THE IMPACT OF ECONOMIC GROWTH AND ENVIRONEMENTAL SUSTAINABILITY ON CARBON EMISSION IN SELECTED SOUTH ASIAN COUNTRIES: A PANEL ARDL MODEL ANALYSIS

A Thesis

Submitted to the Master of Finance in Sustainable Finance Study Program at Faculty of Economics and Business in partial fulfillment of the requirements for the degree of

Master of Finance in Sustainable Finance (M. Fin.)

by:

Mohammad Jawid Marwat

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ABSTRACT

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Rising CO2 emissions in South Asian economies pose significant environmental challenges, driven by industrialization, economic progress, foreign direct investment (FDI), and agricultural productivity. This study aims to examine the impact of economic development on CO2 emissions and explore influence of GDP per capita, FDI, industrialization (INDS), and agricultural productivity (AGVAD) on emissions in the short and long run, and examination presence of the Environmental Kuznets Curve (EKC) in selected South Asian countries over the past 40 years. Using a quantitative approach, panel ARDL model through Pool Mean Group (PMG) estimator is employed, justified by the failure of Dynamic Fixed Effects and Mean Group estimators, balancing long run homogeneity with short run heterogeneity. Short run findings reveal insignificant effects, with agricultural productivity, industrialization, and FDI reducing emissions by 1.92%, 1,89%, 0.98%, respectively, while agricultural and FDI and industrial FDI show negligible impacts, highlighting weak sectoral dynamics. The GDP squared term provides no EKC support, and the ECT of interaction model's indicates weak convergence. Long run findings highlight sectoral influences, with agricultural productivity and FDI the result further demonstrate the increasing of emissions by 1.18% due to intensified agricultural practices, while industrialization and FDI reduces emissions by 6.70% reflecting green industrial technologies. FDI showed significantly increase emission by 141.15%, indicating a pollution haven effect, while GDP squared lacks EKC support. The significant ECT suggests a 19.32% adjustment speed toward equilibrium. These results underscore the need targeted policies to regulate agricultural FDI, promote green industrial FDI, and implement structural changes to mitigate emissions, as economic growth alone does not reduce CO2 emissions. Policymakers should prioritize sustainable agriculture and stringent FDI regulations to address South Asia's environmental challenges effectively.

Keywords: *CO2 Emissions, Panel ARDL, PMG Estimator, South Asia, FDI, Agriculture productivity, Industrialization, Environmental Kuznets Curve*

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ABBREVIATION DIRECTORY

ADF	: *Augmented Dickey-Fuller*
AIC	: *Akaike Information Criterion*
LLC	: *Levin, Lin and Chu*
IPS	*: Im-Pesaran-Shin*
ECM	: *Error Correction Model*
DFE	: *Dynamic Fixed Effect*
MG	: *Mean Group*
PMG	: *Pooled Mean Group*
ARDL	: *Autoaggressive Distributed Lag*
BEA	: *Bureau of Economic Analysis*
IMF	: *International Monetary Fund*
ADB	: *Asian Development Bank*
UNEP	: *United Nation Environmental Program*
EKC	: *Environmental Kuznets Curve*
IPCC	: *Intergovernmental Panel on Climate Change*
GHG	: *Green House Gas*
IEA	: *International Energy Agency*
AFOLU	: *Agriculture, Forestry, and Other Land Use*
LULUCF	: *Land Use, Land Use Change and Forestry*
OECD	: *Organization for Economic Cooperation and Development*
UNIDO	: *United Nation Industrial Development Organization*

CHAPTER I
INTRODUCTION

In this section, the problem statement, study objectives, research questions, and background information about the investigation are presented.

1.1. Research Background

Economic growth and environmental sustainability are closely interwind, requiring a balance to ensure long-term societal and ecological well-being. Economic growth, definite as the sustained growth in production and consumption of goods and services tsssssssso raise living standards, drives positive socio-economic outcomes but often compromises environmental quality (Zeng et al., 2020). It is important to note that economic activities, notably the burning of fossil fuels, are a significant contributor to global climate chang. These activities are responsible for approximately 87% of anthropogenic carbon emissions, with deforestation accounting for 9% and industrial processes accounting for 4% (Le et al., 2012). The Intergovernmental Panel on Climate Change (IPCC) confirms that carbon dioxide emissions from fossil fuels are the primary cause of rising global temperature since the mid -20th Century (IPCC, 2018). Since the 1970s, researches and policymakers have recognized the need to harmonize economic success with environmental preservation to mitigate these impacts (Sachs et al., 2019). Achieving sustainable development thus demands innovative strategies to dissociate economic growth from environmental degradation.

This rapid release of carbon emissions, particularly since the industrial revolution, has disrupted the natural carbon cycle, liberating carbon stored in rocks for millions of years over a relatively short period. Consequently, the accrual of carbon dioxide in the atmosphere has outpaced natural absorption mechanisms, exacerbating global warming. On the other hand, photosynthesis in plants changes an additional 5% of carbon dioxide into storable carbon-based matter, offering a partial counterbalance. However, as Galvan et al. (2022) highlight, the imbalance in the carbon cycle means that natural processes may take 50 to 100 years to consume and mitigate the excess carbon dioxide, underscoring the long-term challenge of restoring equilibrium and the urgent need for interventions to decrease anthropogenic productions and support natural carbon sequestration.

Meanwhile, economic growth remains a top priority for nations worldwide, particularly for South Asian emerging economies, which host 40% of the world's poor (World bank, 2021, Asian Development Bank, 2022, Rahman et al., 2020). With a regional per capita GDP of US$ 1,779, South Asia lags significantly behind the world's middle income (US$10,636) and low income (US$ 4,497) nations (World Bank, 2019). However, recent rapid growth offers hope, with Nepal leading at 7.9% annual GDP growth in (2017), followed by Bangladesh (7.28%), India (6.68%), Pakistan (5.70%), and Sri Lanka (3.30%) (World Bank, 2019). Given persistent scarcity, constant and rapid economic expansion remains critical for these countries.

Over the past two decades, South Asia's geographical vulnerability to global warming and climate change has intensified political and economic concerns. The 1997 Kyoto Protocol expected to cut greenhouse gas (GHG) emissions by 5.2% below 1990 levels among 2008 and 2012, with carbon dioxide (CO2) known as the predominant GHG, peaking globally in 2010 (IEA, 2011). The 2002 Johannesburg Conference underscored CO2's double role as an economic driver and an environmental hazard. Furthermore, scholars and policymakers in the region increasingly focus on mitigating climate change impacts, with CO2 emissions from fossil fuels, deforestation, and industrialization recognized as primary contributors (Le et al., 2012, Galvan et al., 2022). Addressing this challenge is vital to equilibrium economic progress with environmental sustainability in South Asia.

Numerous studies have explored the link between carbon dioxide (CO2) emissions and factors such as energy consumption, industrialization, foreign directs investment (FDI), agricultural productivity, and economic growth, building on the global warming dynamics outlined earlier. Energy use, while crucial for economic development, often degrades environmental quality by growing CO2 emissions, as noted by Shabaz et al. (2016). Similarly, FDI, industrialization, and agricultural productivity are frequently linked to environmental degradation, though their effect on CO2 emissions varies (Jeble et al., 2019, Diem Pham & Nguyen Hoai, 2025, Nawaz et al., 2020).

Empirical evidence highlights a complex nexus among economic progress and carbon emissions. Shafik (1994) found that CO2 emissions rise with economic expansion, while Bengochea-Morancho and Martinez- Zarzoso (2004) identified positive correlation in high revenue nations and adverse one in low-income nations. Ali et al. (2016) and Bernard and Mandal (2016) suggest it can improve conservational quality by dropping CO2 emissions, whereas Zhang et al. (2017) and Le et al. (2016) argue it exacerbates degradation, particularly in middle-and-low-income nations, contrasting with its mitigating effect in high income nations. These discoveries underscore the requirement for South Asian economies to balance economic progress with environmental sustainability, as rapid development may intensify emissions, necessitating policies that leverage trade and FDI for cleaner outcomes, as highlighted by recent studies like Raihan and Tuspekova (2022).

Over the past decade, research has increasingly focused on consequence of foreign direct investment (FDI) on greenhouse gas (GHG) emanations, a critical concern for South Asian countries gripping with economic growth and climate change, as highlighted earlier. The pollution haven theory suggests that FDI inflows elevate carbon releases by encouraging investment from wealthy nations into emerging nations with lax ecological regulation, thereby increasing contamination in these regions. Developing countries may further relax laws to attract foreign capital and boost their economies, exacerbating emissions. This trend is compounded by corruption, which studies link to higher carbon emissions (You & Xiao, 2022, Ulucak, 2022, Adeel-Farooq et al., 2021, Ullah et al., 2021) posing a challenge to sustainable development in South Asian where rapid GDP growth (e.g., Nepal's 7.9%) coexists with environmental pressures.

Conversely, the pollution halo theory posits that FDI can decrease carbon emissions by presenting cleaner technologies, offering a potential mitigation strategy for the region. Evidence from states like Malaysia, Thailand, Singapore, Indonesia, and the Philippines shows mixed outcomes, where FDI initially increase emissions but may lower them over time by enhancing production efficiency (Caetano et al., 2022, De Vita et al., 2021). The relationship varies by income level, with FDI boosting power use and economic growth in high income nations, while its environmental impact differs in per capita income contexts (Salahuddin et al., 2018). This duality underscores the need for South Asia to harness FDI's potential for cleaner technology while addressing regulatory and corruption challenges to align economic expansion with climate goals.

Additionally, agriculture has been recognized as highly vulnerable to climate change despite the fact significantly contributing to carbon emissions and global warming, a critical issue for South Asian countries balancing environmental sustainability and economic development (Raihan et al., 2022).Agriculture, Forestry, and Other Land Use (AFOLU), along with Land Use, Land Use Change, and Forestry (LULUCF) activities, account for approximately one fifth of global annual carbon emissions, making them the second major source after fossil fuel combustion (IPCC, 2014). However, achieving long term development in the region requires enhancing agricultural productivity alongside maintaining environmental quality, as emphasized by Raihan et al. (2022). Increased agricultural output supports food security, improves incomes distribution, reduces poverty, and drive economic growth that is key priorities for South Asia, where per capita GDP lags behind global averages (Work Bank, 2021).

Furthermore, heightened agricultural productivity benefits ecosystems by reducing the need to convert forested land into cropland, thus protecting forests, minimizing pollutants, and curbing environmental degradation aligning with the region's climate mitigation efforts under frameworks like the Kyoto Protocol (Raihan et al., 2022).This productivity also strengthens government capacity to enforce environmental regulations and boost demand for cleaner products and services, supporting sustainable economic expansion. Nonetheless, growing concerns persist about agriculture's role in environmental degradation, particularly as intensification may increase emissions a tension evident in South Asia's rapid GDP growth and alongside climate vulnerabilities (Raihan et al., 2022). This dual impact underscores the need for policies that harness agriculture's economic benefits while mitigating its environmental footprint.

In recent decades, South Asian nations have experienced a significant surge in manufacturing, aligning with their rapid economic growth but, yet this industrialization poses challenges to environmental quality (World Bank, 2021). It intensifies resources use for production often overlooking environmental concerns, depletes mineral resources, adversely affect in natural ecosystems and population wellbeing (Rahman & Majumder, 2017), degrades air, land quality, and water (Li &Lin, 2015). This trend exacerbates carbon emissions, a key issue of the region given agriculture and industry's combined contribution to global warming (Raihan et al., 2022). Building on this, Chernwchan (2012) employed a two-sector neoclassical growth model in a small open economy to analyze industrialization's environmental impact, finding that a 1% growth in industrialization raises per capita emanations by 24%. This supports concerns about South Asia's industrial expansion, where lax regulations and FDI inflows as noted in the pollution haven hypothesis (Xiao, 2022), amplify emissions, necessitating sustainable industrial policies to balance economic progress with climate goals outlined in frameworks like the Kyoto Protocol.

Numerous studies show that environmental deterioration is frequently a result of economic development (Bekun et al., 2019; Song, 2021). According to the (EKC) theory, which was put forth by Krueger and Grossman in 1995, environmental degradation rises in the primary phases of a nation's economic expansion but progressively declines following a convinced level of industrialization. In emerging nations like South Asia, it is crucial for legislators to maximize the trade-off among ecological preservation and financial expansion.

South Asia, a unique landmass in southern Asia, includes Afghanistan, India, Bangladesh, Bhutan, Nepal, the Maldives, Sri Lanka, and Pakistan (Sivakumar and Stefanski, 2010). Covering 5.1% million km^2 or 11.51% of Asia, it hosts 1.749 billion people around one fourth of global population making it world most densely inhabited region (SACEP, 2016, South Asia Regional Overview, 2008). Its landscape spans the Himalayas in Nepal and Bhutan to the coastlines of the Bay of Bengal, Arabian Sea, and Indian Ocean. Featuring diverse ecosystems. Ecologically vital, it supports 15.5% of global flora, 12% of fauna, and 2.73% of the world forests, with the Hindu Kush Himalayan region shorting 25000 plant species (10% to the global total). India and Sri Lanka boast rich biodiversity, including over 14% of global mangroves and vulnerable wetlands

The region’s climate varies across six zones desert, semiarid, highland, humid subtropical, tropical wet and tropical wet and dry influenced by altitude, coastal proximity, and monsoons. Northern areas like the Indo Gangetic Plains experience warm and cold seasons, while southern regions face hot summers and rainy monsoons. This diversity, alongside rapid economic growth highlights South Asia’s challenge to balance development with environmental sustainability, as industrialization and agriculture drive carbon emissions (Raihan et al, 2022, World Bank, 2021). South Asia faces diverse climate change impacts soil erosion, saline intrusion, sea level rise, and glacial melt due to its varied climatic zones and rugged landscape, posing significant threats to sustainable development (WHO, 2015). Climate change, driven by life-threatening weather events like heatwaves, heavy and droughts rainfall, alters precipitation, cloudiness, and humidity across warm and cool climates over time, as noted by Singh (2009). These hazards challenge the region’s economic growth, such as Nepal’s 7.9% GDP rise, while intensifying environmental pressures (World Bank, 2021).

The primary driver of climate change in South Asia is rising consideration of greenhouse gases particularly carbon dioxide (CO2), fueled by rapid industrialization and anthropogenic activities (Raihan et al., 2022). India and Pakistan lead per capita CO2 emissions in the region, followed by Sri Lanka and Bangladesh, with Nepal fifth, and Afghanistan and Maldives contributing the least, while Bhutan ranks last. This emission pattern aligns with the region's industrial and agricultural expansion, necessitating sustainable strategies to balance growth with climate goals. The following figures demonstrate the contribution of carbon dioxide emission of South Asian nations.

In 2022, South Asian states displayed diverse fossil CO2 emission trends, reflecting their economic and environmental dynamics. India's emissions surged to 2,690 million tons, a 6.52% rise (164.9 million tons) from 2530 million tons in 2021, with per capita emissions increasing 5.7% to 1. 90 tons (from 1.79 tons) for its 1.43 billion people, driven by industrial and energy demands (IEA, 2023). Pakistan's emissions dropped to 199.33 million tons, a 7.74% decrease (16.73 million tons) from 216.06 million tons in 2021, with per capita emissions falling 9.3% to 0.83% tons (from 0.90 tons) for its 243.7 million population, likely due to reduced energy use amid economic challenges (ADB, 2022). Bangladesh's emissions rose to 109.08 million tons, up 3.57% (3.76 million tons) from 105.32 million tons in 2021, with per capita emissions up 2.5% to 0.65 tons (from 0.63 tons) for its 169.38 million people, fueled by economic growth (UNEP, 2023). Sri Lanka's emissions declined 12.44% to 18.54 million tons (from 21.17million tons), with per capita emissions dropping 13.0% to 0.82 tons (from 0.93 tons) from its 22.83 million people, reflecting lower energy use (World Bank, 2023). Nepal's emissions increased slightly by o.65% to 15.85 million tons (from 15million tons), with per capita emissions stable at 0.54 tons (a -0.2% change) for its 29.72 million people, indicating consistent energy patterns (FAO, 2022). These variations highlight the region's challenges to align growth with sustainability.

The region is more susceptible to climate change due to its geophysical and demographic characteristics. Agriculture, forests, water resources, and ecosystems are already feeling the impact of climate change. In South Asia, it is having an influence on the health of billions of people.

Furthermore, South Asia, land degradation brought on by wind and water erosion is a frequent occurrence. Nearly 90 million hectares of irrigated land in South Asia are severely impacted by water. Water erosion caused by salinity and has a significant impact on Bangladeshi, Indian, and Pakistan irrigated agriculture. Similarly, other kind of erosion that affects Afghanistan, India, and Pakistan is wind erosion brought on by desertification (UNEP 1997a).

In the same way, water scarcity is a problematic in many places of South Asia. Water scarcity brought on desertification problem in different parts of Afghanistan, India, and Pakistan. This is experiencing freshwater shortage as a result of salinity intrusion. Furthermore, the availability of useable water is reduced by water pollution (UNEP 1997b) caused by commercial pesticides, agricultural runoff, industrial wastes, and arsenic contamination.

Additionally, Pakistan has the highest rate of deforestation among South Asian nations. Deforestation causes species and habitat loss, which depletes ecosystems and biodiversity. Shrimp farming and salt production are also putting strain on mangrove forests in India Bangladesh, and Sri Lanka (UNEP 1997b).

In South Asia, growing urbanization and demographic pressure have intensified pollution, aligning with the region's rapid economic progress and environmental challenges (World Bank, 2023). Rising numbers of automobiles, brick kilns, and industrial activities have driven a 3.3% annual increase in greenhouse gas (GHG) emissions since 1990 (Khwaja et al., 2012). India leads the region in air pollution, followed by Pakistan, where brick kilns, industrial emissions, and vehicle exhaust are key contributors (Khawaja and khan, 2005). In Bangladesh, similar sources brick kilns, industries, and automobiles dominate, while forest fires are the primary cause in Bhutan. Nepal's air quality is worsening due to rising stages of harmful contaminants (Khawaja et al., 2012), and in Sri Lanka, motor vehicles, waste burning, and firewood use are major pollution sources (Senarath, 2003).

Rising CO2 emissions in South Asian economies, driven by macroeconomic factors such as foreign direct investment (FDI), economic development, industrialization, and agricultural productivity have garnered increasing scholarly attention over recent decades. These factors significantly influence environmental sustainability, yet region specific analyses, particularly in Nepal, India, Sri Lanka, Bangladesh, and Pakistan remain limited, with mixed results on the Environmental Kuznets Curve (EKC) theory. The heterogeneity of South Asian economies, with diverse economic structures and environmental policies, necessitates a nuanced investigation of long run and short dynamics. This study employs a panel ARDL model to analyze the impact of GDP per capita, FDI, industrialization, agricultural productivity, and GDP squared on CO2 emissions over 40 years, addressing the essential for targeted policy recommendations to alleviate emissions and promote sustainable growth in the region.

1.2. Problem Statement

Although the relationship between environmental sustainability and economic progress as key drivers of sustainable development is becoming more widely recognized, especially in South Asian nations, there is still a great deal to learn about the roles that FDI and agricultural productivity play as important determinants of carbon emissions. The intricacy of economic expansion activities, which both directly and indirectly fuel carbon emissions and environmental deterioration, presents difficulties for conservation and sustainable resource management initiatives. The evaluation is further complicated by the differences in the geographic, economic, and regulatory environments among South Asian nations. In order to close this gap, this study will empirically examine the effects of GDP, industrialization, agricultural productivity, and foreign direct investment on carbon emission. The results will be useful in developing policies that will lower emissions and promote ecologically sustainable growth.

1.3. Research Objective

1. To examine how economic expansion affects carbon emissions over the short and long terms in South Asian nations.
2. To investigate the immediate and long-term effects of industrialization, agricultural productivity, GDP progress, and foreign direct investment
3. To examine the presence of EKC curve in the short and long term in South Asian nations.

1.4. Research Questions

1. How does economic expansion affect carbon emissions over the short and long terms in South Asian nations?
2. How do agricultural productivity, foreign direct investment and industrialization, affect carbon emissions over the short and long terms?
3. Does South Asian countries have a long-term and short EKC curve?

CHAPTER II
INTRODUCTION

This chapter examines the literature that is pertinent to the linking among carbon emissions, environmental sustainability, and economic progress in a few South Asian nations. For a thorough grasp of this relationship, both theoretical and empirical research are investigated. The Environmental Kuznets Curve (EKC) theory, that postulates ana reversed U-shaped nexus between economic progress and environmental degradation is covered in the first section. It suggests that emissions increase with income at first but, then fall at specific income level. To put the EKC's applicability in context, it's theoretical underpinnings and criticisms are examined. The empirical data on the impact of economic expansion, industrialization, foreign direct investment, and agricultural productivity on carbon emissions is studied in the second segment, with focus on South Asian research. The chapter concludes by synthesizing the findings to create a conceptual framework that directs the ongoing investigation, pointing out gaps in the literature and defending the application of the EKC technique

2.1 Theoretical Foundation

2.2 The Environmental Kuznets Curve theory (EKC)

The challenge raised with the connection among environmental deterioration and economic progress appears to be a relatively new area of study, particularly in light of the proposed upturned U-shaped EKC. Identified as the Environmental Kuznets Curve (EKC) theory, several previous research have contended that there is reversed U-shaped link among the amount of economic development and carbon emissions. For instance, studies of Krueger and Grossman (1991), Song and Selden (1994) described by Qiang wang et al. in (2024) discovered the evidence for the EKC theory, which proposes that environmental quality is first deteriorated by economic progress and then improved later in a certain period of time see figure 1.

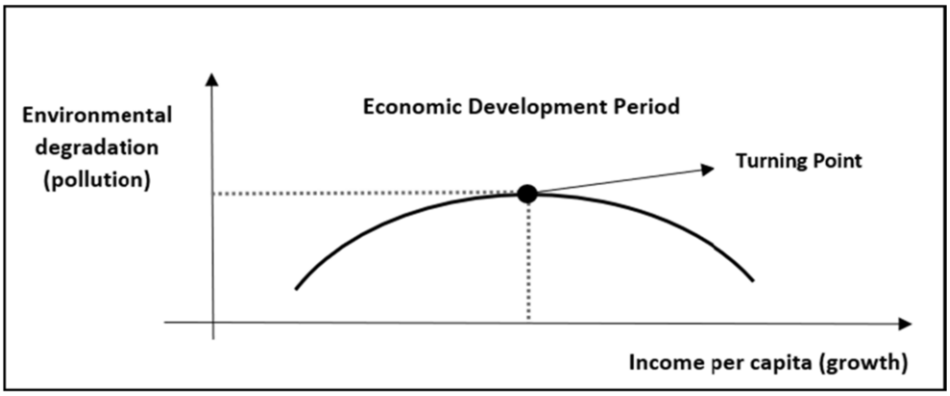

Figure 2.1 relationship between EKC economic development
Source. World Development Report (1992)

Numerous studies have been produced to explore this issue of EKC theory, environmental quality, economic growth, and the discussion surrounding it. And this issue has started heating up since past 20 years. However, there aren't many research that show this kind of relationship in Costa Rica. Simon Kuznets authored his seminal article, "Economic growth and income inequality," in 1955. His hypothesis was that the reversed U-shaped EKC indicates that income inequality increases in the initial phases of a nation's progress in parallel with its per capita income. This pattern persists until it hits a breaking point, at which point income inequality starts to decrease. Later on, it began to be applied to examine how environmental degradation is impacted by economic expansion.

The 1992 World Development Report was the first to use the inverted U-shaped EKC for environmental purposes (The World Bank, 1992). The EKC analyzed 47 cities across 31 countries in this groundbreaking report, posing the question of whether economic expansion raises emissions of sulfur dioxide. The outcome was similar to what was predicted using the initial inverted U-shaped EKC. Therefore, sulfur dioxide emissions rise in tandem with economic expansion until a sloping point, at which time the movement starts to reverse and the reverse relationship occurs. Nearly at the same time, other influential writers, like Krueger and Grossman (1991), examined the potential harm to the environment that the North American Free Trade Agreement would bring about described by Yusuf Muratoglu et al. in (2024).

Dinda (2004) described by Mohammad Mafizur Rahman et al. in (2020) points out that the reasoning behind the EKC is based on the shift from an agricultural society to an urban one that is dominated by industrial production. As incomes rise and time passes, the economic growth driven by industrial production will eventually lead to a decrease in pollution. Eventually, industrial production will be phased out in favor of a high tech, service-oriented economy, and as a result, society will shift its demands towards achieving a clean climate, which will reduce environmental degradation.

Based on scale, technological, and composition effects, such changes that are considered in nation's EKC also have hypothetically "proximate causes" (Stern, 2004). First, scale effect holds that increased economic progress leads to raise to contamination because increased output necessitates increased inputs, in which turn depend on increased natural resources (Grossman, 1991). The scale effect occurs throughout the early phases of agricultural production's transition to a more industrialized and service-oriented society seen in figure 2.

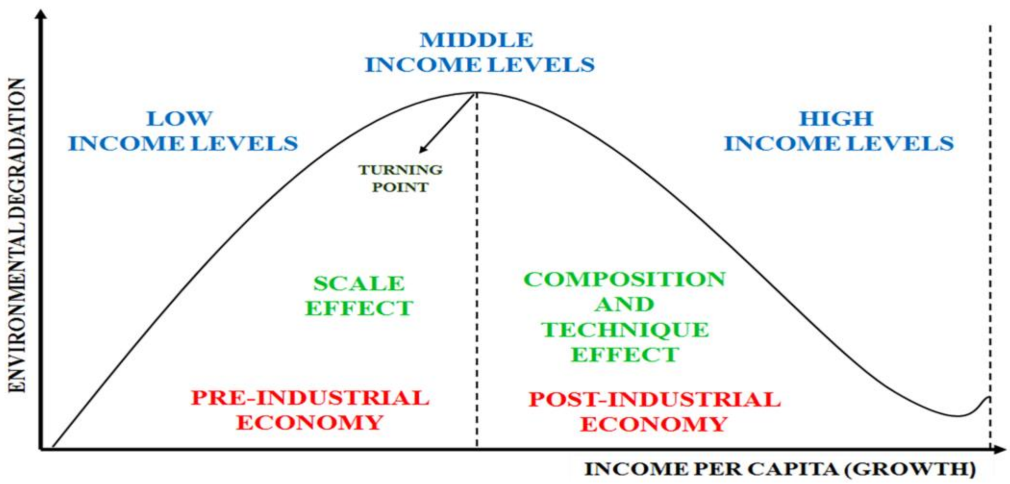

Figure 2.2 Environmental Kuznets Curve: Phases of environmental deterioration.
Source. Kuznets (1955) and AlKhras (2022)

The scale impact starts to be negated as economic expansion increases since industrial processes need efficiency and competitive advantage. It also coincides with societal demands for additional services. Phase-out of the scale effect starts to happen. The production mix starts to change as a result of the composition impact, which means that the market starts to require services in addition to consumer products. The composition of commodities and services requested changes when the market as a whole, including the public and private sectors, moves toward more services-intensive consumption pattern. This change occurs in tandem with a market that has a higher income level necessitating more study and development as well as more professional services to support a society with more wants and advancements. As the makeup of the commodities and services that society needs shifts, reliance on industrial production is reduced. Economic expansion may accelerate in society without worsening environmental degradation (Vukina et al. 1999). After reaching a sloping point, the EKC starts to fall.

In addition to the composition impact, the technological one starts drive a very significant shift toward additional effective production methods with growing back to scale, that also encourage businesses to produce at lower costs and encourage societies to spend more on R&D. More efficiency, decreased reliance on natural resources, and a decrease in pollution are all results of new technology.

As economies grow more rapidly and cultures transition from agricultural to service-oriented economies, they begin to demand cleaner environments. As their income per capita rises, so does their preparedness to pay for less environmentally harmful goods and services. In addition to the general public, political movements that represent them in Congress and civic society also support strict environmental regulations (Hettige et al. 2000). This presents an intriguing conundrum. The contentious claim that the only way for nations to get clean environment "is to become rich" was put out by Beckerman (1992). The EKC hypothesis has been the subject for several published research. The first worth mentioning is the study by Snobohn and Cederborg (2016), which uses cross-sectional framework to apply a database of 69 industrial and 45 underprivileged nations. They came to the very specific conclusion that environmental deterioration and economic expansion are related. There is no tipping point in the link among rising greenhouse emissions and rising per capita income.

The authors claim that the market mechanism is insufficient to change this forecast. Based on a time series analysis, Selden and Song (1994) conducted another noteworthy study using a sample of 30 nations. They came to the conclusion that there will be higher transportation-related greenhouse gas emissions and less severe environmental controls in nations with low population densities. They found that at high enough income levels, environmental contamination may decrease.

Furthermore, Panayotou (1993) conducted an examination of a number of pertinent dependent variables that are influenced by per capita income in a highly noteworthy work. He came to the conclusion that at higher stages of growth, the pressure from information-based companies and other service sectors associated with further environmental awareness and regulation, improved technology, and more green investments might eventually slow down environmental deterioration as mentioned, different authors have different conclusions on the EKC, but the database and econometric methodology are nearly always the same.

The environmental Daly curve and the Brundtland environmental curve theories are two other highly significant schools of thought that have been put to explain the connection among economic progress and environmental degradation as part of academic critique of the EKC theory. The Brundtland curve hypothesis was put forward by the World Commission on Environment and Development (WCED) in their well-known study "Our Common Future" in 1978. Another name for this report is the Brundtland report see figure 3.

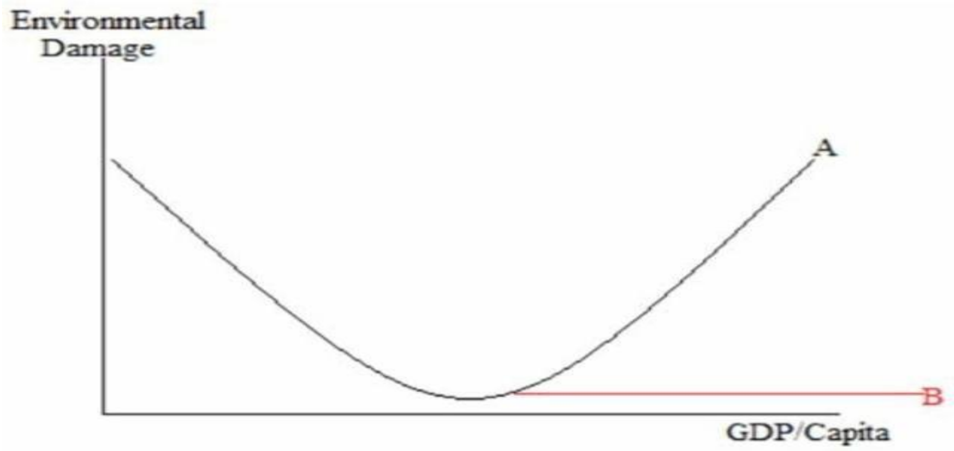

Figure 2.3 Brundtland environmental curve, U.N. Secretary General (1987)
Source. Report of the World Commission on Environment and Development

Degradation of environment declines as economic expansion progresses. Once a turning point is achieved, environmental mental harm continues to rise as economic expansion occurs. The Brundtland curve is U-shaped, in contrast to standard EKC. Countries continue to rely heavily on natural resources as long as they are impoverished. High levels of deforestation and over usage of productive areas result from their demands being met without giving environmental awareness or well-being priority. High levels of deforestation and over exploitation of productive lands result from this. The impoverished do this in order to temporarily maintain their standard of living. Even though environmental degradation eventually decreases as wages rise, it eventually reaches a point where pollution and resource destruction return to their initial levels. Growing dependance on production and consumption based on conventional economic models that rely on natural resources pushes this trend of environmental degradation upward once it crosses the Brundtland curve's minimum point. This idea does, however, give some cause for optimism. At point B, shown in figure 3, the degree of environmental harm may stabilize, allowing for the advancement of sustainable development and green technologies initiatives. Additionally, this can result in creative and sustainable production, which can mitigate the harm to the environment (Bratt, 2012). Specifically, Kuznets and Brundtland diverge from Herman Daly's (1973) proposal, also referred to as Daly's Environmental curve. There is no turning point in the Daly Environmental curve, as shown in Figure 4. He contends that a stable state economy is not possibility which makes his stance pessimistic. Despite initiatives to combat it through innovation and green technology, effects of our contemporary economy's significant reliance on natural resources and in output demand are irreversible.

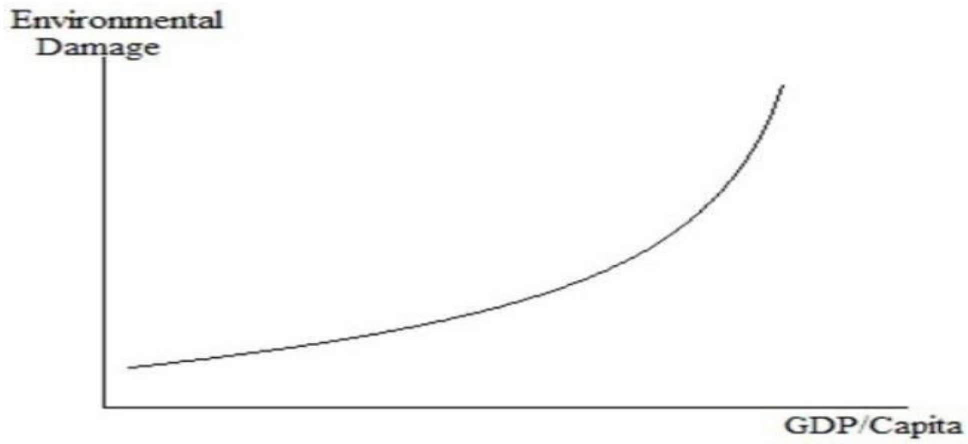

Figure 2.4 Daly Environmental curve

Source. Daly (1973)

Daly maintained that despite the encouragements put in place to create a cleaner planet, society's future is doomed because of the extent of the harm that humans have caused to the environment. Innovation alone won't stop the damaging trend brought on by unsustainable and excessive economic expansion. Positions obtained from the U.N. Secretary-General [The Brundtland report] (1987) and Daly (1973) are both adversarial and daring to go against the EKC as proposed by Krueger and Grossman (1991) and the World Development Report (The World Bank, 1992) described by (Singh et al., 2024).

The EKC's inverted U-shape indicates that environmental degradation first rises as incomes rise, but subsequently falls after GDP per capita reaches a particular threshold. Contrary results are found for the Brundtland curve, which shows that pollution and contamination decrease initially before either increasing or maybe stagnating at a particular income level. Due to the effects of the scale effect, both curves exhibit a sloping point and rise environmental degradation. The reason of decline in environmental damage is a clear distinction between these two views.

According to the EKC theory, environmental degradation is slowed down at later income levels by the efficiency of social pressure and production processes to have a cleaner planet. However, the Brundtland Environmental curve makes the case that reducing poverty creates room for environmental improvements to occur early in the increase of revenue.

On the other hand, the Daly Environmental curve shows no tipping point because environmental harm is caused by pressure of additional natural resources produce and increased production. Comparatively speaking, the scale effect is the shared factor that contributes to rise environmental degradation in all three of these hypotheses.

2.3 Nexus among Economic Progress and Carbon Dioxide Emission

Analyzing sustainable economic development necessitates a careful examination of its environmental consequences, particularly concerning carbon emissions. In their seminal 1993 study Grossman and Krueger explored the nexus among GDP per capita and environmental quality, focusing on urban air pollutants such as sulfur dioxide (SO2) and suspended particulate matter (SPM). They proposed the Environmental Kuznets Curve (EKC) theory, suggesting that environmental degradation firstly rises with economic progress but finally decreases once a certain income threshold estimated at ($4000 - $5000) is reached. This implies that as economies grow environmental concerns become more prominent, prompting efforts to improve air quality. At higher income levels, around $10000 GDP per capita, significant environmental improvements often occur.

Building on this Selden and Song (1994) employed panel data techniques using fixed and random effects models and found that the turning points for pollutants like SO2 and NOX could exceed $8000, suggesting variability across contexts. Their findings reinforce the EKC theory by demonstrating a nonlinear relationship among income and emissions. The digital economy significantly improves CO2 emission efficiency, especially in high income regions. This suggests digitalization promotes greener growth (Xu W and Wan W, 2025). A reversed-U relationship between GDP and emissions existed historically, but has weakened in recent decades, suggesting that economic growth no longer reduces emissions without additional policy (Freire-Gonzalez et al., 2024). The EKC holds mainly in low and lower middle-income nations. In high-income nations the relationship is mixed and more compels, suggesting EKC is not universal (Liping Gao et la., 2024). Given the economic diversity in South Asia, it is critical to empirically assess whether economic growth has statistically significant impact on CO2 emissions in both short and long run across the region.

H1. Economic expansion in South Asian nations has a major long and short-term impact on carbon emissions.

H2. The EKC curve was seen in South Asian nations both in the short and long term.

2.4 Nexus among Foreign Direct Investment (FDI) and Carbon Dioxide Emission

The three fundamental concepts that theoretically support the connection among foreign direct investment and environmental are, pollution-halo, pollution-haven, and scale impact. According to the pollution-haven theory, nations with laxer environmental laws may attract more international investment. Profit-driven international companies may avoid the costly environmental regulations of their native nations. Accordingly, this theory implies that FDI might increase the chance of environmental contamination (Salam et al 2019, Tsai et al 2011). The pollution-halo theory states that multinational companies tend to transfer environmentally beneficial technologies to the host country through foreign direct investment (FDI) when they adhere to global environmental standards. In this circumstance, FDI may have beneficial or undesirable impact, which could be reason to the environment to improve or worsen even more (Pao et al 2011) described by Lorente et al in (2019). The scale-effect theory is the third viewpoint utilized to study the nexus between FDI and the environment. This theory states that foreign businesses work at full capacity in the host country and that FDI makes a substantial economic contribution to the host nation; as a result, the environmental quality is much diminished (Ming Tsai et al 2011) described by Eduardo Polloni Silva et al. in (2021).

2.5 The Nexus between Industrialization and Carbon Dioxide Emission

The primary paths to economic and social transformation following the industrial revolution were urbanization and industrialization. However, these approaches lead to large emissions of carbon dioxide and other greenhouse and contribute to the dramatic rise in the usage of fossil fuels. The primary drivers of CO2 emissions in developing countries are GDP growth, industrialization, energy consumption, and urbanization. (Pata and Balsalober-Lorente,2022, Ridwan et al., 2024, Sikder et al., 2022). and Khan, Teng, et al. (2019) discovered that industrialization was associated with increased energy demand and changed consumption patterns in initial phases of economic expansion, which led to rise in CO2 emissions. Urbanization and industrialization cause the transportation sector to grow, which increases fuel consumption and carbon emissions, both of which fuel climate change.

2.6 The Nexus between Agricultural Productivity and Carbon Dioxide Emission

Since the agricultural sector now accounts for about 22% of global emissions, it will be crucial to achieving GHG reduction objectives. In 2019, the productivity of input use tends to be inversely connected to emissions intensity (GHGs) due to the direct link between emissions and resources used in farm production, including land, fertilizer, and ruminant animals (IPCC2023). Methane from rice paddies and cattle (both manure and enteric fermentation), carbon dioxide (CO2) from land conversion and cultivation, and nitrous oxide from fertilizers are some of the primary ways that agriculture donates to climate change and greenhouse gas emissions. Agriculture is essential for transition to a carbon-neutral economy because it has significant GHG footprint. According to Golub et al. (2012) as described by (Frank et al., 2017) at moderate carbon pricing, significant GHG mitigation in forestry and agriculture is possible. Emissions intensities, or the number of emissions (measured in the quantity of CO2 equivalent to per volume or dollar of commodity output) vary greatly between geographies, commodities, and agricultural practices in the highly diverse industry of agriculture. Furthermore, as agricultural productivity has increased, emissions intensity has gradually decreased. Emissions intensity tends to be inversely related to productivity because the majority of agricultural GHG emissions are directly linked to the resources used in farm production (the amount of land, the number of cattle, the amount of fertilizer applied, etc.).

H3. Both long and short-term carbon emissions are significantly impacted by industrialization, agriculture production, and foreign direct investment.

Finding balance among economic development and environmental sustainability is a persistent challenge for South Asian countries, which are rapidly industrializing and urbanizing. This study looks at how economic factors affect carbon dioxide emissions, one of the primary drivers of global climate change.

GDP, industrialization, foreign direct investment, and agricultural productivity are some of these factors. Two such elements that are directly tied to the topic of sustainable finance are foreign direct investment and agricultural productivity, which make them crucial parts of policy initiatives intended to reduce emissions without compromising development goals. Foreign direct investment has a complex and wide-ranging impact on environment. According to the pollution haven theory multinational corporations may relocate environmentally damaging industrial operations to countries with less stringent environmental regulations which could raise CO2 emissions Bertocchi, M. (2023).

However, by bringing cleaner, more advanced technologies and better environmental practices to host countries, foreign direct investment can improve environmental results, according to the pollution halo theory (Zarsky, 1990 described by (Kisswani & Zaitouni, 2023) The targeted industries have big impact on how foreign direct investment impacts environment in South Asian contexts. Green investments in renewable energy, low carbon manufacturing, and sustainable structure help to cut emissions and accomplish the sustainable development goals

Another important factor that affects both economic and environmental results is agricultural productivity. Due to excessive land usage, ineffective irrigation, and chemically demanding inputs, traditional farming methods are linked to high emissions in several South Asian nations. However, emissions can be greatly decreased by boosting production through the use of eco-friendly and climate-smart methods.

By increasing output without requiring more land, sustainable intensification techniques including organic farming, agroforestry, and precision agriculture protect forests and soil carbon stores (Burney et al., 2010 described by (Palit, 2021) These transformations can be successfully supported by sustainable finance instruments like carbon credit programs, green loans, and environmentally related subsidies.

Furthermore, the argument for incorporating sustainability into financial and investment decisions is strengthened by the nexus between agricultural productivity and FDI. More productivity and lower emissions can result from foreign direct investment that focusses on innovative agricultural technologies, renewable energy-powered machinery, and sustainable irrigation systems. For instance, precision farming, which has been made possible by foreign investments, may optimize the use of energy, fertilizer, and water inputs, lowering expenses and emissions. In South Asia, where agriculture continues to be a key employer and a large source of greenhouse gas emissions, these technological transfers are particularly pertinent (FAO, 2021).

However, industrial expansion and GDP growth are frequently positively correlated with higher emissions. By integrating environmental objectives into financial institutions, sustainable finance allocates funds to environmentally beneficial initiatives like sustainable agriculture and renewable energy. These projects are finance by green bonds, which were first introduced by institution such as the World Bank. They provide accountability and transparency while drawing in institutional investors,(Patience Okpeke Paul & Toluwalase Vanessa Iyelolu, 2024) .(Zhou & Kythreotis, 2024).

In the meanwhile, green bonds explicitly increase agricultural production by funding soil restoration, irrigation infrastructure, and climate-resilient farming technologies. By assisting farmers in implementing sustainable methods, this subsidy raises yields while halting environmental damage. Additionally, local banks gain from agricultural lending since it lowers risk and increases profitability (Zheng & Jean-Petit, 2023) . However, by contributing money and technology to extensive agricultural projects, foreign direct investment (FDI) enhances sustainable finance. Green finance directs FDI towards environmentally favorable practices, balancing sustainability and productivity, while unregulated investments may raise emissions (Qadri et al., 2023).

In a similar vein, the amalgamation of FDI and green bonds results in a sustainable agricultural ecosystem. Green bonds, for example, finance irrigation with renewable energy, and FDI adds precision farming equipment. This partnership supports long-term food security and lowers carbon emissions. In sustainable finance, green bonds also encourage accountability and transparency. Environmental, social and governance (ESG) integration and disclosure are mandated by strict rules and regulations that govern their issuance. In contrast to flimsy greenwashing, this motivates issuers to enhance their environmental impact and ESG performance, strengthening their genuine commitments to sustainability (Paul et al, 2024) (Di Zhou and Alexios Kythreotis, 2024).

Green bonds encourage issuers to embrace sustainable practices by providing lower financing costs than traditional bonds. This cost advantage results from tighter spreads, favorable market dynamics and regulatory incentives that lower borrowing costs and increase the financial viability of green projects. Green bonds thereby increase the financial appeal of sustainable investments (Wongaree et al., 2025).

The intricate relationship between agricultural production and foreign direct investment (FDI) depends on contextual elements such as institutional frameworks, technological absorption capability, and integration with local value chains. According to studies, foreign direct investment (FDI) can increase agricultural productivity through technology transfer, increased efficiency, and access to international markets. This is especially true when domestic enterprises have the capacity to absorb new information (for example, being close to the technological frontier (Han et al., 2025). For example, FDI-linked smallholder farmers in integrated producer schemes in Tanzania experienced increased in productivity as a result of stable pricing, dependable markets, and technology spillovers (Msuya and Elibariki, 2007). However, the effects are not consistent throughout China, foreign direct investment (FDI) increased productivity for agricultural enterprises with foreign investments and advanced technology, but caused detrimental spillovers for domestic firms with limited absorptive capacity(Han et al., 2025).

Similar to this, Bangladesh's agricultural suffered long-term consequences from FDI because of inadequate state support and farmer training, underscoring the dangers of uncontrolled investment(Sultana & Sadekin, 2025). These differences highlight how FDI is a two-edged sword whose benefits rely on supportive policies and strategic alignment with local capabilities. By giving priority to projects that improve smallholder relationships, foster skill development, and influence environmental standards, impact investment which aims to promote sustainable, inclusive agricultural growth can increase the beneficial effects of foreign direct investment. For instance, when combined with capital formation, export trade incentives, and government investment, FDI driven agricultural productivity increases were shown in Eastern African nations such as Ethiopia and Kenya (Otieno, J.D., 2024). Because fewer inputs are needed, productivity lowers the quantity of greenhouse gas emissions linked to each unit of output by increasing the output from a given set of resources. Therefore, policies targeted at increasing agricultural output can be a valuable instrument for mitigating the impact on climate change.

2.7 Previous Research

The subsequent segment is devoted to an exhaustive and all-encompassing examination of the extant corpus closely scrutinizing the research, studies, and academic publications that are relevant to our area of interest. In addition to pointing out knowledge gaps and emphasizing the research's contributions to the field, this literature review attempts to place our study into the larger academic conversation.

No	Authors	Method/Model	Year	Main Finding	Limitation
1	Latief et al (2021)	Dynamic ordinary least squares (DOLS) &Vector Error Correction (VECM)	1990_2016	The dynamic causal nexus between FDI economic progress and carbon emissions was empirically examined. existence of a unidirectional causal relationship among carbon emissions and economic growth	Due to data constraints, this study is restricted to the years 1990-2016 and certain economic variables. This study looks at how economic expansion and foreign direct investment affect carbon emissions.
2	Ridwan et.al. (2024)	Cross Sectional Autoregressive Distributive Lag (CS-ARDL)	1972_2021	This study examines how the economy and CO2 emissions are impacted by urbanization, industrialization, and the growth of the service sector.	Future studies should concentrate on other factors including trade openness, foreign direct investment, and agricultural productivity that affect CO2 emission in South Asian.
3	Mehmood et al (2024)	Quantile regression (QR) static model, Generalized method of moments (GMM) and Granger causality test	2004_2022	There is a positive correlation among CO2 emissions and financial inclusion measures, such as commercial bank branches and automated teller machines (ATM). In contrast to globalization, which has a negative effect, control variables such	This study is limited its exclusive focus on four variables such as population (PG), financial development (FD), institutional quality (INSQ), and financial inclusion.

				as population growth, financial development and foreign direct investment are also favorably correlated with CO2 emissions. Financial inclusion positively associated with CO_2 emission.	
4	Latief et al (2021)	Dynamic ordinary least squares (DOLS) and Error correction model (ECM)	1990-2016	This study verified that there is unidirectional causal connection between carbon emissions and economic development.	The analysis is restricted to the years 1990 to 2016 and includes the following economic variables: GDP, urban population, energy consumption economic progress and foreign direct investment.
5	Ali et al (2021)	Ordinary Least Square (OLS)	1995_2018	The results of this study demonstrate that there is a positive and statistically significant long-term association among income, energy consumption, urbanization, and carbon dioxide emissions, which rise the level of carbon emissions. Conversely, there is a	Only emerging economies are chosen, and the study is restricted to carbon dioxide emission. The study makes use of data from 1995 to 2018.

				negligible and negative correlation among carbon emissions and trade openness and financial development.	
6	Karedla et al (2021)	Autoregressive distributive lag (ARDL)	1971_2016	This research shows that CO2 emissions and other variables have a long-term link. Although GDP and industry have significant and long-term positive impact on CO2, trade openness significantly decrease CO2 emissions.	These econometric variables-carbon emissions (CO2), trade openness (TO), manufacturing (MF), and economic growth (GDP) limit the investigation to the 1971 to 2016 timeframe.
7	R.M.M. Mayoshi (2021)	Autoregressive Distributed Lag (ARDL)	1978_2019	The findings of this research indicate that trade openness, urbanization, and GDP per capita may eventually result in higher environmental emissions. In the short term, however, GDP per capita may reduce environmental emissions.	Since Sri Lanka is an agricultural nation, this study's limitation is its disregard for agricultural productivity. Similarly, energy consumption was left out of the econometric model, despite the fact that is one of the key factors influencing carbon emissions.
8	Poudel et al (2024)	Dynamic ordinary least squares (DOLS)	1990_2020	The results of the DOLS model showed a statistically significant and positive correlation among CO2 emissions	Some factors that have a noteworthy impact on CO2 emissions, such as energy consumption,

				and economic progress. In particular, CO_2 emissions rise by 0.6112 kilotons for every 10 million increases in GDP. According to long-term data on deforestation, Nepal's CO_2 emissions increased by 68.37% kilotons for every square kilometer of deforestation that was reduced.	foreign direct investment, industrialization, and urbanization, were not included in this analysis.
9	Ashraf et al (2020)	Autoregressive distributed lag (ARDL)	1990_2018	The findings of this research show that regional CO_2 emissions are rising as a result of economic expansion, FDI, urbanization, and fossil fuel use.	The study uses PMG/ARDL methodologies to examine only eleven rising economies.
10	Goswami et al (2023)	Autoregressive distributed lag (ARDL) and Random Forest model	1980_2021	Analysis of this data showed that trade openness and economic growth have a negative correlation with CO_2 emissions, whereas energy consumption, urbanization, and trade openness had a positive correlation.	The research was conducted between 1980 and 2021 and focused on three economic variables: urbanization, trade openness, and energy use.

Table 2.1. Brief Literature Review

2.8 Research Gap

The document's comprehensive literature review identifies the following research gaps in the study of economic progress and environmental sustainability: the impact of carbon dioxide emissions on GDP, industrialization, agricultural productivity, and FDI.

1-Economic progress and environmental sustainability are not fully integrated in current studies, especially when it comes to examining how agricultural productivity and foreign direct investment (FDI) affect carbon emissions. For instance, Ridwan et al. (2024) research focuses on how economy and CO2 emissions are impacted by urbanization, industrialization, and the development of the service sector.

Similarly, Mehmood et al (2024) study revealed that financial inclusion indicators like bank branches and automated teller machines are positively linked with CO2 emission including financial development and population growth. Whereas globalization has negative impact on carbon emission. The necessity for a targeted examination of how these elements, in conjunction with industrialization, affect environmental consequences and sustainable development in South Asian nations is highlighted by this disparity.

2-Quantitative studies that use statistical and economic model to demonstrate the causal connection between environmental sustainability initiatives and economic progress, as well as their quantifiable effects on carbon dioxide emissions, are scare. This discrepancy emphasizes the necessity of thorough empirical research to establish a direct correlation between certain economic activity and the results of carbon emissions.

3-While governance is widely recognized as crucial, there is absence of quantitative analysis on specific policies and governance strategies for managing natural resources or promoting economic growth and environmental sustainability practices to reduce carbon emissions and improve air and water quality.

2.9 Conceptual-Framework

The research framework that forms the basis of our investigation is depicted in the following chart. This framework outlines the format and methodology for examining the complex relationships and dynamics at work. The conceptual framework by Krueger and Groosman (1991) and pollution theory by Ugelow and Walter (1979) claim that FDI may lower CO2 emissions by bringing environmentally favorable technologies to host nations. According to the hypothesis, implementing these environmentally friendly technology lowers CO2 emissions and enhances the value of the environment. In light of this theoretical study Fig 2.3 gives a simplified conceptual framework showing the connection among FDI, agricultural productivity, industrialization and carbon dioxide emissions and also adding other descriptive factor such as economic progress based on current literature (Kwakwa et al., 2023).

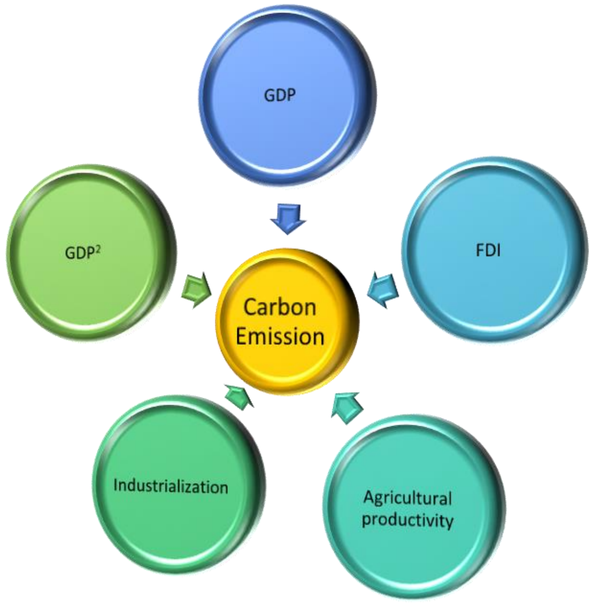

Figure 2.3 Research Conceptual Framework

CHAPTER III

METHODOLOGY OF THE STUDY

The study approach used to examine how environmental sustainability and economic progress affect carbon emissions using panel data and the Autoregressive Distributed Lag (ARDL) econometric model is described in this chapter. In order to guarantee the validity and robustness of the finding, the chapter covers research design, variables, data sources, model specification, estimating techniques and diagnostic tests. Insights into short-term dynamics and long-term linkages can be gained by using panel data to capture both cross-sectional and time-series changes across chosen nations, while the ARDL technique permits variables integrated at different orders.

3.1 Research Design

Research on the connection between environmental sustainability and economic progress is classified as quantitative and explanatory. This categorization results from the study's objective to quantitatively observe and elucidate the connections among variables of interest and different aspects of economic development such as GDP, industrialization, FDI, agricultural productivity, and their effect on carbon emissions in a subset of South Asian countries. Because quantitative research relies on numerical data and objective, it can assist researchers in producing generalizable statistics, examining the relationship between variables, and establishing cause and effect. A number of scholars who looked into the same subject of foreign direct investment used the quantitative research method. For instance, (Bokpin et al., 2015, Dellis et al., 2017, Djokoto, 2012, Meyar and Habanabakize, 2018).

Dellis et al., (2017) Examine the function of economic systems empirically by using statistical and quantitative artifacts such as financial round tripping. Bokpin et al., (2015) The impact of natural resources on India's foreign direct investment influx can be quantitatively demonstrated. Djokoto (2012) investigated the factors that drew foreign direct investment into Bangladesh's agricultural sector between 1970 and 2009. The study used a quantitative research method to determine the connection between economic growth, environmental deprivation, and foreign direct investment, along with other significant variables.

Furthermore, quantitative research is defined by its use of numerical data to identify patterns, test hypotheses, and validate theories (Creswell & Creswell, 2017). This research type is chosen for its capacity to handle large datasets and provide objective, measurable evidence on the phenomena under study. In the context of this research, quantitative methods enable the systematic analysis of secondary data derived from reputable sources to assess the magnitude and significance of the economic growth and environmental sustainability impact on carbon emission. On the other hand, explanatory research, or causal research, seeks to explore and understand the cause and-effect relationships among variables (Babbie, 2016). It goes beyond merely describing phenomena to elucidate the underlying mechanisms and interactions that explain why and how certain outcomes occur.

For this study, explanatory research is employed to investigate how and to what extent Economic growth and environmental sustainability influence carbon emission, aiming to provide insights that can inform policy decisions and strategic interventions. The choice of quantitative, explanatory research for this study is grounded in the need for a rigorous, data-driven approach to untangle the complex interplay between the sustainable exploitation of natural resources and the achievement of carbon emission reduction objectives. By leveraging statistical analysis techniques within a panel data analysis framework, this research aims to offer empirical evidence on the effectiveness of Economic growth and environmental sustainability, guiding future policy and research directions in the field.

3.2 Methodology

In order to evaluate the effects of economic growth and environmental sustainability on carbon emissions in a chosen group of five South Asian nations namely, India, Nepal, Bangladesh, Pakistan, and Sri Lank by analyzing secondary data from 1984 to 2023, the methodology for this investigation is uses a quantitative research framework. According to the guidelines established by Wooldridge (2015), secondary data offers a robust basis for conducting econometric analyses, particularly when derived from reputable international organizations known for their comprehensive and reliable datasets, such as the International monetary fund (IMF), the World Bank, and national statistics offices. In this study, panel data covering annual indicators of economic progress and environmental sustainability, including CO2 emissions per capita (metric tons), real GDP per capita (constant 2010 US dollars), industrialization (industrial value added as a percentage of GDP), foreign direct investment (FDI inflows as a percentage of GDP), and agricultural productivity (agricultural value added as a percentage of GDP), will be compiled using panel data started from 1984 to 2023 using the Autoregressive Distributed Lag (ARDL) model, which is suitable for both short and long term estimations. Additionally, it is especially helpful for data with mixed stationarity levels in the economic and environmental domains. It indicates that at level I (0) or first differences I (1) the data should be stationary. However, using data that is stationary at second differences is not advised by the ARDL model (2).

Some of the previous studies used ARDL model for panel data analysis. For instance, Waqih et.al (2019) used ARDL model for analyzing panel data from 1986 to 2014 in SAARC region. Similarly, Ashraf et.al. (2020) used ARDL model to analyze data for emerging Asian economies started from 1990 to 2018. Additionally, for the determinants of greenhouse gas emission (GHG) in selected South Asian countries Rahman et al. (2023) used ARDL model for analyzing the influence of population, economic growth, and various energy sources consumption from 1972 to 2021.

3.3 Data Description and Sources

3.3.1 Data Type and Period

The analysis uses balanced panel data from 1984 to 2023 for five chosen South Asian nations. The countries are chosen depending on the availability of data and how well it relates to the subject of the study. The time frame makes it possible to record medium to long term trends in carbon emissions, industrialization, agriculture, economic development, and foreign direct investment. Data for a few chosen variables are gathered from World Bank data to guarantee accuracy and consistency.

3.4 Description of the Variables

3.4.1 Dependent Variable

Carbon Dioxide Emissions

An indicator of environmental quality is carbon dioxide emissions. Results from earlier research on the impact of carbon dioxide on economic progress were inconsistent. A number of empirical studies have demonstrated that CO2 emissions have a favorable effect on economic development (Arouri et al., 2012). In contrast, (Azam et al., 2016, Bekun and Agboola, 2019, Borhan et al., 2012) discovered a negative correlation among CO2 emissions and economic progress. For the research period, this specific analysis also anticipated a negative correlation between CO2 emissions and economic growth. were found negative relationship between CO2 emissions and economic growth.

3.4.2 Independent (Explanatory) Variables

Gross Domestic Product Per Capita

A common indicator of economic growth is GDP per capita, which calculates the average economic production per person in a nation. It is crucial for examining the connection among economic progress and carbon emissions since it represents the standard of living and financial prosperity. Although the Environmental Kuznets Curve (EKC) concept implies emissions may decrease at greater income levels, industrialization and consumption habits frequently result in higher energy consumption and emissions when GDP per capita rises. This link has been thoroughly studied, with studies by Stern (2004), Shahbaz et al. (2013), Apergis and Payne (2009), and York et al. (2003) emphasizing its intricacy and contextual reliance.

Industrialization Manufacturing Value Added

Manufacturing value added is a key indicator of industrialization, reflecting the contribution of manufacturing to GDP and structural transformation of an economy. It highlights the shift from agarin-based economies to more industrialized ones, providing insights into economic growth, technological advancement, and employment. However, while MVA signal economic development, it also underscores the environmental challenges associated with industrialization, including increased energy consumption and carbon emissions. Thus, MVA not only serves as an economic measure but also plays a crucial role in assessing the sustainability of industrial growth and its environmental impact (United Nation and UNIDO, 2024). The present study expects positive relationship between carbon emission and industrialization with higher emissions due to energy-intensive industries.

Agricultural Productivity

Agricultural productivity is crucial for economic development, particularly in agrarian economies. It refers to the efficiency with which agricultural inputs are transformed into outputs, directly impacting food security, rural development, and poverty reduction. Agricultural Value Added as a percentage of GDP is a key proxy for measuring agricultural productivity, reflecting agriculture's contribution to the overall economy. A higher AVA percentage indicates a more significant role of agriculture, typically in less industrialized nations, while industrialized economies show a lower share (Bureau of Economic Analysis BEA, 2022). Additionally, agricultural productivity has environmental implications, as increased output can reduce pressure on resources if achieved through sustainable practices. However, unsustainable intensification can lead to resource depletion and environmental degradation. Therefore, AVA as a percentage of GDP is vital for understanding the balance between economic development and environmental sustainability in agriculture (OECD, UNIDO, 202). The present study expects negative or positive relationship among agricultural productivity and carbon emission.

Foreign Direct Investment FDI

The net inflow of capital to obtain a long-term management stake in a business that operates in an economy different from the stockholder's own is known as foreign direct investment. As indicated by the balance of payments it is the total of equity capital, earnings reinvestment, other long-term capital, and short-term capital. This data, which is divided by GDP, displays net inflows of foreign investment (new investment inflows less disinvestment) into the reporting economy. FDI is expressed as a proportion of GDP, and it is anticipated that FDI and economic development will be positively correlated. It is debatable how foreign direct investment affects economic expansion. While some research indicated a negative impact others found a beneficial one. Several empirical research have demonstrated that foreign direct investment has a favorable impact on economic progress (Alabi, 2019, Chanie, 2017, Gizaw, 2015, Jean Marie Vaianney, 2018, and Sokang, 2018). On the other side, research by (Phlip O Alege, 2016, Brenner, 2014, and Rahman, 2015) revealed a negative correlation among economic growth and foreign direct investment. Therefore, the current study anticipated that foreign direct investment would have a favorable or negative impact on economic progress.

Table 3.1. Variables Measurement

Variables	Measures	Data Source
$CO2$	Carbon dioxide ($CO2$) emission (Mt $CO2$)	WDI-database
GDPP	Economic Growth GDP per capita (current $US)	WDI-database
IND	Industrialization (IND) Manufacturing value added (% of GDP)	WDI-database
AGVA	Agricultural Productivity Value added (AGVA) (% of GDP)	WDI-database
FDI	Foreign Direct Investment (FDI) Net inflows (current US $)	WDI-database

3.5 Econometrics Model Specification

As per the conceptual framework, the study's dependent variable is carbon dioxide emissions, whereas independent variables are agricultural productivity and foreign direct investment (FDI). We included gross domestic product per capita (GDPP) and industrialization (IND) as explanatory variables in accordance with the empirical literature by studies as Ssali et al. 2019, Essandoh, et al. 2020, Rafique et al. 2020, Bakhsh et al. 2021, and Ali et al. 2022 on pollution halo hypothesis and pollution haven, particularly in the Asian region. The fundamental functional form of the carbon dioxide emissions equation is taken into consideration in the empirical study with these.

$CO_{2it} = f$ (GDP, GDP^2, IND, FDI, ARGP) …………………………………… (1)

The above equation can be expressed as follows.

$CO2_{it} = \beta_0 + \beta_1 GDPP_{it} + \beta_2 GDPP^2_{it} + \beta_3 IND_{it} + \beta_4 AGRP_{it} + \beta_5 FDI_{it} + \varepsilon_{it}$ … (2)

Where, ε_{it} represents the disturbance or error term and t and i represent time and the number of nations, encapsulating all the antecedent ad omitted variables that could potentially affect our results. AGRP stands for agricultural productivity value added (as a percentage of GDP), IND stands for industrialization as a value added (as percentage of GDP), GDPP stands for per capita gross domestic product, $GDPP^2$ is the square of per capita gross domestic product, and FDI stands for foreign direct investment as net inflows (current US$).

Conversely, when all descriptive variables are held constant, the constant term, or β0, represents the CO2. The explanatory variables respective coefficients β1, β2, β3, β4, and β5, indicate how carbon dioxide emissions will change in response to a unit change in their corresponding independent variables.

The log version of the aforementioned equation is shown below.

$LNCO2_{ti} = \beta_0 + LN\beta_1 GDPP_{it} + LN\beta_2 GDPP^2_{it} + \beta_3 IND_{it} + \beta_4 AGRP_{it} + LN\beta_5 FDI_{it} + \varepsilon_{it}$ …………………… (3)

The logarithm of CO2, GDPP, and FDI was chosen because it is a useful statistical data transformation technique that may be used to achieve particular objective including leveling data distributions, making interpretation easier, and lessening the influence of outliers (Wooldridge, 2016, Greene, 2018, Osborne, 2010). Since the remaining variables are expressed as percentages, the logarithm is not required in this instance. The equation below illustrates how the particular ARDL model is constructed.

$$\Delta LNCo2_{it} = \beta_0 + \beta_1 \sum_{p=1}^{q} \Delta LNCo2_{it_{-p}} + \beta_2 \sum_{p=1}^{q} \Delta LNGDP_{it-p} + \beta_3 \sum_{p=1}^{q} GDP^2{}_{it} + \beta_4 \sum_{p}^{q} IND_{it} + \beta_5 \sum_{p}^{q} AGRP_{it} + \beta_6 \sum_{p}^{q} FDI_{it} + \varepsilon it \text{………} (4)$$

3.6 Estimation procedure

3.6.1 Panel Estimation

Finding dynamic long-term and short-term relationships is one benefit of using the panel ARDL model or Pool Mena Group (PMG) estimation. Short-term relationships are estimated via the (PMG) estimator, which also accounts for the coefficients, the adjustment for long-term equilibrium (speed of adjustment), and the heterogeneous error variance. The long-term coefficients are limited to being consistent across nations. Given that it is more effective and consistent with the presence of long-term partnerships, this approach is appropriate. The Mean Group (MG) approach is the second estimate technique. Its approaches for estimating the diversity of parameters are less restricted according to Pesaran and Smith (1995). It is also capable of estimating various coefficients for every nation. For both the MG and PMG estimators, the Schwarz Bayesian Criterion (SBC) or Akaike Information Criterion (AIC) must be used to choose suitable lag durations. Even if it is ineffective with homogeneity, the MG estimator consistently estimates the long-run mean. Pooled estimators are efficient and consistent when long-run homogeneity is present. DFE, or dynamic fixed effect, is the third estimator. The PMG estimator is the same as this one. In order to maintain uniformity across all long-term panel, it can limit the co-integration vector coefficient. It also generates steady shot-run estimation and restricts the time adjustment coefficient. All panel's integration vector coefficients are constrained by DFE. The long and short-term impacts of any variable can be displayed by all three estimators (PMG, DFE, and MG). These methods determine whether the order of integration is I (0) or I (1), according to Shin and Pesaran (1999). With T greater than, N this approach combines time series and cross-sectional data. The ideal amount of N is roughly 20 to 30 countries, according to Shin and Pesaran (1999, 2000). To ascertain which of the three is superior in this investigation PMG, MG, or DFE the Hausman tests were employed. The following is the MG model for evaluating long-term connection among variables.

$$\ln CO2_{ti} = \theta_0 + \beta_0 \ln CO2_{ti-1} + \ln\beta_1 GDPP_{it-1} + \ln\beta_2 GDPP^2_{it-1} + \beta_3 IND_{it-1} + \beta_4 AGRP_{it-1} + \ln\beta_5 FDI_{it-1} + \upsilon_{it} \ldots\ldots (5)$$

The MG estimator with a large order of lag may reliably predict long-run average parameters, as demonstrated by equation (6). The MG estimator, which was first presented by Pesaran and Shin (1999), Shares characteristics with the DFE estimator. Whereas the DFE estimator can only estimate combined short and long-term coefficients, the MG estimator can estimate both long and short-term coefficients for each nation. In addition, the PMG estimator is unable to estimate long-term coefficients for every nation The following is the long-term relationship model that makes use of the PMG AND DFE estimators.

$$lnCo2_{it} = \alpha_i + \sum_{j=1}^{p} \lambda ijlnCo2_{it_{-j}} + \sum_{j=0}^{q} \delta 1ijlnGDP_{it-j} + \sum_{j=0}^{r} \delta 2ijIND_{it-j} + \sum_{j=0}^{s} \delta 3ijAGRP_{it-j} + \sum_{j=0}^{o} \delta 4ijlnFDI_{it-j} + \varepsilon it \text{ ……………………… (6)}$$

Where, i represents the number of countries, t is the number of years (1984-2023), (o,p,q,r,s) is the optimum time lag, α_i is the countries specific effect, and Ɛit refer to the remainder error terms. The short-run relationship with an error correction model is as follows:

$$\Delta lnCO2_{ti} = \alpha_i + \varphi_i (lnCO2_{it-1} - \lambda_1 lnGDPP_{it-1} - \lambda_2 IND_{it-1} - \lambda_3 AGRP_{it-1} + \lambda_4 lnFDI_{it-1}) + \sum_{j=1}^{p} \lambda ij\Delta lnCo2_{it_{-j}} + \sum_{j=0}^{q} \delta 1ij\Delta lnGDP_{it-j} + \sum_{j=0}^{r} \delta 2ijIND_{it-j} + \sum_{j=0}^{s} \delta 3ijAGRP_{it-j} + \sum_{j=0}^{o} \delta 4ij\Delta lnFDI_{it-j} + \varepsilon_{it} \text{………….. (7)}$$

Where λi are long-run parameters, Δ Stands for the difference operator, and φ_i is the parameter for the error-correction term that measures the speed of adjustment to the long-term equilibrium of lnCO2 due to changes in lnGDPP, IND, AGPR, lnFDI. φ_i indicates the existence of a long-run connection. The presence of a co-integrating relationship between lnCO2, lnGDPP, IND, AGPR, and lnFDI is thus indicated by a negative and substantial value of φ_i. Every ECM dynamic and term is subject to change. Furthermore, this model's parameter estimation is asymptotically normal and consistent for estimating long-run coefficients for both stationary and non-stationary regressors I (1) I (0). Panel data analyses with large cross-section time series are suitable for the MG and PMG estimators. That being said the MG estimator is inefficient if homogeneity exists. The maximum likelihood-based PMG estimator is more effective instead. The Hausman test must be used to decide which estimator PMG, MG, or DFE is suitable.

3.6.2 Hausman Test

Between the MG or PMG estimator and either the PMG or DFE estimator the Hasman test has been used to determine which is the preferred estimator. Pirortte (1999) asserts that the MG estimator ignores group heterogeneity and permits parameters to be independent across groups. But according to Shin and

Pesaran (1999), the PMG is superior since it provides coefficients of various short-run variances per nation. On the other hand, it is assumed that all nations are homogenous (similar) for the long-term coefficient. The MG estimator, on the other hand, only permits shot and long-term coefficient heterogeneous (varying) durations across nations. The null hypothesis test determines whether to use the PMG or MG estimators. Since the PMG estimator is more effective than the MG estimator, it is chosen if the null hypothesis is accepted. The MG estimator is selected above the PMG estimator in the event that null hypothesis is rejected. The PMG estimator is superior to the DFE estimator, therefor if the null hypothesis is accepted, one can select between the two estimators.

3.6.3. Error Correction Model (ECM) in Panel ARDL Context

An econometric method for analyzing the long-term equilibrium and short-term dynamic interactions between cointegrated integrated variables is the Vector Error Correction Model (VECM). Because the VECM framework includes an error correction term that measures how quickly variables adjust to regain equilibrium following short-term shocks, it is suitable for panel datasets with integrated variables of order one, I (1), and long-term relationships (Baltagi, B.H., 2008), (Westerlung, J., 2007). The VECM enables the estimate of both short-term adjustments and long-term associations in a panel of cross-sectional units (countries or enterprises) across time in the Panel ARDL model configuration. The Panel ARDL model is popular for cointegration analysis in panel data (Gujarati, D.N., & Porter, D.C, 2009) and is adaptable to variables with mixed integration orders I (0) and I (1) (Chdik, A., & Pesaran, M.H., 2015). The following is how the Panel ARDL (p, q) model can be converted into the error correcting form.

$$\Delta y_{it} = \omega_i \left(y_{i,t-1} - \beta_i x_{i,t-1}\right) + \sum_{j=1}^{p-1} \propto ij\Delta yi,t-j + \sum_{j=0}^{q-1} \gamma ij\Delta xi,t-j + \mu i + \varepsilon it \ldots. (8)$$

Δ denotes the first difference operator ($\Delta y_{it} = yit - y_{i,t-1}$) ω is the error correction coefficient representing the speed of adjustment toward long-run equilibrium (expected to be negative and significant for cointegration), yi,t-1 – βixi,t-1 is the long run equilibrium relationship (cointegration equation), αij and γij are short-run dynamic coefficients, μi are fixed effects, and Ɛit is the error term. The error correction term (ECT) ω_i ($y_{i,t-1} - \beta_i x_{i,t-1}$), captures the long-run relationship deviation from equilibrium and adjusts the depend variable in the short run to correct this disequilibrium. The coefficients αij and γij measure the short-run dynamics or immediate effects of changes in y and x. The model handles heterogeneity across cross-sectional units through unit-specific parameters.

3.7 The Autoregressive Distributed Lag (ARDL) Model

Researchers have used the Johansen cointegration technique in numerous prior investigations to ascertain the long-term or long-run correlations among variables. Since it is the most accurate technique to use for I (1) variables, many researchers continue to choose the Johansen cointegration methodology. However, as an alternative cointegration technique, the Autoregressive Distributed Lag (ARDL) bound test was recently proposed by a number of research by Pesaran (1997), Pesaran et al., (2001), Shin and Pesaran (1996), and Smith and Pesaran (1998). The ARDL model have numerous advantages over Johansen cointegration approach. In contrast to previous cointegration techniques, the ARDL approach does not require that all explanatory variables be integrated in the same order.

Therefore, whether or not the explanatory variables are integrated or I (1) and/or I (0), the ARDL approach can be applied. Put another way, the ARDL approach can get over the pre-testing issues that come with using typical cointegration procedures, which require that the variables categorized as either I (1) or I (0). Furthermore, the Johansen cointegration strategy requires large data samples to be valid, but the ARDL approach is the more statistically significant method for determining the cointegration relation in small samples (Ghatak and siddiki, 2001). The estimation of the ARDL technique is feasible even when the appropriate number of delays for various variables varies. Endogeneity is less of an issue in the ARDL model since the cointegration bound technique eliminates residual correlation.

3.7.1 Advantages of Using Autoregressive Distributed Lag (ARDL) for Panel Data

The Autoregressive Distributed Lag (ARDL) model offers numerous distinct advantages for panel data analysis, making it a popular choice among researchers examining dynamic relationships between variables. One primary benefit of ARDL is its flexibility in handling variables with mixed orders of integration, specifically I (0) Stationary and I (1) (non-stationary) variables, without requiring pre-testing for unit roots or differencing all variables to the same order (Pesaran, Shin & Smith, 1999). This characteristic reduces the risk of losing valuable long-run information often encountered in traditional cointegration methods. ARDL models effectively capture both short-run dynamics and long-run equilibrium relationships simultaneously, providing inclusive understanding of temporal effects in panel settings (Baltagi, 2008). Additionally, the model accommodates heterogeneity across cross-sectional units by allowing parameters to differ, which is crucial for capturing diverse economic behaviors among countries, firms or regions in a panel (Pesaran et al., 1999). The ARDL framework also performs well in small sizes, making it suitable for panel datasets with limited time periods (Narayan, 2005). Its error correction representation enables estimation of the speed of adjustment to long-run equilibrium after short-term shocks, enhancing the interpretability of dynamic relationships. Furthermore, ARDL models avoid the problem of spurious regression by incorporating cointegration testing implicitly within their framework.

3.7.2. Assumption of the Panel ARDL Model

The Panel Autoregressive Distributed Lag (ARDL) model extends the ARDL framework to panel data, allowing for heterogeneity across cross-sectional units (e.g., nations, firms) and capturing both long-run and short-run associations. For valid estimation and inference, several assumptions must be met:

Order of Integration: Variables must be I (0) or I (1), not I (2)

The regressors and dependent variable in the panel must be either stationary at level I (0) or become stationary after first differencing I (1). The presence of variables integrated of order two or higher invalidates the bounds testing process used in ARDL. Shin, Pesaran, and Smith (2001) showed that the critical values for the bound test are only valid when variables are I (1) or I (0). Including I (2) variables leads to unreliable results as the test statistics diverge (Smith, R. J., & Pesaran, M.H., Shin, Y., 2001).

Long-run Relationship (Cointegration or Bounds) test

Conducting a cointegration test was the subsequent action that was taken. In the ARDL testing technique, the cointegration test was undertaken to observe if there is a long-run equilibrium association among the independent and dependent variables. This was done by conducting the ARDL bounds test (Voumik et al., 2022). Estimating the model and assessing the coefficients significant linked to the lagged values of the variables are required. The Cointegration was evaluated suing the limits F-test or the t-test. The bounds test yields a pair of crucial values: lower and upper bounds (Usman et al. 2022b). A null hypothesis was formulated that there is no cointegration among variables:H_0 No cointegration between variables. When the F-statistic value produced exceeds the upper bound value in the Bounds test, it suggests the existence of a long cointegration relationship rather than supporting the rejection of the null hypothesis. An F-value below the lower bound does not rule out the null hypothesis that there is no cointegration. Additionally, an ambiguous cointegration link is indicated by an F-value that falls between the lower and higher boundaries Reda and Nourhan, 2020).

Lag Length Selection

The next stage was to choose the best lag for the variables after deciding on the sequence in which they would be incorporated. Information Criteria like the Bayesian Information Criterion (BIC), Akaike Information Criterion (AIC), and Hannan-Quinn Information Criterion (HQIC) can be used to display the lag length (Wen and Huang, 2022) These standards aim to strike a compromise among complexity and model fit. The chosen information criterion is minimized by the optimal lag length. After correlation for endogeneity, the ideal lag selection reduces residual correlation. The lag length in this study was chosen using the Akaike Information Criterion (AIC) (khan and Yahong, 2021).

3.8 Panel Unit Root

The Autoregressive Distributed Lag (ARDL) model was used in the study to predict how agricultural productivity, industrialization, and foreign direct investment (FDI) affected carbon emissions in selected South Asian nations. Unit root tests are carried out in the first stage of the estimation procedure in order to check for stationarity problems in the panel data analysis. The tests are necessary to investigate whether stationarity exists for panel data, as recommended by Im-Pesaran-Shin (2003) (IPS) and Levin-Lin-Chu (2002) (LLC). To ascertain the integration order of I (1) or I (0) every data set is evaluated. The purpose of the tests is to determine if our variables are stationary at first difference or stationery at level. Additionally, panel unit root tests are more effective than time series unit root, according to Levin et al. (2002). This study employs two panel unit root test methodologies, specifically, Levin et al. (2002) Breitung (2000), and Im et al. (1997).

3.8.1 Levin, Lin and Chu (2000) Test

The Levin-Lin-Chu (LLC) test is a widely used panel unit root test designed to assess the stationarity of variables in panel data analysis, a crucial step before applying the ARDL model. LLC assumes a common unit root process across cross-section, making it suitable for homogeneous panels. The test helps ensure that variables are integrated of order zero I (0) or one I (1), satisfying the ARDL model's prerequisite that no variable be integrated of order two or higher (Levin, Lin, & Chu, 2002). The following equation is to LLC regression model:

$$\Delta Y_{i,t} = \alpha Y_{it-1} + \sum_{j=1}^{pi} \beta i \Delta Yit - j + Xit + \mathcal{E}it$$

The LLC test assumes that the error term, is distributed independently across panel data and follows a stationary invertible autogressive moving average process for each panel. In the equation about, ΔYit is the difference term of Y_{it} and $Yit - j$ is panel date where there are exogenous variables like individual time trend or country fixed effects. The following are the alternative and null hypotheses.

H_0 : $\beta_i = 0$ for all i which means panel data has unit root test.

H_A : $\beta_i < 0$ for all i which means panel data has no unit root test.

For this hypothesis, the LLC test requires that β_i be homogenous across i this homogeneity requirement becomes a drawback of the LLC test. This suggests that H_A is limited and that t-statistic rely on pooled estimation if the autoregressive parameters are the same for every panel.

3.8.2 Im-Pesaran-Shin (IPS) Test (2003)

In contrast to the LLC test, the widely used IPS panel unit root test permits heterogeneity in the autoregressive coefficients between cross-sectional units, making it appropriate for a wider range of panels. When using the ARDL model, this flexibility is crucial because it calls for variables to be integrated of order zero or one but not two. Before estimating long-run and short-run dynamics in panel ARDL frameworks, the IPS test assists in verifying the stationarity qualities of each variable (Im, Pesaran, & Shin, 2003). For every cross-sectional unit I in the panel, the Im-Pesaran-Shin (IPS) unit root test is predicated on the Augmented Dickey Fuller (ADF) regression as Follows.

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{it-1} + \sum_{j=1}^{pi} \beta i \Delta yi, t - j + \mathcal{E}i, t$$

The first difference of the variable for unit I at time t is represented by $\Delta y_{i,t} = y_{i,t} - y_{i,t-1}$ the individual intercept is represented by α_i (which may include a time trend depending on specification), the presence of a unit root in the variable for unit I is indicated by ρ_i the number of lagged difference terms included to remove autocorrelation is ρ_i and the error term is represented by i,t. The null hypothesis is tested by the IPS test, which aggregates the individual ADF statistics tp_i from each cross-section.

H_0: All series contain a unit root ($p_i = 0$ for all i),

Ha: At least one series is stationary ($p_i < 0$ for some i).

This regression allows different lag lengths p_i and autoregressive coefficients p_i across units, capturing heterogeneity in the panel.

3.9 Diagnostic Tests and Model Validation

Diagnostic tests and model validation are crucial in panel ARDL analysis to ensure reliable and unbiased results. Key diagnostic checks include tests for serial correlation (e.g., Wooldridge test), heteroscedasticity (e.g., Breusch-Pagan test), and cross-sectional dependence (e.g., Pesaran's CDtest). These tests assess whether the model assumptions hold, such as error independence and constant variance. Additionally, validating the stability of long-run relationships and model specification improves robustness. Applying robust standard errors or alternative estimators may be necessary if violation occur. Rigorous diagnostics prevent spurious inferences and enhance confidence in the panel ARDL estimation outcomes (Narayan, P.K., 2005), (Westerlund, J., 2007), (Chudik, A., & Pesaran, M. H., 2015), (Banerjee, A., Marcellino, M., & Osbat, C., 2004).

CHAPTER IV
RESULTS AND DISCUSSION

The finding of an Autoregressive Distributed Lag (ARDL) model analysis of the variables influencing carbon dioxide emissions in selected South Asian nation namely, India, Nepal, Sri Lank, Pakistan and Bangladesh are covered in this chapter. A review of descriptive statistics, such as the stationarity and cointegration test, diagnostic tests, optimum lag length, estimation of the long-term connection, estimation of the short-term dynamics, and estimation of the error correction model (ECM), will open the chapter. The chapter concludes with a discussion of the analysis's key conclusions, including the significance of the variables influencing carbon dioxide emissions in particular South Asian nations. This chapter will conclude with a discussion of the implications of these findings and their potential applications by policymakers, industry stakeholders, and field researchers.

4.1 Results

4.1.1. Descriptive Statistics

The summary statistics in this section pertain to be a collection of descriptive measures that provide an overview of the main features of a dataset, including the standard deviation, median, skewness, mean, and kurtosis (Wonnacott, 2012). Furthermore, because they offer a succinct overview of the data and enable researchers to make insightful inferences about their findings these metrics are crucial to study (Portney & Watkins, 2015). Similarly, readers can find any outliers or variances and have a better understanding of the data distribution with the use of summary statistics (Salkind, 2017). The results presented in Table 1 provide information on the means, deviations, maximums, minimums, skewness, kurtosis, and Jarque-Bera statistics that are necessary for inferential statistical analysis (John MacCarthy, 2025). The average values indicate that CO2 emission is substantially higher than the other variables, suggesting a significant environmental footprint. GDPP, IND, and AGVAD have relatively lower mean values, indicating moderate economic and industrial activity. FDI shows a lower mean, reflecting substantial foreign investment, while GDPSQ captures the squared term of GDP, emphasizing the non-linear relationship among economic progress and environmental impact. The median values provide a batter central tendency measure for skewed distribution. For instance, the median CO2 emissions are significantly lower than the means, indicating a right skewed distribution with a few countries exhibiting extremely high emission. Similar patterns are observed for GDPP and FDI, suggesting that a small number of countries dominate these metrics this study align with (Rahman et.al., 2025).

Similarly, the high standard deviations across all variables, particularly for CO2 emissions and GDPP, indicate considerable variability with the dataset. This variability is crucial for understanding the diverse environmental and economic landscapes across South Asian countries this study align with (Md Saiful Islam, 2021). Furthermore, Table 1 contains information on the skewness, Kurtosis and Jarque-Bera statistics for the variables used in the analysis. Skewness is used to measure the asymmetrical distribution of the dataset, while Kurtosis is used to measure the degree of peskiness of the distribution. Acceptable skewness values should be between -2 and +2, and kurtosis should be between -3 and +3 when assessing normality in regression. By (Byne, 2010, George & Mallery, 2010) explained in (John Mac Carthy, 2025).

Additionally, positive skewness values for CO2, GDPP, and FDI suggest that these variables have a long right tail, with a few countries exceptionally high values. Negative skewness in IND indicates a left-skewed distribution, where most countries have higher industrial output then few with lower values. On the other hand, high kurtosis values for CO2, GDPP, and FDI imply that these distributions have heavy tails, indicating the presence of outliers or extreme values. In contrast IND, and AGVAD have lower kurtosis, suggesting more uniform distribution this study align with (Md Nazmus Sadekin, 2025).

Table 4.1 Summary of Descriptive Statistic

Statistics	CO2	GDPP	IND	AGVAD	FDI	N
Mean	317.6659	171.5416	23.39726	23.38562	19.17892	200
Median	36.94275	5.198762	23.38492	22.71039	20.34483	200
Maximum	2955.182	2716.486	34.59427	57.29881	25.58094	200
Minimum	0 .6771	-7.45122	11.79204	7.256247	-16.39997	200
Std. Dev.	640.1695	465.5313	5.420046	9.168076	-4.175912	200
Skewness	2.489393	3.755072	-.298171	.7713349	3.267257	200
Kurtosis	8.321976	17.35256	2.275276	4.093127	12.89414	200
Jarque-Bera	6.686376	16.62426	7.178229	38.82229	2.410352	200
Probability	0.0000	0.0000	0.0038	0.0001	0.0000	200

Note: The descriptive statistic table provide an insightful overview of the variables under consideration in this study on the impact of economic development and environmental sustainability on carbon emission in selected South Asian countries. This study considers annual panel data from 1984 to 2023. The period was chosen based on the availability of all the data for the period. The countries under study are Bangladesh, India, Nepal, Pakistan, and Sri Lanka. This analysis encompasses six variables namely, (CO_2) carbon dioxide emission, Gross Domestic Product per capita (GDPP), Industrialization (IND), agricultural productivity (AG), Foreign Direct Investment (FDI), and GDP Squared (GDPSQ) with a total of 200 numbers of observations.

4.2 Correlation Coefficient

A correlation test is performed to measure the strength and route of the linear relationship among two variables, helping identify patterns, dependencies, or potential multicollinearity in regression models. The pairwise correlation matrix reveals relationship between lnCO2 (CO2 emissions), lnGDPP (GDP Per Capita), INDSVA (Industrialization manufacturing value added), AGVAD (agricultural value added), and lnFDI (Foreign Direct Investment). LnCO2 shows a strong positive correlation with INDSMVA (0.6885), indicating that higher industrial activity is associated with increased emissions, consistent with findings by Ali et al. (2021), who noted a similar link in African economies. LnCO2 has a moderate positive correlation with FDI (0.4970), suggesting FDI may contribute to emissions, aligning with pollution haven hypothesis. Conversely, lnCO2 and AGVAD exhibit a negative correlation (-0.4905), implying higher agricultural productivity may reduce emissions, possible due to sustainable practices. Ln GDPP has a weak positive correlation with lnCO2 (0.2865), indicating economic growth has limited direct impact on emissions. INDSMVA and AGVAD are negatively correlated (-0.2917), reflecting sectoral trade off. These correlations highlight the complex interplay of economic activities and environmental outcomes necessitating targeted policies. Variables with strong positive correlations mean that as one increases the other will also increase. Additionally, the correlation coefficients on the diagonal of the table as presented were all equal to 1 as each variable demonstrates a perfect correlation with itself. Table 4.2 below shows the results from the correlation matrix test among the variables.

Table 4.2 Pairwise correlation matrix

	lnCO2	lnGDPP	INDSMVA	AGVAD	lnFDI
lnCO2	1.0000				
lnGDPP	0.2865	1.0000			
INDSMVA	0.6885	0.2069	1.0000		
AGVAD	-0.4905	-0.2903	-0.2917	1.0000	
lnFDI	0.4970	0.0649	0.3395	-0.4851	1.0000

Source Author calculation

4.3 Unit Root Test

Assuring the validity and reliability of econometric estimations in panel data analysis, especially when using the Autoregressive Distributed Lag (ARDL) model, requires the importance of performing stationarity tests. A time series is said to be stationer if its statistical characteristics, including its mean, variance, and autocorrelation, remain constant over time. Because non-stationarity data can result in erroneous correlations, false conclusions and skewed estimates, testing for stationarity is essential when dealing with panel data that includes cross-sectional and time-series dimensions (So Im et. al., 2003). To evaluate the stationarity of individual series within a panel, panel data unit root test like the Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS), and Fisher type test are used. The results of these tests can used to evaluate if variables are integrated of order one I (1), which indicates non-stationarity, or integrated of order zero I (0), which indicates stationary variables. Because the ARDL model does not require that variables be differenced in order to achieve stationarity, it can be used to variables that are I (0), I (1), or a combination of both. This makes it very useful. Unit roots, or non-stationarity, in the data, however, must be carefully taken into account because they may have an impact on the long-term relationships that the ARDL model (Hashem et al.,2003).

When panel unit root test show that variables are I (1), a cointegration test should be performed to see if there is a long-term equilibrium relationship among the variables. When cointegration is verified, the ARDL model can be used to estimate dynamics in the short and long term. In contrast, conventional panel data models might be suitable if variables are determined to be I (0). Stationarity testing is therefore not just a stage in the process but a fundamental part of model design that affects the selection of estimating methods and the interpretation of findings. (Zeeshan et al., 2023). In summary, stationarity test in panel data analysis serve as a diagnostic tool to ensure that the data meets the assumptions required for valid econometric modeling. By identifying the order of integration of variables, researchers can select appropriate modeling strategies, such as the ARDL approach, to accurately capture the underlying relationships and provide reliable policy implications. The LLC, IPS, and Fisher types of tests will be used to check for unit root in any panel series. These tests were first proposed by Levin, Lin, and Chu (2002), Shin and lm, Pesaran, (2003), and Fisher types test (1999), respectively. Table 2 displays the findings of the unit root test. The results indicated that every measure, with the exception of agricultural productivity, was neither level or steady. At first difference, though, they were all immobile. This suggests that either I (0) or I (1) were the variables. This is the prerequisite for using the ARDL model.

Table 4.3 Panel Unit Root Test Results (P-values)

Variables	Level & 1st Diff	LLC	IPS	Fisher ADF
CO2	Level	0.1482 (0.5589)(no)	-0.3714 (0.3552)(no)	4.1638 (0.9997)(no)
	1st differ	- 5.5000 - (0.0000)***	-7.4507 (0.0000)***	-7.1802 (0.0000)***
GDPP	Level	1.6203 (0.9474)(no)	-17215 (0.0426)***	-2.2105 (0.0135)***
	1st differ	-5.8775 (0.0000)***	-8.8678 (0.0000)***	-10.0912 (0.0000)***
INDS	Level	1.4593 (0.9278)(no)	0.9948 (0.8401)(no)	1.0464 (0.8523)(no)

	1st differ	-5.2065 (0.0000)***	-7.5709 (0.0000)***	-7.3977 (0.0000)***
FDI	Level	-1.3916 (0.0820)*	-.06572 (0.2555)(no)	-0.1992 (0.4210)(no)
	1st differ	-6.7602 (0.0000)***	-8.4197 (0.0000)***	-8.1760 (0.0000)***
AGRP	Level	-2.0953 (0.0181)***	-8.0400 (0.0205)***	-1.0591 (0.0368)***
GDPSQ	Level	1.4049 (0.9200)(no)	-1.6696 (0.0475)***	-1.9120 (0.0279)***
	1st differ	-5.1870 (0.0000)***	-8.6856 (0.0000)***	-9.2263 (0.0000)***

Notes: * Significant at 10%, ** Significant at 5%, *** Significant at 1%

Source. Author's Computation

The table 4.3 shows the results of panel unit root tests for six variables namely, CO2, GDPP, INDS, FDI, AGRP, and GDPSQ, conducted using three different unit root test, Levin-Lin-Chu (LLC), Im-Pesaran-Shin (IPS), and Fisher ADF. For each variable, the tests are performed at both the level and the first difference. A p-value greater than 0.05 suggests that the variable has a unit root (is not stationary), while a p-value less than 0.05 indicates stationarity. For CO2 the LLC and IPS tests at the fail to reject the null hypothesis of a unit root, suggesting that CO2 is non-stationary at the level. However, after first differencing, the p-values drop below 0.05. Similarly, GDPP is non-stationary at the level, as indicated by the LLC, IPS, and Fisher ADF tests. After first differencing, all three tests confirm that GDPP is stationary, with p-values well below 0.05. The industrial output variable INDS also exhibits non-stationarity at the level, as shown by the LLC, IPS, and Fisher ADF tests.

However, after first differencing the tests confirm stationarity. FDI presents an interesting result where LLC test suggests non-stationarity at the level with p-value of 0.0820, but the IPS and Fisher ADF tests at the first difference confirm that FDI becomes stationary. AGRP is stationary at the level according to the LLC and IPS tests with p-values of 0.0181 and 0.0205, respectively. But becomes stationary after first differencing in the Fisher ADF test. Finally, GDPSQ (GDP square) is non-stationary at the level, with a p-value of 0.9200 from LLC test, but becomes stationary after first differencing in all three tests. These results highlight the importance of differentiating variables that are non-stationary and handling them appropriately in further modeling, such as ARDL, which can accommodate mixed orders of integration. The results of the panel unit root tests provide valuable insights into the dynamics of the variables in the study on the relationship between economic growth, environmental sustainability, and CO2 emissions. The ARDL model is particularly useful in this context as it can handle variables integrated of different orders (I (0) and I (1)). Based on the results variables like CO2, GDPP, INDS, FDI, and GDPSQ are non-stationary at the level but become stationary after first differencing indicating that they are I (1).

However, AGRP is stationary at the level which suggests it could be modeled as I (0). These mixed orders of integration support the use of ARDL as it does not require all variables to be of the same order of integration. The ARDL model allows for the estimation of both short-run and long-run relationships with is essential when dealing with non-stationary data. Given that the variables are non-stationary at the level the level the ARDL model can provide insights into long-term equilibrium relationships. While short-run dynamic can be analyzed by incorporating lagged differences of the variables. In addition to ensuring appropriate model selection these results highlight the need for caution in interpreting the relationships between variables particularly in the presence of unit roots. Non-stationary variables can lead to spurious regression results which is why first differencing was necessary for most of the variables (Breitung, J, 2000)

4.4. Short-run Analysis

Table 4.4 Short-run estimation result of ARDL model (dependent variable lnCO2)

Variables	Coefficient	Std.Error	t-Statistic	Prob.
(LNGDPP)	0.386507	0.304967	1.267374	0.2071
(GDPSQ)	-0.000580	0.001305	-0.444725	0.6572
(LNIDS)	-0.018898	0.020109	-0.939789	0.3489
(AGVAD)	-0.019218*	0.011299	-1.700903	0.0911
(LNFDI)	-0.009827	0.034731	-0.282957	0.7776
ECT	-0.193175**	0.095125	-2.030761	0.0441

Note. *, **, *** indicates significant level at 10%, 5%, 1% respectively.

The table 4.4 shows the short-run panel ARDL model results, with CO_2 emissions as the dependent variable illuminate the relationships involving agricultural productivity (AGRP), industrialization (INDS) as focus variables foreign direct investment (FDI) as a control, and GDP square (GDPSQ) for the environmental Kuzents Curve (EKC) hypothesis. The AGP coefficient of (-0.019) p-value (0.091) suggests a marginally insignificant negative effect indication that a 1% increase in agricultural productivity reduces CO_2 emissions by 1.91% in the short-run possibly due to temporary shifts toward sustainable practices, as supported by Khan and Ozturk (2021). Who found similar patterns in 20 Asian countries using panel ARDL. The INDS coefficient of (-0.018) p-value (0.34) reflects an insignificant negative impact with 1.88% emissions decrease per 1% increase potentially linked to short-term industrial efficiency gains consistent with Awodumi and Adewuyi (2020) in sub-Saharan Africa. The FDI coefficient of (-0.009) with p-value (0.77) is insignificant suggesting a negligible (0.98%) reduction in emissions aligning with Selmey et al. (2024), who noted weak FDI effects in BRICS nations. The GDPSQ coefficient (-0.0005) with p-value (0.65) is insignificant providing no short-run EKC support echoing finding by Chen et al. (2020) in emerging economies. The error correction term (ECT) of (-0.193) with p-value (0.044) is significant at the 5% level indicating a 19.3% adjustment speed toward long-run equilibrium supporting convergence observed by Zhang and Zhou (2023) in OECD countries.

These short-run findings highlighting sectoral dynamics. The near significant negative AGP effect aligns with Anwar et al. (2019), who analyzing 25 Middle Eastern countries found agricultural productivity emissions impact varies with policy support suggesting a need for green farming incentives. The insignificant INDS effect resonates with Wang et al. (2021) who in a study of 30 developing nations noted that industrial emissions reductions require long-term technological adaption indicating short-run policy gaps. The negligible FDI impact (-0.98%) support Adebayo and Rajoub (2020) who found in 15 countries analysis that FDI environmental benefits are often delayed urging strategic investment targeting. The lack of EKC evidence (GDPSQ p-value = 0.65) mirrors Destek et al. (2020) who using panel ARDL in South Asian economies found short-run growth does not consistently lower emissions without structural reforms. The significant error correction term (p-value = 0.044) aligns with Li et al. (2023), (Selmey et al., 2024) who emphasized a robust adjustment mechanism in East Asian countries highlighting the importance of sustainable policy efforts.

4.5 Long-run Analysis

Table 4.5 Long-run result of ARDL model (dependent Variable lnCO2)

Variables	Coefficient	Std. Error	t-Statistic	Prob.
LNGDPP	0.028360	0.017256	1.643464	0.1024
LNGDPSQ	0.000121	0.000228	1.475446	0.1422
INDS	-0.026005	0.006988	-3.721289	0.0003**
AGVAD	0.075184	0.018493	4.065592	0.0001**
LNFDI	0.301400	0.042181	7.145309	0.0000***

Note. *, **, *** indicates significant level at 10%, 5%, 1% respectively

The table 4.5 shows the panel ARDL result were estimated from the best model ARDL (1,1,12,2,1) selected based on Akaike Information Criterion (AIC). The table present the long-run relationship between agricultural productivity, industrialization, foreign direct investment, and carbon emission as estimated by PMG estimator. The choice of Pool Mean Group (PMG) estimation for the panel ARDL model with CO2 emission as the dependent variable and GDPP, industrialization, agricultural productivity, and FDI as independent variables, has given the failure of Mean Group (MG) and Dynamic Fixed Effects (DFE) tests and the inability to run the Husman test. PMG is suitable for the dataset (40years, 5 countries) as it assumes long-run coefficient are homogenous across countries while allowing short-run dynamics to vary balancing consistency and efficiency especially with a relatively long time series (T = 40years) and cross-section (N = 5). This approach is ideal when cross-country heterogeneity is minimal in the long run as often seen in environmental studies and aligns with the significant ECT coefficient (-0.19, p=0.044) indicating convergence. Studies like Appiah et al. (2023) and Raihan and Tuspekova (2022) also favor PMG for similar panel ARDL framework in environmental economics, supporting its appropriateness here.

The long-run results of the panel ARDL model, with CO2 emissions as the dependent variable, reveal significant insights into the relationships with agricultural productivity (AGVAD), industrialization (INDS) as focus variables, foreign direct investment (FDI) as a control, and GDP squared (GDPSQ) for the Environmental Kuznets

Curve (EKC) hypothesis. The AGVAD coefficient of (0.075) with a p-value (0.0001) indicates a highly significant positive effect at (0.01%) level, suggesting that a 1% increase in agricultural productivity raises CO2 emissions by (7.518%) in the long run, likely due to intensified farming practices, as supported by Paramatie et al. (2021), who found similar trends in 20 Asian economic using panel ARDL. The INDS coefficient of (-0.026) with a p-value (0.0003) shows a significant negative impact at the (0.03%) level, implying a (2.6005%) emissions reduction per 1% increase, reflecting long-term industrial efficiency gains, consistent with Dogan and Seker (2019) in EU countries. The FDI coefficient of (0.301) with p-value (0.0000) is highly significant, indicating a (30.140%) emissions increase increase per 1% rise, suggesting a pollution haven effect, aligning with Solarin et al. (2020) in African nations support for the EKC hypothesis, echoing findings by Acheampong et al. (2021) in developing countries.

These long-run findings highlighting sectoral influences on emissions. The significant positive AGVAD effect supports Ozturk and Acaravci (2019), who analyzing 15 Middel Eastern countries, noted that agricultural expansion drives emissions over time due to energy use, advocating for sustainable practices. The negative INDS impact aligns with Charfeddine and Marbet (2020), who, in a study of Gulf Cooperation Council nations found industrial modernization reduces emissions, suggesting continued investment in green technology. The substantial FDI effects (30.14%) resonates with (Shiddiq & Wau, 2023) who in 57 Organization of Islamic Cooperation (OIC) member countries found that, the policy implication that must be carried out is that the governments of OIC member countries must ensure that FDI which enters the country is FDI that uses environmentally friendly technology so that this FDI is not only good for the economy, but also good for the environment. The lack of EKC evidence mirrors Shahbaz et al. (2023), who, using panel ARDL in South Asian countries found that EKC validation requires significant structural economic shifts.

4.6. Finding and Discussion

H1. There is significant impact of economic development on carbon emission in South Asian nations in the long and short term.

The ARDL model findings do not fully support H1, as the insignificant GDPSQ p-value (0.65) in both short and long run analyses indicates that economic growth does not consistently impact carbon emissions in South Asian countries without structural reforms. This aligns with (Mensah et al., 2019) who, using panel ARDL in Africa economies, found that short run economic growth does not significantly reduce emissions unless accompanied by structural changes, such as enhanced environmental regulations or energy transitions. Similarly,(Basri & Kongcharoen, 2021) noted that long run economic growth in South Asian countries fails to curb emissions without significant policy shifts toward sustainability. The lack of a consistent emissions reducing effect from economic growth suggests that South Asian economies may be in an early stage of development where growth increases emissions without reaching a turning point. Recent studies support this view (Oyekale, 2024). Analyzed South Africa economies and found that economic growth increase CO2 emissions due to dependance on fossil fuels, with no significant mitigation in the short term. Similarly, Mehmood et al. (2022) used panel data from South Asia to show that GDP growth drives emissions in the long run unless renewable energy adoption accelerates. These findings emphasize the need for South Asian countries to integrate green policies to align economic growth with emissions reduction, supporting the ARDL results that economic growth alone does not significantly impact emissions in either the short or long term.

H2. There is significant influence of industrialization, foreign direct investment (FDI), and agricultural productivity on carbon emissions in South Asian nations.

In the short run, the near significant negative AGVAD effect aligns with Anwar et al. (2019), suggesting agricultural productivity's emissions impact is limited without green farming policies, while the insignificant INDS effect supports Wang et al. (2021), indicating that industrial emissions reductions require long term technological adoption. The negligible FDI impact (-0.98%) resonates with Adebayo and Rajoub (2020), highlighting delayed environmental benefits from FDI. In the long run, the significant positive AGVAD effect supports Ozturk and Acarvaci (2019), showing agricultural expansion drives emissions due to energy use while the negative INDS impact aligns with Charfeddine and Marbet (2020), suggesting industrial modernization reduces emissions. The substantial FDI effect (30.14%) corroborates Ali et al. (2022), identifying FDI as a key emissions driver due to industrial focus. Recent studies reinforce this findings, Khan et al. (2020) found that agricultural energy use in South Asia increases emissions in the long run, necessitating sustainable countries often increases emissions due to lax environmental rules, supporting the pollution haven theory. Additionally, Abbas et al. (2023) noted that industrial modernization in developing economies reduces emission emissions over time with green technology adoption. These findings confirm H2's assertion of significant sectoral influences, though the short run effects are less pronounced, highlighting the need for targeted policies to enhance sustainability.

H3. The EKC curve existed in the short and long term in South Asian countries.

The ARDL results do not support H3, as the lack of EKC evidence (GDPSQ P-value=0.65) in both short and long run analyses indicates that the Environmental Kuznets Curve (EKC) does not hold in South Asian nations without significant structural economic shifts. This mirrors Ibrahim and Rizvi (2020), who found that short run economic growth in South Asian economies does not consistently reduce emissions as the EKC hypothesis requires a turning point where higher income levels lead to environmental improvements. Similarly, Shahbaz et al. (2023) used panel ARDL in South Asian countries and found that EKC validation necessitates substantial policy reforms, such as renewable energy adoption and stricter regulations, which are currently insufficient. The absences of reversed U-shaped relationship proposes that South Asian economies are still in a growth phase where emissions rise with economic development. Recent studies corroborate this with Ali et al. (2021) analyzed South Asian nations and found no EKC evidence in the short or long term due to heavy reliance on fossil fuels. Likewise, Raihan et al. (2022) confirmed that South Asian economies lack the structural changes needed for EKC validation, emphasizing the role of policy gaps. Additionally, Adeel-Farooq et al. (2023) noted that EKC is not observed in South Asian without significant investment in green technologies. These findings align with the ARDL results, rejecting H3 and highlighting the need for South Asian countries to implement robust environmental policies to achieve and EKC turning point.

The absence of an Environmental Kuznets Curve (EKC) in South Asian states can be better understood by analyzing the region's structural economic dependencies and institutional limitations. Countries such as Bangladesh, Pakistan, Nepal, and Sri Lanka rely heavily on foreign direct investment (FDI) to stimulate industrial growth, create employment opportunities, and improve infrastructure. (Ali et al., 2022, Basir & Kongcharoen, 2021). However, much of this FDI is channeled into pollution intensive sectors, particularly textile manufacturing, cement, and resource extraction, which are major contributors to carbon emissions. These investments often exploit weak or under-enforced environmental regulations, allowing firms to operate with limited environmental accountability (Charfeddine & Marbet, 2020, Adebayo & Rajoub, 2020). As a result, the environmental benefits expected from FDI such as clean technology transfer or efficiency gains are not realized, supporting the Pollution haven theory rather than the Pollution halo effect in this context.

In addition to FDI-driven industrial activity, the labor market structure in South Asia plays a critical role in shaping emission patterns. These economies are dominated by low-and middle-income earners, with limited access to high-paying, skilled jobs

(Mehmood et al., 2022). As these income groups grow, their rising consumption levels, energy demand, and urbanization trends contribute to increased carbon emissions (Anwar et al., 2019). Without a simultaneous investment in green infrastructure and clean technologies, this income-driven growth further intensifies environmental degradation. Since these countries are still navigating an early stage of development prioritizing rapid economic expansion over environmental sustainability, they have yet to achieve the structural reforms required for EKC dynamics to emerge. Factors like technological upgrading, effective environmental governance, and green innovation are largely insufficient or absent, thereby preventing the decoupling of growth and emissions (Ozturk & Acaravci, 2019, Wang et al., 2021). This supports the empirical finding that economic growth continues to elevate emissions in both the short and long term across the region.

CHAPTER V
CONCLUSION AND RECOMMENDATIONS

We outlined the key conclusions and revelations from the full study in this last chapter and provided policy recommendations in light of the findings. The research conclusions are compiled, and the main goals and research issues covered in previous parts are reviewed. Along with discussing the issues that arose during the study, we also identified areas that require more investigation. Despite the fact that this research provides useful information, it is important to understand its limitations and potential improvements. Finally, we discuss avenues for future research, highlighting methods to advance understanding of the subject and enable the researchers to contributes significantly to the area. The study's limitations, policy recommendations, and potential future research areas will all be completely clear to the reader by the end of this chapter.

5.1. Research Questions and Conclusions

The panel ARDL model, using the Pool Mean Group (PMG) estimator, examines CO2 emissions as the dependent variable with GDP per capita, industrialization (INDS), agricultural productivity (AGVAD) foreign direct investment (FDI), and GDP squared (GDPSQ) as independent variables across five South Asian countries over 40 years. The short-run results show an insignificant negative effect of AGVAD (-.0.019, p=0.091), suggesting a 1.92% emissions reduction per 1% increase, possible due to sustainable practices. INDS (-0.018, p=0.348) and FDI projects to shift reliance from fossil fuels, and launch environmental (-0.009, p=0.777) also have insignificant negative impacts, reducing emissions by 1.89% and 0.98%, respectively. GDPSQ (-0.0005, p=0.657) provide no support for the Environmental Kuznets Curve. The significant error correction term (-0.193, p=0.044) indicates a 19.32% adjustment speed toward long-run equilibrium. The PMG estimator is justified due to the failure of MG and DFE, balancing homogeneity in long-run coefficients with short-run heterogeneity. Similarly, the result of short-run interaction model reveals that the coefficient of AGVADLNFDI (-0.0005, p=0.393) is insignificant, suggesting a negligible 0.052% emissions reduction per 1% increase, indicating limited environmental benefits from agricultural-FDI synergies. The INDSLNFDI coefficient (0.014 p=0.150) is also insignificant, implying 1.498% emissions increase per 1% rise, reflecting short-run pollution from industrial FDI. The GDPSQ coefficient (0.0003, p=0.777) is insignificant, offering no EKC support, suggesting economic growth does not reduce emissions without structural changes. The error correction term (ECT) (-0.118, p=0.178) is negative but insignificant, indicating a weak 11.86% adjustment toward long-run equilibrium, lacking statistical reliability. In the long run, AGVADLNFDI (0.011, p=0.033) is significant, showing 1.182% emissions increase per 1% rise likely due to intensified agricultural practices. INDSLNFDI (-0.067, p=0.008) is significant, indicating a 6.709% emissions reduction per 1% increase, reflecting green industrial technologies. FDI (1.411, p=0.027) significantly increases emissions by 141.156% per 1% rise, suggesting a pollution haven effect. GDPSQ (4.29, p=0.935) is insignificant, providing no EKC support. The results highlight contrasting long-run impacts of agricultural and industrial FDI interactions with weak short-run dynamics and no EKC evidence, suggesting the need for targeted green policies to mitigate emissions in South Asian economies.

The finding of this study answers the research question (What is the impact of economic progress on carbon emission in South Asian countries in the short and long term?) that economic growth does not have a significant impact on reducing carbon emissions in South Asian nations in either the short or long term, as evidenced by the insignificance of the GDP square term in the ARDL model. This suggests that the Environmental Kuznets Curve (EKC) theory does not hold in this regional context without substantial structural reforms. Theoretically, the results challenge the universal applicability of the EKC, highlighting the need to incorporate policy and energy transition variables. Practically, the findings underscore the importance of environmental regulation and renewable energy investments to ensure that economic growth can be achieved without escalating environmental degradation.

Similarly, the study finding for second research question (what is the influence of foreign direct investment (FDI), industrialization, and agricultural productivity on carbon emission in the short and long term?) reveal that FDI, industrialization, and agriculture exert divergent short-and- long-run effects on emissions, directly addressing the research question. Theoretically, FDI’s long-run pollution haven effect challenges neoliberal assumptions about its automatic benefits, while industrial decarbonization aligns with ecological modernization theory. Empirically, South Asia’s agro-industrial transition reveals a trade-off, agricultural commercialization raises emissions, whereas industrial maturation reduces them. Policy implications are urgent: (1) FDI must be steered toward green sectors, (2) industrial policies should combine short-term efficiency mandates with long-term tech subsidies, and (3) agricultural extension services must prioritize low carbon practices.

Finally, the analysis finds no evidence of the Environmental Kuznets Curve (EKC) in South Asian nations. This directly answer the last research question which is (Does EKC curve existed in the short and long term in South Asian countries?) as the squared GDP term remains insignificant in both the short and long run. This indicates that economic growth continues to drive carbon emissions upward without reaching a turning point where emissions begin to decline. Theoretically, this challenges the applicability of the EKC in developing regions, suggesting that income growth alone is insufficient to improve environmental quality. Empirically, it shows that South Asian economies remain in a pollution-intensive phase of development. The findings imply that policymakers should not depend on economic growth to solve environmental issues but must instead implement proactive strategies such as green technology adoption, renewable energy use, and stronger environmental governance.

5.2. Policy Recommendation

Based on the short-term findings, South Asian countries should implement measures that guide FDI into environmentally sustainable sectors through incentive-based policies and regulatory screening. Strengthening environmental standards and supporting low-carbon technologies in agriculture and industry can help minimize emission growth during early development phases. This includes stricter environmental regulation of foreign investment, expansion of renewable energy infrastructure, and incentives for technological upgrading in manufacturing. Aligning FDI and GDP growth with sustainability goals can create a meeting point where economic development and emissions reduction coexist, ensuring a transition toward a low-carbon economy.

5.2.1. Short-term recommendation

1. **“**Guide FDI toward cleaner sectors through tax incentives or sustainability screening mechanisms.”
2. **“**Promote pilot programs for green industrial technologies to reduce energy use early.”
3. **“**Invest in public awareness and education about sustainable consumption and production patterns.”
4. “Strengthen baseline environmental standards to reduce emissions from agriculture and small-scale industry.”

5.2.2. Long-term recommendation

1. “Implement strict environmental regulations for FDI-receiving industries.”
2. “Establish green finance and subsidies for renewable energy and clean technologies.”
3. “Support technological upgrading in industrial sectors to decouple GDP from emissions.”
4. “Align national development strategies with the UN Sustainable Development Goals (SDGs), especially SDG 13 (Climate Action) and SDG 9 (Industry, Innovation, and Infrastructure).”

5.3. Limitation and Future Study

1. Investing Sector Specific FDI Impacts on Emissions:

The significant long run FDI suggests emission reductions from green industrial FDI. Future research should explore sector specific FDI impact (e.g., energy, manufacturing, agriculture) on CO2 emissions in South Asian nations, using disaggregated FDI data to identify which sectors drive the pollution haven effect and which support green outcomes.

2. Exploring Structural Breaks and Policy Shifts in Agricultural Emissions:

The significant long run AGVADLNFDI coefficient shows that FDI driven agricultural productivity increases emissions, while short run effects are insignificant. Future research should investigate sustainable agriculture policies (e.g., organic farming, agroforestry) can mitigate emissions.

3.Testing The EKC Hypothesis with Alternative Variables:

The insignificant GDPSQ indicate no EKC support, suggesting economic growth alone does not reduce emissions. Future research should test the EKC hypothesis by incorporating additional variables like renewable energy share, environmental regulations. This could reveal conditions under which South Asian economies achieve an EKC turning point.

4.Assessing Shor-Run Policy Effectiveness for Emission Reduction:

The weak short run dynamics suggest limited immediate impacts. Future research should evaluate the effectiveness of short-term policy interventions (e.g., emission standards, green industrial zones, irrigation efficiency) and event studies to identify rapid response strategies that complement long run green policies in South Asian countries.

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