C, E, and P represent the gross domestic product, carbon emissions, total energy consumption, and total population.

Many studies have decomposed the changes in total carbon emissions in Pakistan through the Kaya identity model by employing the LMDI-I approach (Lin & Ahmad, 2017), (Khan et al., 2019) and (Khan & Majeed, 2019). This research further extends the carbon emission index decomposition analysis for Pakistan by quantifying the factors causing energy-related carbon emissions in Pakistan. To that purpose, this is the very first study to measure the effect of renewable energy penetration on total primary energy consumption from the decomposed function of energy-related carbon emissions in Pakistan which is similar to the study (Mahony, 2013). Unlike Mahony (2013), carbon emissions from each fuel type i has been calculated based on the IPCC guidelines (IPCC 2006).

Mathematically, total energy-related carbon emissions can be expressed as follows:

$$C_{tot} = \sum_{i}^{n} C_i \qquad \text{Eq. (21)}$$

Where C_i represents the carbon emissions due to the burning of i^{th} type of fossil fuel,

and i = 1, 2,…, 9

According to Mahony (2013), to assess the changes in energy-related carbon emissions, Kaya's identity can be extended as follows:

$$C_{tot} = \sum_i \left(\frac{C_i}{E_i^{ff}}\right) \times \sum_i \left(\frac{E_i^{ff}}{TFF}\right) \times \left(\frac{TFF}{TEC}\right) \times \left(\frac{TEC}{GDP}\right) \times \left(\frac{GDP}{P}\right) \times P \qquad \text{Eq. (22)}$$

$$C_{tot} = F \times S_{ff} \times S_e \times I \times A \times P \qquad \text{Eq. (23)}$$

Where

$F = \frac{C_i}{E_i^{ff}}$ the total carbon emissions for the i^{th} fossil fuel

$S_{ff} = \frac{E_i^{ff}}{TFF}$ is the share of i^{th} fossil fuel in total fossil fuel consumption

$S_e = \frac{TFF}{TEC}$ is the share of total fossil fuels in total primary energy consumption

$I = \frac{TEC}{GDP}$ is the energy intensity of the economy

$A = \frac{GDP}{P}$ GDP per capita or economic activity per capita

P = total population

- Total energy consumption includes coal, oil, gas, traditional biomass, hydropower, wind, solar, modern biofuels, and other renewables.
- Total fossil fuels include natural gas, coal, and oil
- This study considers nine main types of fossil fuel consumed in Pakistan, namely, natural gas, bituminous coal, lignite, fuel oil, gas/diesel, kerosene, motor gasoline, LPG, and other oil products.

Take the total differential of Eq. (23), on both sides,

$$\frac{dC}{dt} = \left(P \times S_{ff} \times S_e \times I \times A \times \frac{dF}{dt}\right) + \left(F \times P \times S_e \times I \times A \times \frac{dS_{ff}}{dt}\right) + \left(F \times S_{ff} \times P \times I \times A \times \frac{dS_e}{dt}\right) + + \left(F \times S_{ff} \times S_e \times A \times P \times \frac{dI}{dt}\right) + \left(F \times S_{ff} \times S_e \times I \times P \times \frac{dA}{dt}\right) + \left(F \times S_{ff} \times S_e \times I \times A \times \frac{dP}{dt}\right) \qquad \text{Eq. (24)}$$

Re-arrange Eq. (24)

$$\frac{dC}{dt} = \left(P \times S_{ff} \times S_e \times I \times A \times F \times \frac{dF/F}{dt}\right) + \left(F \times P \times S_e \times I \times A \times S_{ff} \times \frac{dS_{ff}/S_{ff}}{dt}\right) + \left(F \times S_{ff} \times P \times I \times A \times S_e \times \frac{dS_e/S_e}{dt}\right) + \left(F \times S_{ff} \times S_e \times A \times P \times I \times \frac{dI/I}{dt}\right) + \left(F \times S_{ff} \times S_e \times I \times P \times A \times \frac{dA/A}{dt}\right) + \left(F \times S_{ff} \times S_e \times I \times A \times P \times \frac{dP/P}{dt}\right)$$

From Eq. (23), we know

$$\frac{dC}{dt} = \left(\sum_i^n C_i \times \frac{dF/F}{dt}\right) + \left(\sum_i^n C_i \times \frac{dS_{ff}/S_{ff}}{dt}\right) + \left(\sum_i^n C_i \times \frac{dS_e/S_e}{dt}\right) + \left(\sum_i^n C_i \times \frac{dI/I}{dt}\right) + \left(\sum_i^n C_i \times \frac{dA/A}{dt}\right) + \left(\sum_i^n C_i \times \frac{dP/P}{dt}\right)$$

Multiply on both sides with the term $\frac{1}{C}$, we get

$$\frac{dC}{dt} \times \frac{1}{C} = \left(\frac{\sum_i^n C_i}{C} \times \frac{dF/F}{dt}\right) + \left(\frac{\sum_i^n C_i}{C} \times \frac{dS_{ff}/S_{ff}}{dt}\right) + \left(\frac{\sum_i^n C_i}{C} \times \frac{dS_e/S_e}{dt}\right) + \left(\frac{\sum_i^n C_i}{C} \times \frac{dI/I}{dt}\right) + \left(\frac{\sum_i^n C_i}{C} \times \frac{dA/A}{dt}\right) + \left(\frac{\sum_i^n C_i}{C} \times \frac{dP/P}{dt}\right) \qquad \text{Eq. (25)}$$

$$\frac{\sum_i^n C_i}{C} = \frac{C_1}{C} + \frac{C_2}{C} + \cdots\cdots \frac{C_n}{C} = \sum \frac{C_i}{C}$$

Similarly for any variable "Y", $\frac{dY}{dt} = d\ln(Y)$. Therefore Eq. (25) becomes:

$$\frac{dlnC}{dt} = \left(\sum \frac{C_i}{C} \times \frac{dlnF}{dt}\right) + \left(\sum \frac{C_i}{C} \times \frac{dlnS_{ff}}{dt}\right) + \left(\sum \frac{C_i}{C} \times \frac{dlnS_e}{dt}\right) + \left(\sum \frac{C_i}{C} \times \frac{dlnI}{dt}\right) + \left(\sum \frac{C_i}{C} \times \frac{dlnA}{dt}\right) + \left(\sum \frac{C_i}{C} \times \frac{dlnP}{dt}\right) \quad \text{Eq. (26)}$$

Take integration on both sides of Eq. (26),

$$\int_{t-1}^{t} \frac{dlnC}{dt} dt = \int_{t-1}^{t} \left(\sum \frac{C_i}{C} \times \frac{dlnF}{dt}\right) dt + \int_{t-1}^{t} \left(\sum \frac{C_i}{C} \times \frac{dlnS_{ff}}{dt}\right) dt + \int_{t-1}^{t} \left(\sum \frac{C_i}{C} \times \frac{dlnS_e}{dt}\right) dt + \int_{t-1}^{t} \left(\sum \frac{C_i}{C} \times \frac{dlnI}{dt}\right) dt + \int_{t-1}^{t} \left(\sum \frac{C_i}{C} \times \frac{dlnA}{dt}\right) dt + \int_{t-1}^{t} \left(\sum \frac{C_i}{C} \times \frac{dlnP}{dt}\right) dt$$

$$\int_{t-1}^{t} \frac{dlnC}{dt} dt = \sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C} \times \frac{dlnF}{dt} dt + \sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C} \times \frac{dlnS_{ff}}{dt} dt + \sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C} \times \frac{dlnS_e}{dt} dt + \sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C} \times \frac{dlnI}{dt} dt + \sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C} \times \frac{dlnA}{dt} dt + \sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C} \times \frac{dlnP}{dt} dt$$

$$\ln\left(\frac{C_t}{C_{t-1}}\right) = \left\{\sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C}\right\} \times \ln\left(\frac{F_t}{F_{t-1}}\right) + \left\{\sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C}\right\} \times \ln\left(\frac{S_{ff_t}}{S_{ff_{t-1}}}\right) + \left\{\sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C}\right\} \times \ln\left(\frac{S_{e_t}}{S_{e_{t-1}}}\right) + \left\{\sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C}\right\} \times \ln\left(\frac{I_t}{I_{t-1}}\right) + \left\{\sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C}\right\} \times \ln\left(\frac{A_t}{A_{t-1}}\right) + \left\{\sum\nolimits_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C}\right\} \times \ln\left(\frac{P_t}{P_{t-1}}\right) \quad \text{Eq. (27)}$$

Now from Eq. (27)

$$\sum_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C} = \sum_{i=1}^{n} \frac{L(C_i^t, C_i^{t-1})}{L(C^t, C^{t-1})} \qquad \text{Eq. (28)}$$

As we know, $L(a, b) = \frac{(a-b)}{(\ln a - \ln b)}$ for $a \neq b$

Therefore, Eq. (28) becomes.

$$\sum_{i=1}^{n} \int_{t-1}^{t} \frac{C_i}{C} = \sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \qquad \text{Eq. (29)}$$

After putting Eq. (29) in Eq. (27), it becomes:

$$\ln\left(\frac{C_t}{C_{t-1}}\right) = \sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{F_t}{F_{t-1}}\right) + \sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times$$

$$\ln\left(\frac{S_{ff_t}}{S_{ff_{t-1}}}\right) + \sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{S_{e_t}}{S_{e_{t-1}}}\right) + \sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times$$

$$\ln\left(\frac{I_t}{I_{t-1}}\right) + \sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{A_t}{A_{t-1}}\right) + \sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times$$

$$\ln\left(\frac{P_t}{P_{t-1}}\right)$$

Taking exponential on both sides and applying the rule of exponential $e^{a+b} = e^{a} \times e^{b}$, we get

$$\frac{C_t}{C_{t-1}} = \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{F^t}{F^{t-1}}\right)\right\} \times \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{{S_{ff}}^t}{{S_{ff}}^{t-1}}\right)\right\} \times \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{{S_e}^t}{{S_e}^{t-1}}\right)\right\} \times \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{I^t}{I^{t-1}}\right)\right\} \times \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{A^t}{A^{t-1}}\right)\right\} \times \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{P^t}{P^{t-1}}\right)\right\} \qquad \text{Eq. (30)}$$

According to Eq. (30), the decomposition of the total changes in carbon emissions from a base year $(t-1)$ to a target year (t) associated with the pre-defined factors can be expressed as follows:

$$D_{tot} = \frac{C^t}{C^{t-1}} = D_F \times D_{S_{ff}} \times D_{S_e} \times D_I \times D_A \times D_P \qquad \text{Eq. (31)}$$

Where

$$D_F = \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{F^t}{F^{t-1}}\right)\right\}$$

$$D_{S_{ff}} = \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{{S_{ff}}^t}{{S_{ff}}^{t-1}}\right)\right\}$$

$$D_{SE} = \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{{S_e}^t}{{S_e}^{t-1}}\right)\right\}$$

$$D_I = \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{I^t}{I^{t-1}}\right)\right\}$$

$$D_A = \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{A^t}{A^{t-1}}\right)\right\}$$

$$D_P = \exp\left\{\sum_i \frac{(C_i^t - C_i^{t-1}) / (\ln C_i^t - \ln C_i^{t-1})}{(C^t - C^{t-1}) / (\ln C^t - \ln C^{t-1})} \times \ln\left(\frac{P^t}{P^{t-1}}\right)\right\}$$

In Eq. (31), D_{tot} is the total index of carbon emissions: $D_F, D_{S_{ff}}, D_{S_E}, D_I, D_A, D_P$ are decomposed indices referred to fuel quality, fossil fuel substitution, renewable energy penetration in total primary energy consumption, energy intensity, affluence, and population effect, respectively. The description of these decoupling indices is given in Table 5.2.

Table 5.2 Description of the Effects Evaluated in the LMDI-I Decomposition Analysis

Effects	**Type**	**Description**
D_F	Fuel quality	Effect of change in carbon emissions per unit of fossil fuel
$D_{S_{ff}}$	Fossil fuel substitution	Effect of fuel switching of fossil fuel type i in total fossil fuels
D_{S_E}	Renewable energy penetration	Effect of development, technology, and utilization of renewable energy resources
D_I	Energy intensity	Effect of change in energy requirement per unit of GDP.
D_A	Affluence	Effect of change in GDP per capita or economic activity per capita
D_P	Total Population	Effect of change in the total number of inhabitants

5.3 RELATIONSHIPS BETWEEN ECONOMIC GROWTH AND CARBON EMISSIONS

The third objective of the study is analyzed through Tapio's (2005) classification of decoupling states. Based on the Organization for Economic Co-operation and Development (2002) decoupling model, Tapio (2005) has provided a comprehensive framework of the eight different aspects of decoupling between carbon emissions and economic output. A variation of ±20% around 1.0 in the elasticity values is referred to as coupling. Therefore, the coupling is described as an elasticity value ranging from 0.8 and 1.2. The growth of the variables can be negative or positive; therefore, the relationship between them is expressed as expansive coupling or recessive coupling. Decoupling can be further divided into three types. Eight logical possibilities of decoupling between carbon emissions and economic growth can be distinguished as shown in Table 5.3 below:

Table 5.3 Classification of coupling and decoupling relationship between Carbon emissions and Economic Growth

Relationship between carbon emissions and economic growth	State of relationship	$\Delta C / C_{t-1}$	$\Delta G / G_{t-1}$	Value of ŋ
Expansive	Expansive negative decoupling	>0	>0	ŋ >1.2
	Expansive coupling	>0	>0	0.8 ≤ ŋ ≤1.2
Weak	Weak decoupling	>0	>0	0 ≤ ŋ ≤ 0.8
	Weak negative decoupling	<0	<0	0 ≤ ŋ ≤ 0.8
Recessive	Recessive coupling	<0	<0	0.8 ≤ ŋ ≤1.2
	Recessive decoupling	<0	<0	ŋ >1.2
Strong	Strong decoupling	<0	>0	ŋ <0
	Strong negative decoupling	>0	<0	ŋ <0

Source: Adopted from Tapio (2005) classification of decoupling states

Mathematically, the elasticity of energy-related carbon emissions and economic growth between a base year (t-1) to a target year (t) can be written as:

$$\text{Decoupling elastic index } (\eta) = \frac{\text{Percentage change in carbon emissiosns}}{\text{Percentage change in economic growth}}$$

$$\eta = \frac{\beta C}{\beta G}$$

Where

$$\beta C = \frac{C^t - C^{t-1}}{C^{t-1}}$$

and

$$\beta G = \frac{G^t - G^{t-1}}{G^{t-1}}$$

$$\eta = \frac{C^t - C^{t-1}/C^{t-1}}{G^t - G^{t-1}/G^{t-1}} \qquad \text{Eq. (32)}$$

In Eq. (32), η is the decoupling index. C^{t-1}, G^{t-1}, C^t, and G^t are the carbon emissions and GDP of the base year (t-1) and target year (t), respectively. $\beta G = \frac{G^t - G^{t-1}}{G^{t-1}}$ and $\beta C = \frac{C^t - C^{t-1}}{C^{t-1}}$ stand for the growth rates of GDP and carbon emissions, respectively.

CHAPTER 6

RESULTS AND DISCUSSION

The first objective of this study has applied Structural Equation Modelling (SEM) to analyze path dependencies between green growth indicators in Pakistan. The objective of this investigation is to find if sustainable economic growth is possible: 1) without putting pressure on natural resources and climate; and 2) by reducing poverty and increasing employment. The investigation attempts to utilize 30 years of historical data of pre-defined indicators to observe the sustainable development possibility in Pakistan. If it is so, the findings can be worthwhile for Pakistan and international organizations for their role in the inclusive and ecologically sustainable development of the region.

6.1 Interpretation of the Green Growth Model

The SEM analysis is depicted in Figure 6.1, with error terms for all endogenous variables. The Seoul Initiative Network on Green Growth, which was adopted during the 5th MCED in 2005, served as the foundation for the model's design.

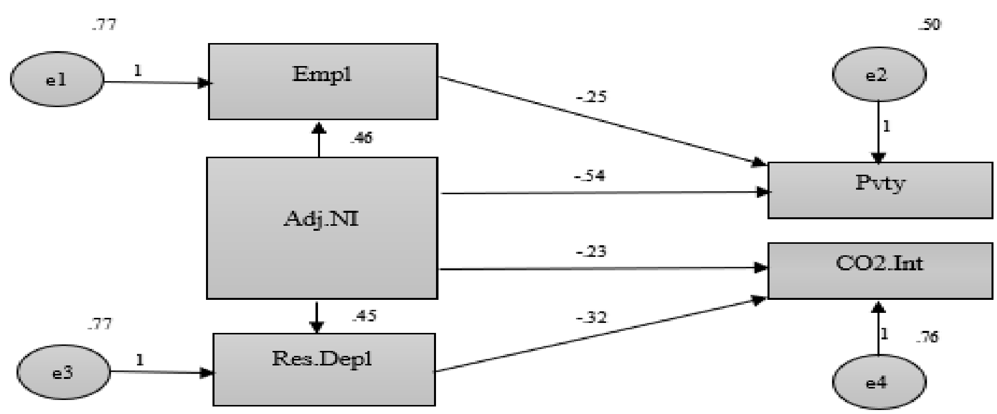

Figure 6.1 Green Growth Model in SEM

The bootstrap output begins with a table of diagnostic information that is given in Table 6.1 below:

Table 6.1: Bootstrap Iteration Results

Iterations	Method 0	Method 1	Method 2
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	20	0
6	0	109	0
7	0	224	0
8	0	377	0
9	0	390	0
10	0	379	0
11	0	263	0
12	0	113	0
13	0	69	0
14	0	31	0
15	0	14	0
16	0	6	0
17	0	5	0
18	0	0	0
19	0	0	0
Total	0	2000	0

0 bootstrap samples were unused because of a singular covariance matrix.
0 bootstrap samples were unused because a solution was not found.
2000 usable bootstrap samples were obtained.

If one or more bootstrap samples have a singular covariance matrix then Amos fails to identify a solution for some bootstrap samples, Amos reports their occurrence and excludes them from the bootstrap analysis. In our research, no bootstrap sample had a singular covariance matrix, and each of the 2000 bootstrap samples had a solution. The normality of the variables and multivariate normality is presented in Table 6.2.

Table 6.2: Assessment of Normality

Variables	**Minimum**	**Maximum**	**Skewness**	**Critical Ratio**	**Kurtosis**	**Critical Ratio**
Empl	48.910	51.400	-0.808	-1.806	0.574	0.642
Pvty	33.950	87.730	-0.172	-0.384	-1.171	-1.310
Res.Depl	0.600	2.000	0.486	1.088	-1.111	-1.242
Adj.NI	0.265	7.733	-0.178	-0.398	-0.649	-0.725
CO2.Int	0.167	0.209	-0.277	-0.619	-0.852	-0.952
Multivariate					-1.539	-0.504

When researchers use maximum likelihood estimation multivariate normality is compulsory. When we check the data multivariate normality critical ration it should be within the range of -1.96 to +1.96. The results confirm that there is multivariate normality for the model. Table 6.3 shows the summary of descriptive statistics for all five variables of the model, including their means, standard deviations, and Pearson coefficients of correlations. Pearson coefficient calculation provides a quick and simple summary of the direction and strength of the relationship between these variables, with no assumption of causality.

Table 6.3 Summary of Descriptive Statistics of Variables

	Mean	Standard Deviation	Correlations Between Coefficients				
			Empl	**Pvty**	**Res.Depl**	**Adj.NI**	**CO2.Int**
Empl	50.499	0.561	1	-0.497**	0.523**	0.455*	-0.281
Pvty	60.203	16.772	-0.497**	1	-0.303	-0.655**	0.272
Res.Depl	1.171	0.426	0.523**	-0.303	1	0.446*	-0.419*
Adj.NI	5.648	2.206	0.455*	-0.655**	0.446*	1	-0.369*
CO2.Int	0.187	0.0111	-0.281	0.272	-0.419*	-0.369*	1

**Correlation is significant at the 1% level

*Correlation is significant at the 5% level

According to the findings, opportunities exist in Pakistan for poverty eradication and reduction in carbon intensity with sustainable economic growth. Regression weights estimated by SEM are reported in Table 6.4. Standardized regression weights are simple linear regression providing the estimated path coefficients between the response variable and the explanatory variable based on the specified statistical model. Pearson coefficient of correlation is driven into the regression. With the help of standardized regression weights, we are looking to predict and explain a number of responses among the variables with the best-fitting line through the data points. It is important to know how two variables are correlated because it opens up further investigation for predicting trends in the presence of any mediator. The direct effect of variables in the absence of any mediator is reported through the estimation of regression weights in the Structural Equation Modeling. As provided in Table 6.4, estimation results of Eq. (1) and Eq. (2) imply that adjusted net national income is a significant predictor of poverty reduction, and employment creation as p-values are less than 0.10 significance level and sign of path coefficients are positive. Similarly, according to Eq. (11) natural resource depletion is also positively affected by adjusted net national income. The arrows in the Table 6.4 delineate the directionality. On the other hand, the impact of the adjusted net national income effect is insignificant for carbon intensity with a p-value > 0.10 significance level, which means that adjusted net national income does not affect carbon intensity (carbon emissions per unit of GDP).

Table 6.4 Regression Weights from SEM Model

	Standardized path coefficients	Lower bound	Upper bound	P-Value
Adj.NI ⇨ Empl	0.455	0.165	0.698	0.002
Adj.NI ⇨ Res.Depl	0.446	.0183	0.640	0.001
Adj.NI ⇨ Pvty	-0.541	-0.750	-0.308	0.002
Res.Depl ⇨ CO2.Int	-0.318	-0.624	0.066	0.107
Empl ⇨ Pvty	-0.250	-0.475	0.123	0.169
Adj.NI ⇨ CO2.Int	-0.227	-0.516	0.108	0.197

According to the values of standardized regression coefficients in Table 6.4, when Adj.NI increases by 1 standard deviation (SD), Pvty significantly decreases by 0.541SD as p-value = 0.002. This outcome is consistent with the findings of Hynes & Wang (2012) and Jacob et al. (2015) that growth in sustainable national income leads to a reduction in poverty. Similarly, a 1SD increase in Adj.NI significantly (p-value = 0.002) increases Empl by 0.455SD. The result supports Borel-Saladin & Turok (2013) argument that when green industry is prioritized, job gains are more than the job losses in the traditional fossil fuel-based economy. Rather more important to understand is that adjusted net national income leads to increased natural resource depletion. Res.Depl increases by 0.446SD when Adj.NI increases by 1SD, indicating that Pakistan is continuing the path of weak sustainability despite the economic growth concept that sustainable growth protects natural resources. Additionally, with a p-value of 0.001, the relationship between Adj.NI and Res.Depl is highly significant. The results are consistent with Barua & Khataniar

(2016) finding that growth-oriented development in middle-income Asian nations, including Pakistan, is only weakly sustainable in the quest for better socioeconomic position. Weak sustainability necessitates that human well-being remain non declining in the long run. Therefore, increasing inclusive wealth focuses on improved living standards despite declining natural capital (Johnson, 2000), (Raudsepp-Hearne et al., 2010) and (DeFries, 2014). The findings have supported the argument that the low and middle-income countries, particularly those of the Asia-Pacific region, have experienced rapid economic development, poverty reduction, and improved welfare over the past forty-fifty years; however, the environmental implications of this have not been fully understood (Galli et al., 2012).

Furthermore, Table 6.4 also reports that the path coefficient of Eq. (3), the direct effect of Empl on Pvty, is insignificant as the p-value = 0.169 > 0.1. This finding further opens up research for understanding how the relationship between these two variables is altered when employment opportunity is introduced as a mediator between net national income and poverty. Similarly, the path coefficient of Eq. (12) and Eq. (13) implies that Adj.NI and Res.Depl does not directly impact CO2.Int. The p-value for both these path coefficients is greater than 0.1. Thus, the study also investigates further the indirect effect of net national income on carbon intensity via the mediating effect of natural resources constraint, in order to estimate the influence conveyed through the indirect pathway.

6.1.1 Bootstrapping Mediation Model in AMOS (Version 20)

The results of Table 6.5 reveal that net national income indirectly impacts carbon intensity through the mediating effect of natural resource constraints. Likewise, it also causes poverty eradication by the significant mediating role of employment generation although a direct effect is also present. The total effects confirm that sustainable economic growth eradicates poverty and reduces carbon emissions per unit of GDP as p-value = 0.001 and 0.032, respectively. The results of the mediation model in Table 6.3 reveal that Hypotheses H_1 and H_2 are accepted as the total effect of Adj.NI causes a decline in Pvty and CO2.Int as the p-values are less than one, respectively. The path coefficient of the total effect ($\rho_{31} + \rho_{32}\,\rho_{21}$) of Adj.NI according to Eq. (7) is -0.369, which implies that the total impact of net national income causes a decline of -0.369 in poverty. Similarly, the path coefficient of the total effect ($\rho_{31}{}^{*} + \rho_{32}{}^{*}\rho_{21}{}^{*}$) of Adj.NI according to Eq. (17) reports the total impact of net national income on CO2.Int is -0.655.

Table 6.5 Results of Total Effects, Direct Effects, and Indirect Effects (Based on Hypotheses)

	Standardized path coefficients			
	Total effects	Indirect effects	Direct effects	Results
Adj.NI ⇨ CO2.Int	**H_1**: -0.369 (0.032)	**H_3**: -0.142 (0.061)	-0.227 (0.194)	Full Mediation is present
Adj.NI ⇨ Pvty	**H_2**: -0.655 (0.001)	**H_4**: -0.114 (0.078)	-0.541 (0.002)	Partial Mediation is present

Note: P-values are in parenthesis

The path coefficient, $\rho_{32}\,\rho_{21}$, of Eq. (7) implies that with a 1SD increase in Adj.NI, Pvty is indirectly decreased by 0.114SD. Similarly, the path coefficient, $\rho_{32}{}^{*}\rho_{21}{}^{*}$, of Eq. (17) reveals that with a 1SD increase in Adj.NI, CO2.Int is indirectly decreased by 0.142SD. The outcomes of indirect effects indicate that Hypotheses H3 and H4 are accepted with p-values = 0.061 and 0.078, respectively and the correlation between the response variable and the explanatory variable is present via indirect pathway. The results of Table 6.3 reveal that the full mediation effect is present as the only indirect effect ($\rho_{32}{}^{*}\rho_{21}{}^{*}$) of Adj.NI on CO2.Int is significant with a p-value = 0.061, while the direct effect ($\rho_{31}{}^{*}$) of Adj.NI on CO2.Int is insignificant with a p-value = 0.194. The structure of Pakistan's economy has experienced significant changes over the last few decades. Sustainable economic growth promotes the service sector with resource efficiency measures but does not save the natural resource base from depleting. The share of the service sector has increased to 62% of GDP and posted a growth of 4.4% (Government of Pakistan, 2021a). Structural change in the economy, such as shifting from agriculture to the manufacturing sector and then from manufacturing to the service sector, encourages technological advancements that help adopt environmentally friendly technologies (Dogan & Seker, 2016) and (Destek & Sarkodie, 2019). Danish et al. (2019) argue that economic development mode transition simultaneously reduces CO2 emissions per unit of GDP, a parameter of weak sustainability. According to (Yuan et al., 2012), the composition change of goods and services in final demand hastens the drop in

CO_2 intensity. The manufacturing of low-carbon commodities and environmental protection technologies both have a favorable impact on the environment (Xu et al., 2017).

Ekins et al. (2003) also pointed out that man-made capital replaces natural capital under weak sustainability, but technological progress and innovations continually generate technical solutions for the environmental issues caused by the increased production of goods and services. Similarly, Turner (1993) also argues that a technology-optimistic or technology-centric viewpoint is considered to be an example of weak sustainability. Therefore, the findings reveal that the environmental regulations are significantly facilitating a decrease in carbon intensity through cutting-edge technology. World Bank (2021) estimated that human capital made up 68.6% of the total wealth of Pakistan in 2018, followed by produced capital at 17.4% and natural capital at 14.0%. UNU-IHDP and UNE (2014) also found a general trend toward declining natural capital and increasing human and man-made capital both in absolute and percentage terms in Pakistan with increased inclusive wealth. According to Neumayer (2003), weak sustainability refers to a situation, in which the overall amount of stock of total capital (or inclusive wealth) increases or remains constant throughout the time, although natural and man-made capitals are substitutable.

In addition, with the partial mediation effect of employment, net national income can improve the incidence of the end of poverty. Partial mediation describes the situation where both direct effect (ρ_{31}) and indirect effect($\rho_{32}\,\rho_{21}$) are significant, with p-values = 0.002 and 0.078, respectively. The results indicate that with a 1SD increase in Adj.NI, Pvty is partly reduced by 0.114SD via the mediating role of Empl. At the same time -0.541SD is the direct effect of 1SD increase in Adj.NI on Pvty. The findings indicate that hypotheses H_2 and H_4 are accepted as p-values = 0.001 and 0.078 < 0.1 level of significance. The outcomes are in line with the studies carried out by (Lewis, 1954), (Aghion & Bolton, 1997), and (Todaro & Smith, 2020) that economic growth has a trickle-down impact on poverty by creating jobs and other income opportunities. Based on hypothesis testing criteria, the effect of employment on poverty turned significant after entering employment as a mediating variable in the model. The outcomes confirm that it is not enough to increase employment opportunities to lift the poor and their families above the $3.20 a day poverty line. Karnani (2009) argued that the poor need productive and decent jobs that lead to higher income to escape poverty. Income generation from sustainable development-related economic growth initiatives can have a ripple effect on alleviating poverty. The results reveal that the income growth in Pakistan is inclusive, creating more productivity and income opportunities to prevent poverty and ensuring their livelihood enough to mitigate any shock due to ill health or natural disaster etc. A mechanism is needed to speed up trickle-down growth so that the poor accrue income proportionately more than the wealthy, such as increased levels of employment, appropriate natural resources, adequate human development, and macroeconomic stability with financial development. Long-term sustainable development will be improved by the way these elements could be incorporated into an efficient growth policy package, and both the rich and the poor will benefit from the process of economic expansion. With the aid of these kinds of mechanisms, the income transfer system starts to function in favor of the poor, and the trickle-down effect of growth raises everyone's standard of living, but especially that of the poor. Sustainable economic growth can surely lessen income gaps in place of ruthless economic growth. The benefits of economic expansion are wisely redistributed during the process of sustainable growth in order to steadily improve the income distribution. Sustainable development can create chances for workers to earn a productive wage with the aid of economic policy. Similar to this, by focusing on climate mitigation policies, the resources of the poor will be invested in beneficial ways, leading to increased access to health and education services that can help people become more literate and develop their abilities. More money would also be invested in the creation of new technologies.

Although there is no direct significant relationship between employment and poverty as reported in Table 6.2, it is more informative to understand why an increase in employment does not always result in a decrease in poverty. The significant indirect effect of employment on poverty as reported in Table 6.5 confirms and solidifies the widely accepted view that improvement in poverty incidence is assisted when adjusted net national income (known as economic growth in qualitative terms) provides stable income sources to Pakistani citizens. The finding indicates that hypothesis H_4 is accepted when the impact of employment on poverty turns significant when employment intervenes between economic development and poverty as a mediating variable in our model. As a result, we can state that green growth exists in Pakistan, benefiting the underprivileged through economic prosperity.

Labor asset is the source of earning, but an employed person can be poor and vulnerable to poverty, as the empowerment of the poor is not only just having an income. The overall socio-economic welfare requires environmental support programs, infrastructure development, education, essential services to health, and skill development. Therefore, the result of this study reveals that sustainable economic growth is a prerequisite to reducing poverty.

For a country, the national income guides the level of development and provides a budget for it. So, realizing an increase in the national income is required. As it removes the backlogs in development projects through the role of government and investment in public services, infrastructure, and innovations in science and technology. The results of our study state that, in no uncertain terms, an increase in affluence (Adjusted net national income) promotes greater employment making the labor market more efficient (demand of labor = supply of labor).

The empirical results of Table 6.5 imply that

1. An increase in net national income generates productive employment in the economy and ultimately leads to social inclusion. Employment opportunities help the poor to rise out of poverty. With a decent job being the primary source of income, people earn enough to escape poverty.

2. There is a strong coupling between net national income and natural resource depletion. Net national income reduces the carbon intensity of production but does not reduce natural resource depletion. Low carbon intensity is directly associated with resource-efficient modes of production representing a case of weak sustainability.

6.1.2 Model's Goodness of Fit

The model's goodness of fit is based on the criteria of 1) absolute model fit, 2) baseline comparisons, and 3) parsimony-adjusted measures. These criteria indicate that the model is good and explains significant variation.

The hypotheses are:

H_0: There is no significant difference between the observed model and the hypothesized model.

H_1: There is a significant difference between the observed model and the hypothesized model.

In AMOS, the chi-square value is called CMIN. For a good model, if χ^2 p-value (Chi-squared p-value) is > 0.05, the model is regarded as acceptable. Similarly, the Goodness of fit index (GFI) > 0.95, the Adjusted Goodness of fit index (AGFI) > 0.9 Root mean square residual (RMR) < 0.10, and the Standardized Root Mean Square Residual (SRMR) < 0.08. Our values are: $\chi 2$ with p-value = 0.234, RMR = 0.085, SRMR = 0.0881, GFI = 0.935 and AGFI =0.755 as shown in Table 6.6 below.

Table 6.6 Absolute Model Fit Indices and their Values

Model	NPAR	CMIN	DF	P	CMIN/DF	RMR	SRMR	GFI	AGFI
Default model	11	5.565	4	0.234	1.391	0.085	0.0881	0.935	0.755

As absolute model fit is not only the ultimate deciding factor. Therefore, values of baseline comparisons and parsimony-adjusted measures are also checked for analyzing model fit. For a good model, Comparative Fit Index (CFI) > 0.95, Normalized Fit Index (NFI) > 0.95, Tucker-Lewis Index (TLI) > 0.95, Incremental Fit Index IFI) > 0.9 and Relative Fit Index (RFI) > 0.9. Our values are: CFI = 0.955, NFI = 0.876, RFI = 0.689, IFI = 0.962 and TLI = 0.887 as shown in Table 6.7.

Table 6.7 Baseline Comparison Model Fit Indices and their Values

Model	NFI	RFI	IFI	TLI	CFI
Default model	0.876	0.689	0.962	0.887	0.955

Parsimony-adjusted measures suggest that for an excellent model, the Root Mean Square Error of approximation (RMSEA) should be < 0.08, while for a medium model, it ranges from 0.1–0.08. As shown in Table 6.8, for our model, RMSEA = 0.116.

Table 6.8 Parsimony-Adjusted Measures and their Values

Model	RMSEA
Default model	0.116

6.1.3. Standard Residual Covariance Matrix (SRCM) Values

Table 6.9 indicate the standardized differences between the observed covariances computed based on the collected data and the proposed covariances based on the model. Standardized residual covariance matrix value > 2.0 significantly reduces model fit and indicates that the path could be eliminated to improve the model fit. According to Table 6.9, paths presented in the SEM model are found to hold true as standardized residual covariance matrix values are less than 2.0.

Table 6.9 Standardized Residual Covariances from SEM Model

	Adj.NI	Res.Depl	Empl	CO2.Emis	Pvty
Adj.NI	0.000				
Res.Depl	0.000	0.000			
Empl	0.000	1.691	0.000		
CO2.Emis	0.000	0.000	-0.600	0.000	
Pvty	0.000	-0.056	0.000	0.162	0.000

The second objective of the study calculates the quantitative relationship of carbon emissions with driving forces guided by the extended Kaya identity model for Pakistan using time series data from 1990 to 2019. The extended Kaya identity model is employed to find out the impacts of fuel quality, energy efficiency, technological effect, energy intensity, economic activity per person, and population size for describing environmental outcomes. The Eq. (31) is estimated to calculate the effect of all mentioned factors on carbon emissions.

6.2 Index Decomposition of Energy-Related Carbon Emissions in Pakistan

The complete time series LMDI-I decomposition analysis of carbon emissions in Pakistan according to Eq. (31) is reported in Table 6.10. Similarly, graphical results of cumulative effects from annual time series decomposition results of LMDI-I are shown in Figure 6.2. While the complete cumulative effect values of influencing factors of carbon emissions from 1990 to 2019 are given in Table 6.11. The results reveal that energy intensity, fuel quality, affluence, renewable energy penetration effect, and population effect contributed positively to increasing carbon emissions.

Table 6.10 Annual time series decomposition results from 1990 to 2019

Years	D_F	$D_{S_{ff}}$	D_{S_E}	D_I	D_A	D_P	DC_{tot}	Residual
1990-91	0.997	0.945	0.998	1.008	1.021	1.029	0.996	-3E-06
1991-92	0.995	1.025	0.992	0.975	1.047	1.028	1.062	8E-05
1992-93	1.005	0.998	1.003	1.088	0.990	1.028	1.114	2E-05
1993-94	0.995	0.986	1.009	0.998	1.009	1.028	1.025	1E-05
1994-95	0.998	1.012	1.000	1.005	1.021	1.028	1.066	1E-05
1995-96	1.002	0.997	0.997	1.016	1.019	1.029	1.061	4E-05
1996-97	0.992	1.014	1.043	0.959	0.982	1.029	1.017	4E-06
1997-98	1.000	1.013	0.970	1.045	0.997	1.029	1.053	4E-06
1998-99	0.997	0.991	1.028	1.008	1.008	1.028	1.062	2E-05
1999-00	0.997	0.938	1.017	0.980	1.015	1.027	0.972	-6E-06
2000-01	0.996	0.991	0.992	0.988	1.010	1.026	1.003	2E-06
2001-02	0.997	1.015	0.993	1.012	1.001	1.024	1.043	2E-05
2002-03	1.010	1.020	0.988	1.028	1.033	1.024	1.107	3E-04
2003-04	0.992	1.033	1.006	1.035	1.051	1.023	1.147	2E-04
2004-05	1.001	0.983	0.994	0.986	1.022	1.012	0.996	-2E-03
2005-06	1.000	0.990	1.011	0.996	1.035	1.023	1.057	1E-04
2006-07	1.011	1.034	1.005	1.014	1.025	1.023	1.116	1E-04
2007-08	0.978	0.926	1.022	0.989	0.994	1.023	0.931	-1E-04
2008-09	0.999	1.031	0.993	0.985	1.006	1.023	1.036	2E-05
2009-10	0.999	0.990	0.997	0.988	0.994	1.022	0.990	-1E-05
2010-11	0.998	1.036	1.000	0.973	1.005	1.021	1.026	-7E-03
2011-12	0.998	0.985	1.081	0.902	1.013	1.021	0.991	-4E-06
2012-13	1.002	0.978	0.861	1.118	1.022	1.021	0.984	-5E-06
2013-14	1.017	1.022	1.072	0.920	1.025	1.021	1.072	1E-04
2014-15	1.009	1.034	1.004	1.006	1.026	1.021	1.103	2E-04
2015-16	1.003	1.005	0.999	1.033	1.033	1.021	1.099	3E-05
2016-17	1.019	0.994	1.009	1.002	1.034	1.021	1.081	9E-05
2017-18	1.008	0.943	1.000	0.975	1.037	1.021	0.980	-3E-05
2018-19	1.000	1.007	0.981	1.014	0.990	1.020	1.011	4E-09

Table 6.11: Cumulative Effect Values of Driving Factors of Carbon Emissions from 1990 to 2019

Years	D_F	$D_{S_{ff}}$	D_{S_E}	D_I	D_A	D_P	DC_{tot}	Residual
1990-91	0.9966	0.9445	0.9984	1.0084	1.0209	1.0291	0.9957	-2.82E-06
1990-92	0.9915	0.9686	0.9900	0.9832	1.0691	1.0578	1.0575	3.75E-04
1990-93	0.9968	0.9670	0.9930	1.0691	1.0584	1.0871	1.1784	9.39E-04
1990-94	0.9921	0.9538	1.0017	1.0668	1.0680	1.1179	1.2079	6.59E-04
1990-95	0.9905	0.9652	1.0022	1.0719	1.0899	1.1485	1.2879	2.18E-03
1990-96	0.9930	0.9623	0.9995	1.0885	1.1104	1.1813	1.3670	3.31E-03
1990-97	0.9853	0.9761	1.0422	1.0444	1.0900	1.2151	1.3907	4.14E-03
1990-98	0.9854	0.9889	1.0111	1.0908	1.0864	1.2484	1.4644	6.74E-03
1990-99	0.9823	0.9804	1.0391	1.0996	1.0951	1.2831	1.5548	8.54E-03
1990-00	0.9790	0.9204	1.0571	1.0781	1.1118	1.3162	1.5116	8.95E-03
1990-01	0.9755	0.9127	1.0488	1.0654	1.1224	1.3492	1.5161	9.59E-03
1990-02	0.9725	0.9259	1.0419	1.0783	1.1228	1.3836	1.5808	9.03E-03
1990-03	0.9822	0.9440	1.0299	1.1080	1.1592	1.4185	1.7502	1.03E-02
1990-04	0.9744	0.9743	1.0357	1.1460	1.2167	1.4702	2.0070	-8.41E-03
1990-05	0.9756	0.9452	1.0248	1.1164	1.2647	1.5071	1.9996	-1.12E-02
1990-06	0.9761	0.9368	1.0360	1.1115	1.3055	1.5483	2.1141	-1.42E-02
1990-07	0.9865	0.9675	1.0405	1.1264	1.3351	1.6080	2.3599	-4.16E-02
1990-08	0.9654	0.8979	1.0630	1.1149	1.3280	1.6682	2.1978	-7.81E-02
1990-09	0.9649	0.9248	1.0560	1.0985	1.3342	1.6749	2.2779	-3.53E-02
1990-10	0.9641	0.9152	1.0534	1.0866	1.3292	1.7249	2.2559	-5.95E-02
1990-11	0.9623	0.9486	1.0449	1.0572	1.3350	1.7547	2.3145	-4.77E-02
1990-12	0.9607	0.9344	1.1268	0.9562	1.3522	1.7906	2.2946	-4.70E-02
1990-13	0.9630	0.9142	0.9742	1.0654	1.3808	1.8183	2.2588	-3.52E-02
1990-14	0.9790	0.9340	1.0418	0.9823	1.4124	1.8551	2.4225	-2.91E-02
1990-15	0.9872	0.9643	1.0454	0.9880	1.4474	1.9344	2.6713	-8.18E-02
1990-16	0.9902	0.9693	1.0447	1.0197	1.4919	1.9933	2.9357	-1.05E-01
1990-17	1.0079	0.9639	1.0539	1.0215	1.5367	2.0671	3.1730	-1.49E-01
1990-18	1.0151	0.9120	1.0532	0.9970	1.5815	2.1834	3.1101	-2.47E-01
1990-19	1.0148	0.9182	1.0344	1.0100	1.5662	2.2863	3.1455	-3.41E-01

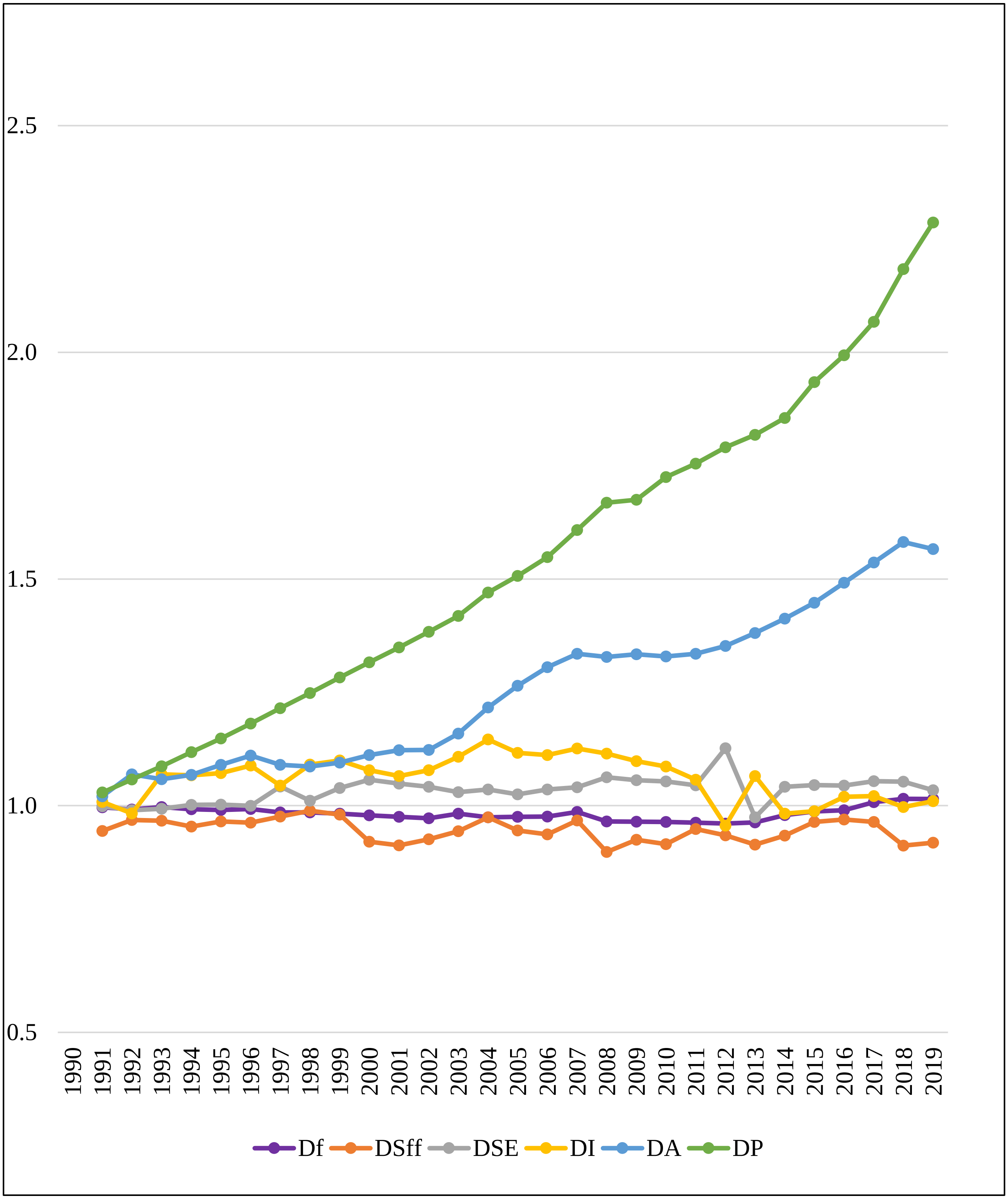

Figure 6.2 Cumulative effects of influencing factors of carbon emissions from 1990 to 2019

The results estimated by using Eq. (31) reveal that the population effect (D_P) and affluence effect (D_A) significantly contributed to the carbon emissions over the period of analysis, corresponding to the conclusions of (Khan & Majeed, 2019) and (Lin & Ahmad, 2017). Though a declining trend has been observed in D_P, however, it remained the most dominant factor in increasing the carbon emissions (with effect values greater than 1 in all periods). The population size effect contributed exponentially to Pakistan's growth in carbon emissions from energy consumption. The cumulative effect of population size on carbon emissions is 2.286, much greater than the effects of other factors. Affluence was also a contributory factor to the increase in carbon emissions from energy consumption in Pakistan; the trend increased annually, with effect values greater than one and a cumulative effect reaching 156.6% in 2019. This result complies with the earlier results drawn by Khan et al. (2019) for Pakistan. During 1991-92, 2002-07, and 2012 to 2018, the affluence effect was found to be higher than the population effect. The fuel switching $D_{S_{ff}}$ is the inhibitory factor in carbon emissions. The contribution of fuel switching declined from 0.945 in 1990 to 0.918 in 2019.

The renewable energy penetration effect (D_{S_E}) also contributed positively to increasing carbon emissions in many time periods (with effect values greater than 1). The cumulative effect of (D_{S_E}) on carbon emissions increased from 0.998 to 1.034 in 2019. Mahony (2013) argued that the contribution of renewable energy penetration could be ascribed to inadequate national policy support, not internalizing externalities in the prices of fossil fuels, the technological costs, and physical constraints such as the expansion of hydropower plants in Pakistan. There is significant potential in Pakistan for the expansion of energy with wind and solar, but these renewable technologies are less mature.

On the other hand, the effect of fuel quality used (D_F) and energy intensity (D_I) effect is relatively minor (as the index value is less than 1 for most of the time period) among all contributing factors during the period of analysis, with cumulative values of 1.014 and 1.01, respectively, for the year 2019.

Figure 6.2 reveals that in the initial years of analysis, the difference between the effect of inhibitory factors and the pulling effect of contributing factors on the increase in carbon emissions was small. With the passage of time, the magnitude of this gap has widened. The impact of the inhibiting factors became far less than the size of pulling factors, which led to a rise in the total carbon emissions. The contribution of affluence and population size to carbon emissions in

Pakistan is growing exponentially. The rapid growth of the GDP per capita or affluence demands more energy. Carbon emissions continue to rise as a by-product of energy consumption. The affluence effect declined slightly after 2018.

These findings are summed up as follows:

1. The GDP per capita effect and population effect are the dominant drivers of carbon emissions for Pakistan throughout the time series. Population size effect values increased at a higher rate than that of economic activity per person.
2. Figure 6.2 reveals that the fuel mix effect was the inhibitory factor for energy-related carbon emissions, but its effect was dwarfed by the population size and affluence effect.
3. It can be seen from Figure 6.2 that fuel quality also remained an inhibitory factor for energy-related carbon emissions for a considerable time period.
4. The renewable energy penetration effect and energy intensity also contributed positively to decreasing carbon emissions in various years. However, the impact of the renewable energy penetration effect is less than the energy intensity effect.
5. The cumulated impact of factors reducing emissions is outweighed by cumulative effects of factors driving increasing emissions, as a result of which total energy-related carbon emissions (C_{tot}) have surged up significantly from 0.996 in 1990 to 3.145 in 2019.

The period-wise effects are presented in Table 6.12.

Table 6.12 Period-wise (1990-2019) decomposition of results from 1990 to 2019

Years	D_F	$D_{S_{ff}}$	D_{S_E}	D_I	D_A	D_P	DC_{tot}	Residual
1990-1998	0.985	0.989	1.011	1.091	1.086	1.250	1.464	4E-03
1998-2001	0.990	0.922	1.038	0.977	1.034	1.082	1.035	6E-05
2001-2008	0.989	0.982	1.015	1.049	1.189	1.173	1.450	9E-03
2008-2015	1.023	1.075	0.983	0.884	1.093	1.159	1.215	3E-03
2015-2019	1.029	0.949	0.990	1.023	1.096	1.085	1.178	1E-03

The period-wise effects over the entire period of analysis are illustrated in Table 6.12. The analysis depicts five distinct phases in development trends 1) 1990-1998 boom period of a significant increase in privatization and economic liberalization in Pakistan along with a significant increase in carbon emissions. 2) 1998-2001, when the macroeconomic situation deteriorated due to nuclear test sanctions and suspension of the IMF program, and a decline in carbon emissions was observed, 3) 2001-2008 period when the economy of Pakistan greatly benefited from favorable terms granted in the wake of 9/11 and carbon emissions increased at a higher rate, 4) 2008-2015 period after the global economic recession during which carbon emissions fall slightly and 5) 2015-2019, the post-SDG era when Pakistan recognized sustainable consumption and production a necessary framework for green development and emissions in this period further declines.

1. Carbon emissions continued to increase from 1990 to 1998. Population size, energy intensity, renewable energy penetration, and affluence effect had a positive effect during the period 1990-1998. Fuel switching and fuel quality exerted a declining effect on the emissions. After the population size effect, rapid economic growth acted as a contributory factor to intense carbon emissions by increasing the proportion of the fossil fuel energy requirement.
2. The positive impact of population, renewable energy penetration, and affluence effect can be seen between 1998 and 2001. The consumption and production patterns in the economy were not significantly decoupled from energy. The affluence effect was less significant when compared with the population and renewable energy penetration effect. The trend in fuel switching and energy intensity improved from 1998 to 2001. The fuel-switching effect mainly reflects the substitution of oil for coal and gas, as well as the transition to more efficient energy sources via technical developments. Energy intensity is interpreted as the technological effect.
3. The affluence effect, energy intensity effect, population size effect, and renewable energy penetration effect increased from 2001 to 2008. In the same time period, fuel quality and fuel switching made significant progress in reducing national emissions.
4. The population effect and affluence effect were again recorded as the most significant positive effects for total carbon emissions increase during the period 2008-2015. Fuel

quality and fuel switching also contribute positively while renewable energy penetration impact and the energy intensity declined the carbon emissions.

5. The population size, affluence, energy intensity, and fuel quality effects increased the carbon emissions during 2015-2019, while these effects were countered by renewable energy penetration and fuel switching, both decreasing the carbon emissions.

GDP per capita effect and population effect are significantly affecting the increase in carbon emission across all the sub-periods/time intervals. This conclusion is similar to that of (Lin & Ahmad, 2017). The high output growth along with population growth have been recognized as paramount factors that drive carbon emissions throughout the analysis. Therefore, when carbon emissions are taken as a measure of pollution, our analysis confirms that the increase in economic growth is followed by an increase in environmental harm. The existence of this kind of relationship can be taken as an indication that Pakistan is operating on the first half part of the Environmental Kuznet curve. Although the carbon emissions were tapered off for some periods, but they are not strictly on the fall.

The results of the substitution effect reveal that shifting energy consumption from fossil fuel to lower carbon intensity forms has effectively decreased emissions. But fuel substitution cuts emissions in the short run; as a result, to achieve significant long-term emissions reductions, energy demand needs to be met by carbon-free sources. (Unruh, 2000). When carbon-free (clean) alternatives to the market's dominant fossil fuel-based (dirty) technology are dynamically more effective, the transition to a low-carbon economy is impeded by fossil fuel-based technologies, and the nation is currently experiencing carbon lock-in (Mattauch et al., 2012). Similarly, the climate-induced damage of the growing population with the exhaustibility of natural resources will result in the emergence of the Malthusian trap of climate change. The findings show that the counterforces of fossil fuel substitution, fuel mix, and renewable resources of energy production may not be strong enough to break out of this trap.

People are debating how growth and climate stability can coexist as nations move toward low-carbon economies. The emerging development patterns of 21 nations—including Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, the Netherlands, Portugal, Romania, Slovakia, Spain, the United Kingdom, the United States, and

Uzbekistan—that have reduced GHG emissions while increasing GDP are used to support this argument (Aden, 2016). The World Resources Institute claims that since the start of the twenty-first century, these 21 nations have made great strides in their economic development while lowering yearly GHG emissions. The majority of these countries' decoupling of GDP and GHG emissions shows the viability and rising popularity of the switch to cleaner forms of economic activity. More than 90% of the nations that uncoupled GHG emissions from economic expansion have decreased the GDP proportion of the industrial sector. With an average reduction in carbon emissions of 15%, the industry share of GDP fell by around 3% throughout the group of 21 countries.

Objective three of the study is to determine different decoupling states, i.e., expansive coupling, expensive negative decoupling, recessive coupling, strong decoupling, weak decoupling, weak negative decoupling, recessive decoupling, and strong negative decoupling of energy-related carbon emissions from economic growth for every year from 1990 to 2019. In order to represent this scale of sustained economic growth, we have employed Eq. (32) below and calculated the decoupling index to indicate the progression of the economic system toward sustainable development.

6.3 TAPIO DECOUPLING STATUS OF CARBON EMISSIONS AND ECONOMIC GROWTH OF PAKISTAN

Table 6.13 displays the findings of the Tapio decoupling index analysis with the help of Eq. (32). Figure 6.3 depicts the graphical results of the decoupling indictor. The results reveal that the outlier values of the coupling index appear in the period of 2005–06, 2010–2011, and 2018–2019. These three points turn out to be in the state of expansive coupling, whereas the rest of the points are in the state of decoupling. When it comes to the decoupling elasticity, three points appear in the same weak decoupling state. Similarly, eight points represent the state of strong decoupling, while fifteen points are in the expansive decoupling state. Furthermore, we figured out that the decoupling index values are largely distributed in an area that is greater than 1, representing that during the past three decades, as economic development has increased, so have fossil fuel-related carbon emissions in Pakistan.

Table 6.13 States of Coupling and Decoupling of Carbon Emissions and Economic Growth for 1990-2019

Years	β C	β G	Elasticity = β C / β G	Interpretation
1990-91	-0.0043	0.0506	-0.08	Strong decoupling
1991-92	0.0620	0.0771	0.80	Weak decoupling
1992-93	0.1144	0.0176	6.51	Expansive negative decoupling
1993-94	0.0251	0.0374	0.67	Weak decoupling
1994-95	0.0662	0.0496	1.33	Expansive negative decoupling
1995-96	0.0614	0.0485	1.27	Expansive negative decoupling
1996-97	0.0173	0.0101	1.71	Expansive negative decoupling
1997-98	0.0530	0.0255	2.08	Expansive negative decoupling
1998-99	0.0618	0.0366	1.69	Expansive negative decoupling
1999-00	-0.0278	0.0426	-0.65	Strong decoupling
2000-01	0.0030	0.0355	0.09	Weak decoupling
2001-02	0.0427	0.0251	1.70	Expansive negative decoupling
2002-03	0.1071	0.0578	1.85	Expansive negative decoupling
2003-04	0.1468	0.0755	1.94	Expansive negative decoupling
2004-05	-0.0037	0.0652	-0.06	Strong decoupling
2005-06	0.0573	0.0590	0.97	Expansive coupling
2006-07	0.1163	0.0483	2.41	Expansive negative decoupling
2007-08	-0.0687	0.0170	-4.04	Strong decoupling
2008-09	0.0365	0.0283	1.29	Expansive negative decoupling
2009-10	-0.0097	0.0161	-0.60	Strong decoupling
2010-11	0.0260	0.0275	0.95	Expansive coupling
2011-12	-0.0086	0.0351	-0.25	Strong decoupling
2012-13	-0.0156	0.0440	-0.36	Strong decoupling
2013-14	0.0725	0.0467	1.55	Expansive negative decoupling
2014-15	0.1027	0.0473	2.17	Expansive negative decoupling
2015-16	0.0990	0.0553	1.79	Expansive negative decoupling
2016-17	0.0808	0.0555	1.46	Expansive negative decoupling
2017-18	-0.0198	0.0584	-0.34	Strong decoupling
2018-19	0.0114	0.0099	1.15	Expansive coupling
1990-2019	2.15	2.24	0.96	Expansive coupling

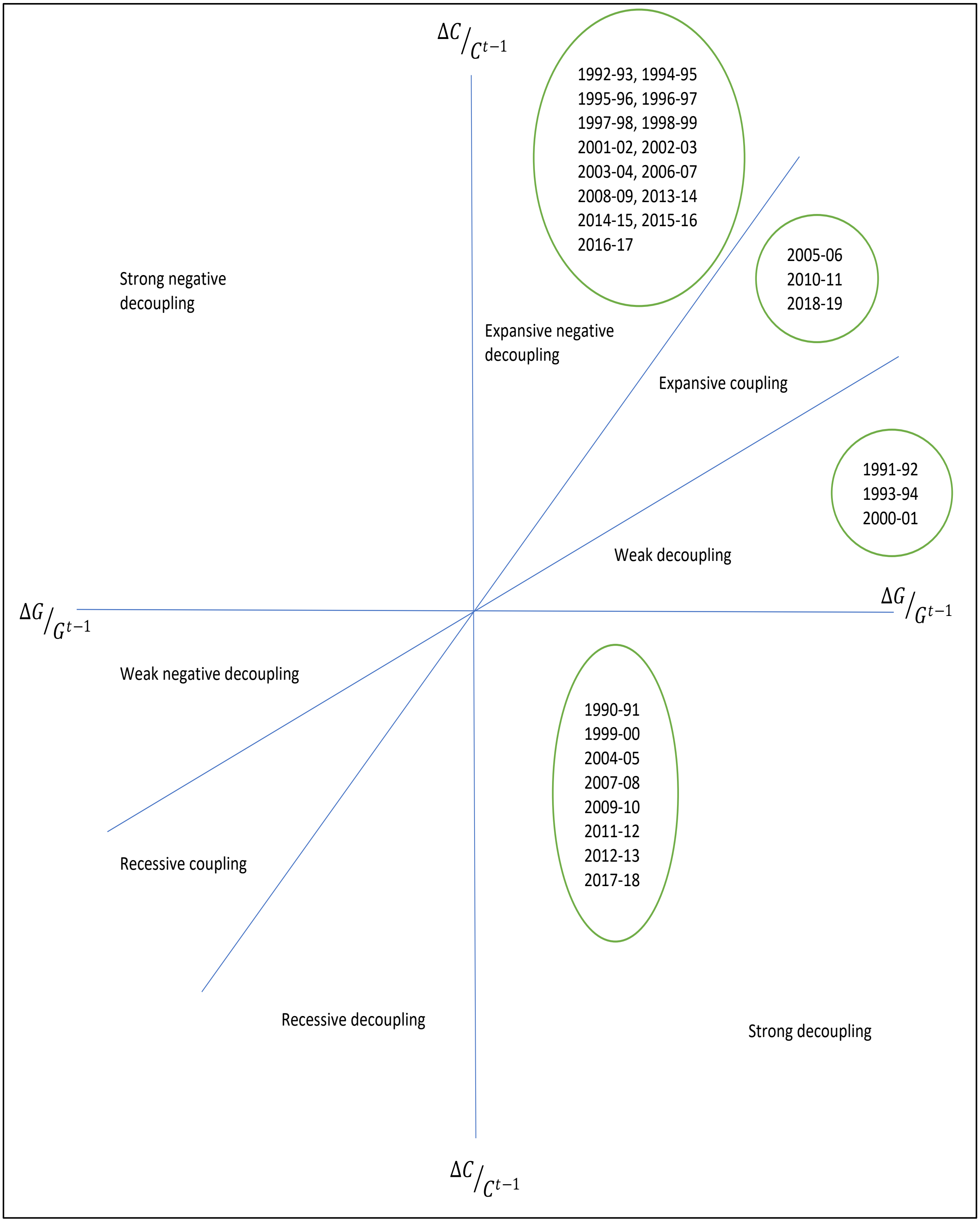

Figure 6.3 States of decoupling and coupling of carbon emissions and economic growth for 1990-2019

The Tapio decoupling indicator results reveal that during the period of analysis, Pakistan had experienced four decoupling states: strong decoupling, weak decoupling, expansive negative decoupling, and expensive coupling. Strong decoupling was observed in 1990-91, 1999-00, 2004-05, 2007-08, 2009-10, 2011-12, 2012-13 and 2017-18, demonstrating that while economic growth climbed, carbon emissions decreased. Furthermore, weak decoupling was reported in 1991-92, 1993-94 and 2000-01. Weak decoupling occurs when economic growth exceeds the growth of carbon emissions. Nevertheless, Pakistan has also experienced expensive negative decoupling during 1992-93, 1994-95, 1995-96, 1996-97, 1997-98, 1998-99, 2001-02, 2002-03, 2003-04, 2006-07, 2008-09, 2013-14, 2014-15, 2015-16 and 2016-2017, indicating that during these time periods, the growth of carbon emissions outpaced economic growth. This warns the government that it must diverge away from the energy systems that rely on fossil fuel energy and towards renewable energy. Moreover, Tapio's decoupling status shows that during 2005-06, 2010-11, and 2018-19, the country experienced expansive coupling. The expensive coupling illustrates that carbon emissions and economic growth were not decoupled, implying that there was no indication of decoupling, and both rose in positive terms. The outcomes of the Tapio elasticity analysis confirm the presence of expensive negative decoupling state in Pakistan during most of the period of analysis, while weak decoupling, strong decoupling, and expensive coupling have also been seen in different years. These results are comparable to those of (Khan & Majeed, 2019). The burning of extremely carbon-intensive fossil fuels in Pakistan has been attributed as a main contributor to the expensive negative decoupling state.

Hydropower was once a key component of the power sector of Pakistan, accounting for 45% of total power generation in 1991 (Asian Development Bank, 2016). Since 1992-93, the trend in the share of power generation between thermal and hydel has been changed. The proportion of hydel is continuously decreasing while the percentage of thermal is rapidly increasing. In 1998, hydel had a nearly 13.1% share, which had dropped to 7.7% in 2017-18. One of the primary causes of decreasing power generation from hydel power plants is the non-availability of water (Government of Pakistan, 2019b). At the same time, the declining hydel ratio demonstrates policy shortsightedness as well as the government's failure to complete such projects on time.

During the 1990s decade, the average consumption of petroleum products showed upward trends. On average, it has increased by 6% per year. In terms of the consumption of gas, it increased by 2.7% per annum. However, the consumption of coal, which showed wide variation in its annual consumption pattern, grew only by 0.9%. During this decade, the transport sector was the largest consumer of petroleum products, accounting for 47.7% of total consumption. It was mainly due to the growth in motorized vehicles at about 8% per annum. The transport sector's demand for petroleum increased at a 6.8% annual rate (Government of Pakistan, 2001).

Pakistan's dependence on natural gas in its total energy mix is decreasing over time. In 2005, gas accounted for about half of Pakistan's primary energy mix. In 2006, Pakistan's reliance on natural gas hit an all-time high of 50.4% of the total energy mix. Since then, due to the lack of major gas field expansion, the share of gas has steadily declined, and the proportion of imported energy demand started to increase. Between 1998 to 2001, Pakistan's dependency on oil reached 43.5% (Government of Pakistan, 2019b). Moreover, recently increased coal and imported LNG consumption since 2015 constituted a magnificent increase of these fuels in energy consumption. In 2017–18, the domestic supply of gas was nearly around 35% of the total primary energy supply, while oil reported 31% of the total supply (Malik et al., 2019). Weak decoupling was recorded in 2000-01, which might be attributed to decreasing consumption of petroleum products as a result of the September 11, 2001, events.

According to Mahmood & Shahab (2014), after 2001, the coal consumption in the cement industry increased by 61%. The primary reason for the expensive negative decoupling is the cement industry's shift from gas to coal, a very carbon-intensive fuel. Carbon emissions showed strong decoupling in 2007-08. During this period, the country experienced a serious energy shortage, and the factories had to cope with frequent power outages, which restrained the manufacturing units from working at their full production capacity. When the cost of generating thermal energy grew, WAPDA, due to its weak financial position, was unable to procure all of the electricity that private sector power projects could supply (Khawaja et al., 2010).

During the first three years of the 2010s, high oil prices (above $100 per barrel) decreased demand for petroleum, resulting in fewer imports. During the same time period, a steady decline in coal prices induced local traders not to import a large quantity of coal, due to which the sectors were bound to move to informal sources of energy, like biofuels. The second reason for the apparent reduction in carbon emissions might be the shortage of energy in the early years this study period, as a result, the high-energy-consuming industries simply reduced their operating rates (Malik et al., 2019).

The percentage of consumption of oil has decreased significantly since 2014. The proportion of the power sector in oil consumption fell substantially. The newly installed power plants shifted to inexpensive fuels, but the transport sector's proportion of oil use grew. The rise in the share of transportation is primarily due to the lower domestic petrol prices and higher imports of used automobiles. During July– February in 2017–18 (a period of strong decoupling), the percentage of transport sector share in oil consumption climbed to 64.40% from 57.20% over the course of the same months as of the previous year. However, with the advent of less expensive alternative energy sources such as LNG, hydro, and coal, the percentage of power fell to 26.40% from 33.20% during the periods under discussion (Malik et al., 2019).

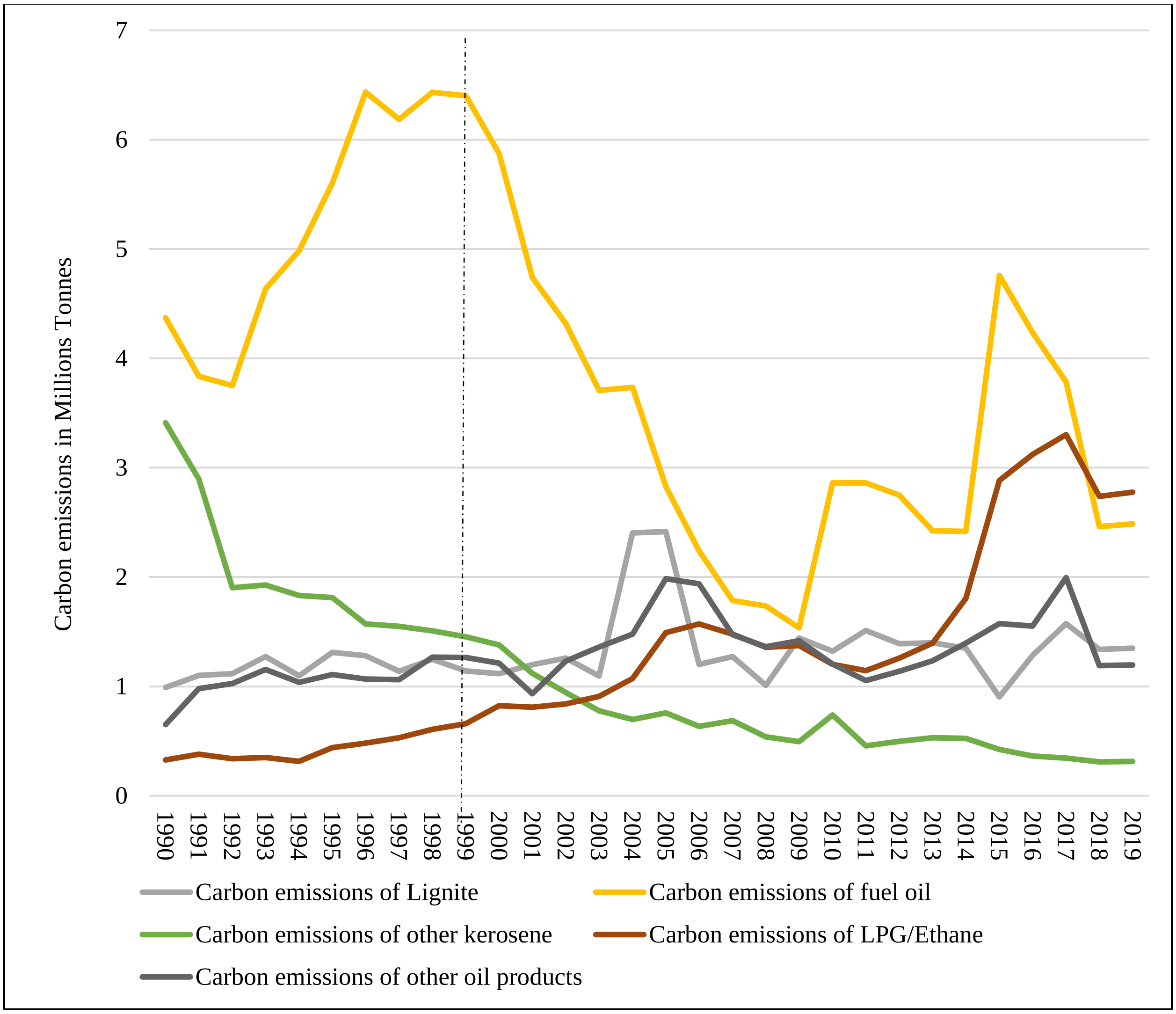

Figure 6.4A Trends of Carbon Emissions from Various Fossil Fuels from 1990-2019

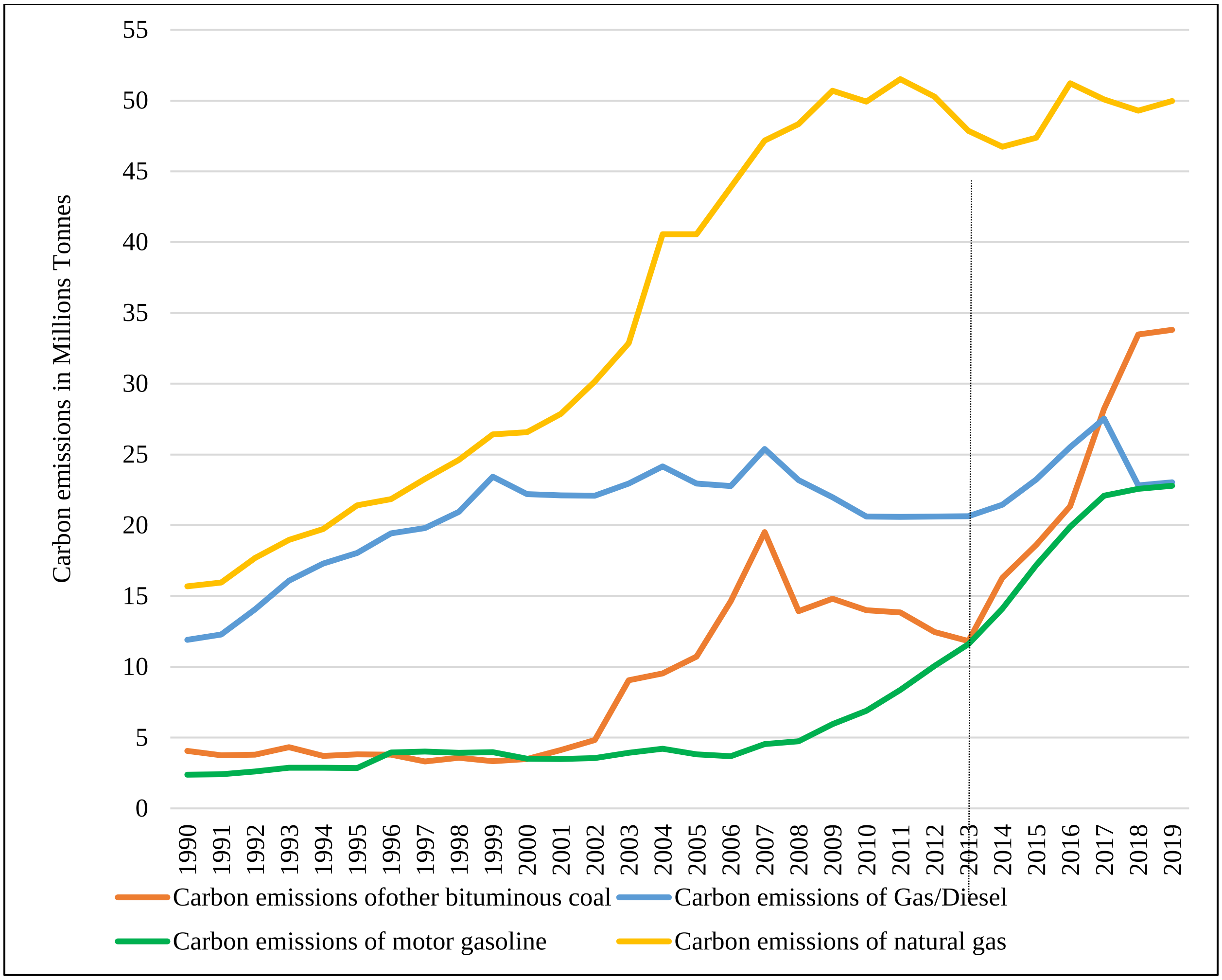

Figure 6.4B Trends of Carbon Emissions from Various Fossil Fuels from 1990-2019

There are several reasons why Pakistan is exploring alternatives to fossil fuels. Pakistan's natural gas reserves are depleting rapidly, and the country is struggling to keep up with the demand for gas. As a result, the government has been exploring other sources of energy, such as petroleum and coal. Pakistan's economy is growing rapidly, and with it, the energy demand is increasing. Pakistan is also exploring renewable sources of energy. However, these sources are not yet able to meet the country's growing energy demands. The cost of producing petroleum-based energy is relatively lower compared to gas. Petroleum can be transported easily, and its distribution network is well established, which makes it easier for the government to ensure an uninterrupted supply. Similarly, Pakistan has large coal reserves, particularly in the Thar region, which can be used for power generation. This makes it a cheaper and more abundant source of energy compared to other sources, which have to be imported. Especially, Pakistan is heavily dependent on imported gas, particularly from the UAE, which makes it vulnerable to supply disruptions and price fluctuations. Shifting to coal would help reduce this dependence and improve energy security. As Pakistan's power demand is growing rapidly, and coal-fired power plants can help meet this demand. Coal-fired power plants can also be built relatively quickly, which makes them a more attractive option for meeting short-term energy needs. While coal is a dirtier source of energy than gas, Pakistan has taken steps to mitigate the environmental impact of coal-fired power plants by using cleaner technologies, such as ultra-supercritical boilers and emissions control systems.

There could be several reasons why Pakistan is not using kerosene as extensively as it used to in the past. For example, Pakistan has diversified its energy mix in recent years, with a focus on LPG, coal, and renewable energy sources like solar and wind power. As a result, the demand for kerosene has decreased, and other fuels have become more readily available and affordable. Kerosene prices are subject to significant fluctuations in global markets, which can make it an unreliable fuel source. Additionally, Pakistan has struggled with inflation and economic instability, which can make it difficult for consumers to afford more expensive fuel options. Moreover, kerosene is a flammable and hazardous material that can pose a risk to users if not handled correctly, which may have contributed to a decline in its use. Overall, while kerosene may still be used in some parts of Pakistan for specific purposes, its use has declined in recent years due to a combination of economic, environmental, and safety factors.

There are several reasons why Pakistan is using more bituminous coal. Bituminous coal is a type of coal that has a higher energy content and lower sulfur content compared to other types of coal, such as lignite or sub-bituminous coal. Pakistan has significant reserves of bituminous coal, and it is one of the most abundant fossil fuels in the country. This makes it a readily available and affordable source of energy. Bituminous coal is a reliable source of energy that can help meet this growing demand. Bituminous coal is more efficient compared to other types of coal, as it has a higher energy content and burns cleaner. This makes it an attractive option for power generation and other industrial processes. Bituminous coal is relatively inexpensive compared to other sources of energy, such as oil and natural gas. This makes it a cost-effective option for power generation and other industrial processes.

Pakistan has been facing an energy crisis for many years, with frequent power outages and load shedding affecting households and industries. LPG is seen as a more reliable and efficient alternative to traditional fuels like natural gas and electricity. Pakistan's population is growing rapidly and with it the demand for energy. LPG is seen as a convenient and affordable fuel source, particularly in rural areas where there is limited access to electricity and gas pipelines. The government of Pakistan has been providing subsidies for LPG to make it more affordable for low-income households. LPG is considered to be a cleaner burning fuel compared to other traditional fuels, which is an important consideration for countries trying to reduce their carbon footprint.

Figure 6.4A and 6.4B shows a long-term perspective of carbon emissions in Pakistan from 1990 to 2019 from various fossil fuel types. Total emissions due to most of the fossil fuel burning in Pakistan have increased with time. It can be observed from Figure 6.4A that the carbon emissions due to fuel oil has started declining after 1999. This is so because the utilization of coal is replacing the utilization of oil in power generation. Reduction in the emissions from the use of kerosene can be observed with the passage of time. Kerosene is often used in households without electricity usually in rural areas. LPG/ethane contributes more to carbon emissions than other oil products and lignite. Figure 6.4B reveals that natural gas, motor gasoline, diesel, and bituminous coal contribute significantly to environmental degradation. Carbon emissions due to the use of bituminous coal consumption have increased significantly after 2013. A sharp increase in the carbon emissions due to motor gasoline can be seen from Figure 6.4B. On the other hand, the carbon emissions due to motor gasoline and diesel remained a minority as compared to the bituminous coal in the past few years due to the rise in coal fire plants in the country.

In recent years, Pakistan has embraced new sources of energy such as solar, wind, LNG, and bagasse-based power. Despite the fact that addition sources of energy have been added, the scale of the addition of renewable energy remains minor. The share of coal stayed in the single digits throughout the previous two decades, except for 2018, where it has a recorded share of 12.7% in total energy consumption. Likewise, the share of renewables was 0.3% in 2015, which has steadily increased to 1.1% in 2018. Similarly, the share of nuclear has also gradually increased to 2.7% in 2018 from 0.2% in 1997 (Government of Pakistan, 2019b). Furthermore, in recent years construction sector has begun working on LNG-based power projects and imported coal, with the anticipation that such kind of projects would boost the need for these imported fuels in the future. To summarize, as growth in the primary energy supply mostly comes from a rise in the fossil fuel supply, due to this reason, Pakistan’s carbon emissions are growing with time.

CHAPTER 7

CONCLUSION

The study sought to investigate the likelihood of the simultaneous existence of three fundamental pillars of sustainability in Pakistan from 1990 to 2019. The constituents of sustainable development are selected from the Seoul Initiative Network on Green Growth presented in MCED-5. Green growth, according to the ministerial declaration, is an approach towards sustaining economic growth and creating employment opportunities, both of which are required to effectively reduce poverty while dealing with natural resource depletion and climate change issues.

The findings of the study pointed out the importance of employment as the key link between sustained growth and poverty alleviation. The rise in long-term economic growth is supposed to effectively mobilize and employ all possible mechanisms for promoting employment to decrease poverty. Sustainable economic development drives resource-efficient technologies that reduce the carbon intensity of production, but it does not save natural resources from depletion. Our study found that natural resources are being exploited in pursuit of higher living standards with rising productivity. Increasing net national income and increase in natural capital degradation indicate that Pakistan is following a path that is weak sustainable. Due to this reason, Pakistan seems to be concentrating on increasing the total stock of capital. Hence, there is a possibility of irreversible damage to the natural capital. The results essentially confirm that Pakistan's domestic biocapacity is under pressure due to the business-as-usual approach. Thus, it is needed to transform our economy from the path of weak sustainability to strong sustainability. The economic development of Pakistan requires measures to improve its stock of natural capital. The future sustainability of many industries such as forestry, fisheries, tourism, mining, and agriculture is based on it.

Increased carbon dioxide emissions have made climate change a global issue. Due to this reason, exploring the elements that cause carbon emissions is required as it is essential to adopt effective mitigation programs. As a result, forces that drive carbon emissions are investigated by employing Log Mean Divisa Index-1 (LMDI-I) decomposition techniques on the extended Kaya identity model for the period from 1990 to 2019. Energy intensity, fuel quality, renewable energy penetration effect, economic activity, and population size all contribute positively to increased carbon emissions, according to the decomposition results. Fuel switching is a factor that reduces carbon emissions. The data reveals that across the study period, both population and economic activity played a substantial role in carbon emissions. Pakistan's rising energy-related carbon emissions are hastened by the population size effect during the period of analysis. The cumulative effect of population size on carbon emissions itself is 2.286, which is much bigger than the effect of any other factor. With a single threat of this scale, it is highly likely that there will be a significant rise in the amount of carbon emissions produced over the next decades.

Tapio's decoupling status of energy-related carbon emissions from economic growth depicts Pakistan's decoupling status from 1990 to 2019. During the study period, Pakistan experienced four decoupling states; however, the most notable is expensive negative decoupling indicating that the growth in carbon emissions exceeds economic growth. In some years, the expensive coupling has also been seen, which indicates that carbon emissions and economic growth also have an upward trend and do not appear to be decoupled. Weak decoupling has also been noticed in many years, which implies that economic growth has been relatively higher than carbon emission growth. However, in a few years, economic growth has been positive while carbon emissions have been negative, indicating a strong decoupling. Pakistan’s most prominent state among all decoupling states is expensive negative decoupling, which highlights the need for some specific policy actions to support long-term economic growth and reduce carbon emissions.

This study provides the following policy insights for the government on protecting Pakistan's natural wealth.

7.1 Policy Implications

1. Fiscal policy reforms and the reallocation of government budgets can support investment in natural capital. For example, removing fossil-fuel subsidy of about 250 billion Pakistani rupees in the fiscal year 2022 and reallocating funds to develop green technologies, best sustainable land management practices, and building climate-resilient coastal

infrastructures, would reverse not only environmental degradation but also enhance human well-being.

2. The private sector has a vital role to play in natural resource conservation and management. The government can provide incentives to the private enterprises to protect and enhance the natural capital. Incentives can be provided in various ways, e.g., grants, low-interest loans, and tax benefits.

3. The government can shift a portion of agriculture subsidies to stimulate landscape restoration. Agriculture subsidies (e.g., on pesticides and fertilizers) often lower soil productivity and fail to boost farmer income. The government can better achieve environmental goals and ensure sustainable farm income by providing subsidies to those who adopt better land management practices or the latest technology. The importance of aligning agricultural subsidies with a comprehensive set of societal goals that include the environment is increasingly important. According to the World Bank report 2020, redirecting agricultural subsidies to fund more R&D, innovation, and research might reduce emissions while feeding a growing global population. According to the report, shifting subsidies to support R&D will help small farmers and lead to a more equitable allocation of the economy. Therefore, governments should reorganize subsidies to encourage effective fertilizer usage, safeguard against additional clearing, and restore abandoned agricultural land.

4. The high initial cost of installation is one of the major obstacles to the adoption of renewable energy projects. In addition to this, the large-scale storage capacity of the produced energy is expensive and represents a major challenge of these technologies in terms of storage capabilities, especially during days when the weather events are unpredictable. To combat this, finance availability should be viewed to help alleviate the capital costs of renewable technology. Nature performance bonds (NPBs) could be one way for the government to access credit not only for economic and social priorities but also to fulfill its commitment to spending on nature. United Nations Development Program is providing technical assistance to Pakistan for the best design of NPBs. Pakistan must engage in dialogue and negotiations with the creditors to explore this opportunity for financing its biodiversity conservation initiative.

5. In spite of the fact that substituting fuel can facilitate a transition path and compliance with the Sustainable Development Goals for 2015 (SDG 2015), this only results in a reduction of emissions over the course of the short term. In order to achieve significant and long-term reductions in emissions, it will be necessary to find carbon-free sources of energy. Energy efficiency can be enhanced by increasing energy intensity and the penetration of renewable energy, but this needs investment in such technological improvement.
6. The government of Pakistan has set a goal to increase the proportion of renewable energy production in the total energy mix to 30% by the year 2030 under the Alternative and Renewable Energy Policy 2019 (Government of Pakistan, 2019a). Maximum energy projects of Pakistan are financed by China under the China-Pak Economic Corridor for exploring coal reserves with financing as most effective to achieve energy security and self-reliance, and few renewable energy projects. Coal-fired power generation has increased from 61 GWh in 2012 to 15,774 GWh in 2018 (Bhandary & Gallagher, 2022). Prioritization of coal-fired plants must be prohibited in order to tackle the barriers that stand in the way of lower carbon. To keep the temperature below 1.5ºC-2ºC under the global climate agreement known as the Paris Agreement, the energy policies should focus on greener policies (Asian Development Bank, 2017).
7. The main driving forces of carbon emissions are population size and wealth. Population growth and wealth increase lead to a direct impact on the unsustainable and complex nature of consumption and production of goods/services. The cost of environmental and resource degradation is not incorporated in the prices of goods and services. Therefore, many goods remain cheap and low prices become a major reason for overconsumption and production. Fiscal reforms using economic instruments can integrate such negative externalities in the prices to reflect the true cost of the goods and services. For example, the removal of subsidies and increasing tax burden on activities causing environmental pressure and natural resource use will help the society to move towards a sustainable development path and increased welfare.

7.2 Limitations and Future Directions of the Study

The following are the limitations of the study:

1. The study has analyzed the impact of factors affecting energy-related carbon emissions at the national level only. On the other hand, we found distinctive disparities in energy-intensive carbon emissions among different productive sectors in an economy. The country's improved economic condition benefits the population by increasing income levels across all regions, which leads to an increase in energy consumption in every sector of the economy. However, carbon emission per unit of GDP of a given economic sector depends upon the economic activity and the consumption of the natural resources in that area. Hence, two factors explain the disparities in carbon intensity between different sectors: 1) differences in energy efficiency and 2) differences in each sector's economic activity. The study was unable to estimate these two factors at the sectoral level due to limited data available.

2. This study has established the systematic relationship among the variables that constitute "sustainability" depending upon the objective of the study. However, the quality of life is inextricably linked to sectoral policies of development. In this regard, the strategic planning for sustainable development at the sectoral level is particularly significant.

Limitations of the study point towards the future directions of the study as follows:

1. It is important to determine and analyze the different patterns of carbon emissions across different economic sectors.
2. Likewise, population growth contributes to the emissions by demanding more from different sectors, e.g., transportation, goods/services, and power supply. Similarly, deforestation, land use, and burning of wood fuel due to population increase can also pose a risk to the potential ability of the environment to absorb emissions. This further increases environmental pollution. This implies that population distribution in different sectors may have an impact on carbon emissions at different scales. This aspect needs to be explored in the future.
3. Similarly, analyzing different decoupling states based on the factors that influence carbon emissions at the sectoral level is important. The analysis of exploring decoupling states for different sectors will provide further support for classifying the sensitivity of the environment. Such analysis will also provide further opportunities to deepen the present investigation to sketch a more comprehensive view of the economy.

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