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ESCAP secretariat

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Early Career Researcher

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Salma Ahmed

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ABOUT ASIA-PACIFIC SUSTAINABLE DEVELOPMENT JOURNAL

The Asia-Pacific Sustainable Development Journal (APSDJ) is published twice a year by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP). It is the continuation of UNESCAP's Asia Pacific Development Journal (APDJ) with an explicit recognition of sustainable development in line with the United Nations Agenda 2030 for Sustainable Development Goals (SDGs).

APSDJ welcomes submissions of original contributions on themes and issues related to sustainable development that are policy-oriented and relevant to Asia and the Pacific. Articles should be centred on discussing challenges pertinent to one or more dimensions of sustainable development, policy options and implications and/or policy experiences that may be of benefit to the region. Editorial policy is to maintain a sound balance between theoretical and empirical studies, and to highlight policy relevance.

APSDJ particularly welcomes papers that deal with sustainable development issues using a multi-disciplinary approach. Submissions may range from overviews spanning the region or parts of it, to papers with a detailed focus on issues facing individual countries.

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EXPLANATORY NOTES

References to dollars ($) are to United States dollars, unless otherwise stated.
References to “tons” are to metric tons, unless otherwise specified.
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Use of a hyphen between dates (e.g. 1980-1985) indicates the full period involved, including thebeginning and end years.

The following symbols have been used in the tables throughout the journal:
Two dots (..) indicate that data are not available or are not separately reported.
An em-dash (—) indicates that the amount is nil or negligible.
A hyphen (-) indicates that the item is not applicable.
A point (.) is used to indicate decimals.
A space is used to distinguish thousands and millions.
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EDITORIAL

I am pleased to present the first issue of the Asia-Pacific Sustainable Development Journal (APSDJ, vol. 30, No.1) for 2023. The issue comes out at a critical juncture when the region is confronted with the challenges of changed global circumstances while still recovering from the devastations caused by the COVID-19 pandemic amid ongoing climate change-induced existential threats.

Nowhere is the global climate emergency more immediate than in Asia and the Pacific. Climate-induced disasters sweep across the region with ever-increasing force and frequency. Lives are lost, communities displaced, and people's health damaged. As vital livelihoods, infrastructure and services are disrupted, the most vulnerable are left cruelly exposed, and the economic costs are phenomenal. In the region responsible for more than half of global greenhouse gas emissions, with economies powered largely by fossil fuels, climate change is exacerbating poverty and imperilling sustainable development. Now is the time to step up the region's climate action.

If the urgency is clear, the context is challenging. The COVID-19 pandemic was hard felt in Asia and the Pacific, and the crisis in Ukraine continues to cause a great deal of uncertainty. As governments work to consolidate a recovery, they must contend with multiple challenges, but the existential threat posed by climate change means the region's response cannot be postponed. Measures to put the economies of Asia and the Pacific on a low-carbon pathway and adapt and become more resilient to the impacts of climate change must be front and centre of the region's post-pandemic recovery.

Accordingly, this issue contains a survey article by the ESCAP secretariat that provides a brief assessment of the region's vulnerability and highlights the needed transformations for its transition to a "net-zero-carbon" future in support of sustainable development. Recommendation given in the article include building regional frameworks or partnerships on green power corridors, low-carbon transport, and a low carbon and climate-smart transition. In addition, collaboration among countries and development partners for climate-smart trade and investment, climate finance, and monitoring is encouraged.

The issue also contains a collection of five thematic articles focusing on national efforts towards a "clean energy" transition and "net-zero" greenhouse gas emissions by 2030 as set out by the international community. This thematic section, "Green transition and national efforts towards net-zero targets," has been ably guest-edited by Editorial Board member Tae Yong Jung, Professor of Sustainable Development at Yonsei University in the Republic of Korea.

The first thematic article provides an assessment of emissions reduction efforts of Japan in comparison with other countries nationally determined contributions. The Paris Agreement requires each participating country to prepare its nationally determined contributions. Japan submitted a 26 per cent emissions reduction target for 2030 in 2020 and resubmitted a 46 per cent target (relative to 2013) in 2021. The authors express concerns that the targets were determined in a top-down manner without detailed scientific assessments and argue that well-coordinated climate policies are needed to meet the targets.

The second thematic article includes an evaluation of the nationally determined commitments and the 2050 net-zero commitments of the Republic of Korea, thus, the country's mitigation progress. Three key challenges are identified, namely limited time to meet targets, energy transition difficulties and difficulties in transforming carbon-intensive industries. The authors suggest strategic directions in four areas: accelerating low-carbon transitions in key sectors; enhancing mitigation policy effectiveness; building stakeholder consensus on transition costs; and bolstering international cooperation for carbon neutrality.

The third thematic article gives an assessment of the energy strategies, policy regimes and the prospects for clean coal technology development in China in the context of attaining a successful energy transition by 2050. The authors argue that clean coal development is crucial for meeting the carbon targets and other development targets, such as the Sustainable Development Goals, especially air quality targets.

In the fourth thematic article, the authors evaluate how a rapidly growing country, such as Bangladesh, can overcome the barriers towards achieving the Sustainable Development Goals. They identify continuous access to modern energy and enhancing energy efficiency as critical factors and argue that the barriers can be overcome through a systematic packaging and prioritization approach.

The fifth thematic article contains an analysis of the perceived and prioritized barriers to access climate funds using Nepal as a case for least developed countries. The authors find that inadequate ministerial coordination, insufficient evidence-based research and limited understanding of the public-private partnerships as prominent barriers in Nepal. They argue that despite some success in accessing climate finance, additional challenges remain relating to disbursement, the information-base and the choice of financial instruments.

One of the key features of APSDJ is to provide a platform for interactions between researchers and policymakers. Accordingly, the thematic section is followed by a policy paper on challenges for the achievement of Sustainable Development Goals that may arise from the significant increase in demand for critical minerals, including critical raw materials, in the process of the low-carbon energy transition. The authors argue that the extraction and processing of critical raw materials create challenges for sustainable development, particularly in Asia and the Pacific, which is a major supplier and consumer of these inputs. Globalized trade of critical raw materials and diverse supply chains result in fragmentation, which, in turn, calls for enhanced international cooperation to ensure that the extraction of critical raw materials is in line with the Sustainable Development Goals. The authors see opportunities for the United Nations to do more to align the extraction and processing of critical raw materials with the implementation of the 2030 Agenda for Sustainable Development.

The issue also includes two submitted papers. One of them assesses the achievements of the Millennium Development Goals in least developed countries. In the light of the experiences, the authors propose a synthetic approach by creating a composite index to measure these countries' comparative progress towards implementation of the 2030 Agenda. In the second submitted paper, the growth performance, potential and environmental sustainability of cotton production in India is evaluated. The author argues for a holistic view regarding the performance of the cotton crop and, accordingly, in framing policies to exploit the potential of this sector in generating additional employment while preserving the sustainability of cotton production.

One of the mandates of ESCAP is the provision of capacity-building support. Accordingly, submissions to the ASPSD from early career researchers are encouraged, especially from countries in special situations, such as least developed countries. The editors provide mentoring and guidance to such authors who demonstrate potential. This issue includes a paper from an early career researcher. Using qualitative analysis, the author assesses development progress of Asia-Pacific countries resulting from the China-led Belt and Road Initiative. The author finds significant trade expansion associated with growing connectivity via infrastructure finance from China to Belt and Road Initiative economies vis-à-vis their non-Belt and Road Initiative counterparts. The rising trade ties are also associated with output growth, contributing to the development of Belt and Road Initiative countries and some modest positive spillover effects to non-Belt and Road Initiative members.

I thank the authors, the guest editor and the editorial team, as well as support staff, including the copy editor and designer, for their contributions to the publication of this issue with highly significant research findings and policy implications. I am confident researchers and policymakers will find this issue enormously useful.

Armida Salsiah Alisjahbana

Under-Secretary-General of the United Nations and Executive Secretary,
United Nations Economic and Social Commission for Asia and the Pacific

ACCELERATING CLIMATE ACTION IN ASIA AND THE PACIFIC FOR SUSTAINABLE DEVELOPMENT

ESCAP secretariat[1]

The Asia-Pacific region is in urgent need for enhanced climate ambition and action. Climate change-induced disasters, e.g., heatwaves, droughts, typhoons and floods, are increasingly undermining hard-won development gains. This paper provides a brief assessment of the region's vulnerability and sets out the transformations needed for a net-zero carbon future in support of sustainable development. It recommends building regional frameworks or partnerships to support decarbonizing key sectors – energy, transport and industry – and improve enabling conditions, such as financing and monitoring. Multistakeholder cooperation on broad national policies and long-term strategies is also needed for the low-carbon and climate-resilient transition.

Keywords: climate change, sustainable development, greenhouse gas emissions, net zero, regional partnerships

JEL classification: G10, Q01, Q30, Q54, Q58

[1] This paper is based on the secretariat's submission to the seventy-ninth session (15-19 May 2023) of the United Nations Economic and Social Commission for Asia and the Pacific on the theme topic: "Accelerating climate action in Asia and the Pacific for Sustainable Development". The submission was drafted by the Environment and Sustainable Development Division. For any queries, the correspondent author is Sangmin Nam, nams@un.org.

I. INTRODUCTION

While the climate emergency is global, nowhere is the need for greater ambition to respond to climate change more urgent than in Asia and the Pacific. Over the past 60 years, temperatures in the region have increased more rapidly than the global mean (WMO, 2021). Extreme, unpredictable weather events and natural hazards have become more frequent and intense. Tropical cyclones, heatwaves, floods and droughts have brought tragic loss of life, displaced communities, damaged people's health and pushed millions into poverty. Of the 10 countries most affected by these disasters, 6 are in the Asia Pacific region,[2] where food systems are being disrupted, economies damaged and societies undermined (UNDRR and CRED, 2020). In the absence of accelerated action, climate change will remain a central driver of poverty and inequality across the region. Most countries in Asia and the Pacific are insufficiently prepared. They lack the financial means to support adaptation and mitigation efforts as well as the data required to inform climate action. Existing infrastructure and services are insufficiently climate resilient.

Asia and the Pacific accounted for more than half of global greenhouse gas emissions in 2020 (ESCAP and others, 2022). The region's share continues to increase; greenhouse gas emissions have more than doubled since 1990, driven by electricity generation and the manufacturing and transport sector.[3]

Global greenhouse gas emissions must be reduced by 45 per cent by 2030 compared to 2010 levels to keep the world within a temperature rise of 1.5°C above pre-industrial levels. Achieving this objective depends on the greenhouse gas emission trajectory of Asia and the Pacific. Yet, the sum of countries' actions in nationally determined contributions (NDCs) to cut emissions falls short of the required ambition. In fact, a 16 per cent increase in greenhouse gas emissions from 2010 levels is forecast, a world away from the reductions needed.

Adaptation plans and early warning systems reduce vulnerability to the impacts of climate change and deliver a very large return on investment. Investment in early warning systems to mitigate climate hazards, avoid humanitarian crises and protect development gains is an immediate necessity. For example, such systems have helped to reduce the death toll more than one hundredfold over the past four decades in Bangladesh and have mitigated the damage these events inflict by helping communities to move their properties and assets to safer areas. Yet, existing early

[2] China, India, the Philippines, Indonesia, Japan, Viet Nam, Bangladesh and Afghanistan are among the top 10 countries in terms of disaster occurrence, while in terms of population affected, China, India, the Philippines, Bangladesh, Thailand, Pakistan and Viet Nam are among the 10 top countries.

[3] See https://edgar.jrc.ec.europa.eu/.

warning systems are simply insufficient, meaning that too many people are left exposed, particularly in small island developing States. Ensuring that early warning systems cover all communities in Asia and the Pacific must be a priority. The cost of increasing the coverage of multi-hazard early warning systems is far outweighed by the cost of inaction.

The present paper provides a brief survey of the state of the vulnerability of the Asia Pacific region and sets out the transformations needed for the region to transition to a net-zero-carbon future in support of sustainable development. It provides an outline of the regional context of climate change and policies and actions that could be taken in various sectors of the economy to support the global climate agenda, while also making broad economic, social and environmental gains. It also contains information on climate-related financing needs in the region and addresses data gaps for better monitoring. Given that enhanced regional cooperation is needed for faster, bolder climate action for sustainable development in the region, policy options in this regard are presented.

II. A VULNERABLE REGION

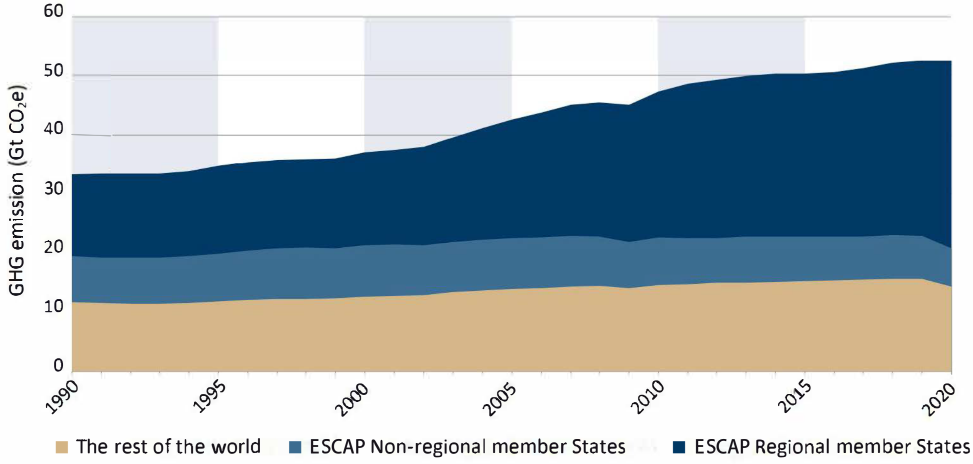
Between 2000 and 2019, 8 out of the top 10 countries most affected by disasters were in Asia and the Pacific (UNDRR and CRED, 2020). Under all forecast scenarios, the region will remain the most affected by heavy rainfall, drought, heatwaves and intensifying tropical cyclones. The ever-increasing costs of climate change are exacerbating poverty and jeopardizing sustainable development.

The environmental impacts of climate change in Asia and the Pacific are alarming. Over the past 40 years, significant mass losses have been recorded in five glaciers in the High-Mountain Asia region in East and North-East Asia and South Asia. This trend has accelerated in the twenty-first century. Glaciers in this area cover approximately 100,000 km^2 and contain the largest volume of ice outside the polar region. Their retreat imperils the freshwater supplies of the most densely populated part of the planet. The global average sea level continues to rise. In the Indian Ocean and parts of the Pacific Ocean, including the western tropical Pacific, slightly more rapid rates of sea-level change than the global mean of 3.3 mm per year have been recorded, with existential implications for the future of small islands States (WMO, 2021).

2.1 Rising greenhouse gas emissions

Asia and the Pacific emits more than half of the global greenhouse gas emissions (figure 1). The region’s share continues to increase as countries continue to power their development with fossil fuels. Its greenhouse gas emissions have more than doubled between 1990 and 2020.

Figure 1. Greenhouse gas emissions trends in the Asia-Pacific region compared to the rest of the world, 1990–2020 ($GtCO_2e$)



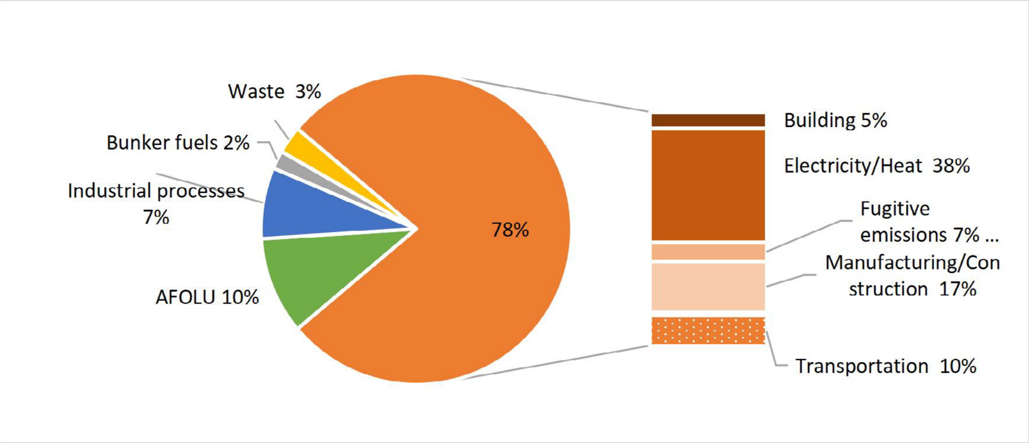
Source: IPCC (2022) and European Commission (2021)

The major sources of greenhouse gas emissions in the Asia-Pacific region are electricity and heating, manufacturing and construction, and transportation (figure 2). Electricity and heating account for the bulk of energy emissions, 38 per cent of total emissions, which is higher than emissions from electricity and heating in the rest of the world. The share of manufacturing and construction in regional greenhouse gas emissions is twice as high as in the rest of the greenhouse gas emissions. Heavy industries, such as steel and cement production, account for more than 50 per cent of all industrial emissions globally and 70 per cent of global steel production takes place in Asia. The Asia-Pacific region produces 73 per cent of the cement output globally and consumes 81 per cent of it. The transport sector is the third major source of energy-related carbon dioxide emissions in Asia and the Pacific. Transport-related emissions in the region is the leading factor behind the 40 per cent increase in regional greenhouse gas emissions over the past decade, as demand for passenger and freight transport has expanded.

Figure 2. Greenhouse gas emissions in the Asia-Pacific region by sectors,

2020

Source: IPCC (2022) and European Commission (2021).



To keep the world well below a 2°C temperature rise and within the 1.5°C temperature rise in accordance with the Paris Agreement, IPCC has called on the world to reduce greenhouse gas emission by 45 per cent by 2030 compared to 2010 levels, which is critical to achieving carbon neutrality by 2050 and realizing a global 1.5°C development pathway.

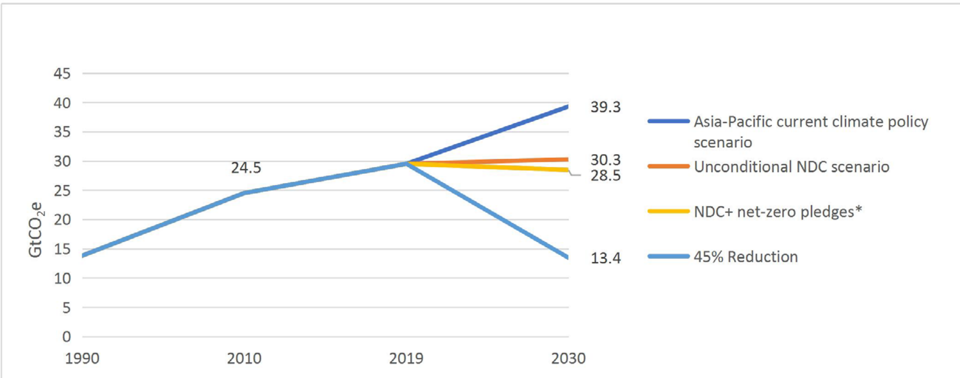
Countries in Asia and the Pacific collectively emitted 31.6 GtCO2e in 2020. Current NDC commitments for greenhouse gas emission reductions and regional greenhouse emissions trajectories are projected to result in greenhouse gas emissions of 25.2 GtCO2e in 2030. As shown in figure 3, this represents a 16 per cent increase from 2010 levels, rather than the 45 per cent reduction required to achieve the 1.5°C pathway.[4] The current gap in the regional NDC commitments needs to be addressed at the national level to avoid a large overshoot. Collective efforts are required to spur the region's mitigation ambition and support the mid-century climate neutrality trajectory that would keep the region within the 1.5°C target.

Figure 3. Greenhouse gas emissions scenarios with compounded nationally determined commitments and carbon-neutral pledges for the Asia-Pacific

[4] United Nations Framework Convention on Climate Change, document FCCC/PA/CMA/2022/4.

region (GtCO2e), 1990–2030

Source: IPCC (2022) and European Commission (2021).



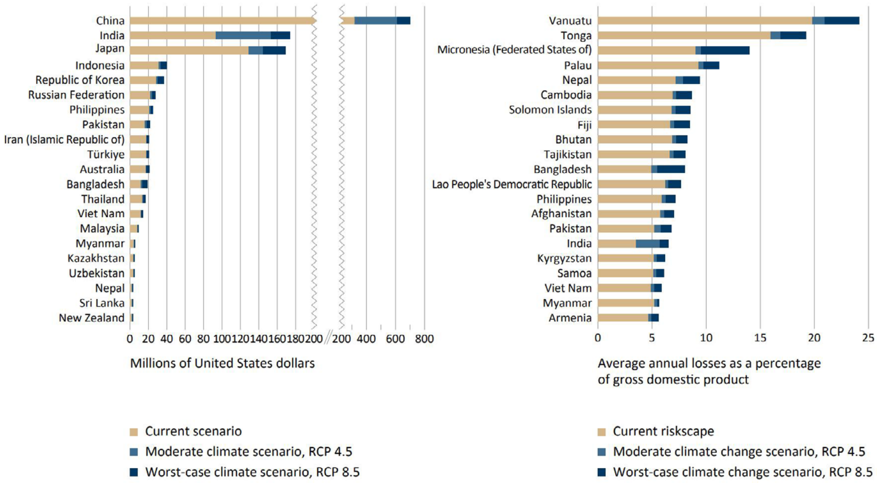
2.2 Costs of climate change

The costs of climate change are already too high. Figure 4 presents ESCAP forecasts of average annual losses in different countries of the region under varying scenarios of natural and biological hazards. As indicated, costs vary significantly across countries. As a share of gross domestic product (GDP), ESCAP forecasts that the Pacific small island developing States and least developed countries will be the worst hit economically. The Pacific small island developing States, heavily burdened by natural and biological hazards, are expected to face some of the worst climate change outcomes. Natural hazards lead to an increase in vector-borne diseases, such as malaria or dengue, heatwave-related strokes and malnutrition. These conditions are increasing with climate change and heeds the call for stronger integration of health and disaster risk reduction management systems (ESCAP, 2020). China, India, Japan, Indonesia, the Republic of Korea and the Russian Federation are projected to suffer the greatest losses in absolute terms under the worst-case climate scenario.

Figure 4. Average annual losses due to natural and biological hazards in millions of United States dollars and as a percentage of gross domestic product.

Source: ESCAP (2021)

In 2021 alone, more than 100 natural hazards – floods, tropical cyclones, heatwaves



and droughts – killed 4,000 people and disrupted the lives of 48.3 million people in Asia. The cost of the damage was estimated at $35.6 billion. The greatest losses were caused by flooding, such as what occurred in India, which led to losses equivalent to $3.1 billion from infrastructure and agricultural damage. Flooding in Pakistan led to losses equivalent to 2.2 per cent of GDP, affected 33 million people, displaced 8 million people and pushed almost 9 million people into poverty. Compared to the past 20-year average for economic losses caused by disasters in Asia, in 2021, economic damage from drought increased by 63 per cent, from flooding by 23 per cent, and from landslides by 147 per cent (ESCAP, 2020).

III. CLOSING EMISSION GAPS IN KEY SECTORS

This section contains an outline of the regional context of climate change and presents policies and actions that could be taken in various sectors of the economy, such as energy, logistics and manufacturing – the three highest greenhouse gas-emitting sectors.

3.1 Accelerating the energy transition

Eighty-five per cent of the region's primary energy supply came from fossil fuels in 2020, according to the International Energy Agency (IEA).[5] Coal accounted for more than 40 per cent of the total energy supply, but was responsible for more than 60 per cent of the region's energy-related carbon dioxide emissions. One third of the region's emissions came from natural gas and oil. To limit temperature rises to 1.5°C, use of oil and gas need to be radically phased down by 2050 and used of coal needs to be completely phased out.

The rapid uptake of renewable energy requires the restructuring of national energy systems, new technical capacities and significant investment in supply and infrastructure. To date, investment is insufficient and more ambitious commitments to phase out fossil fuels, scale up renewable energy and improve energy efficiency are needed, requiring the allocation of greater financial resources. In existing NDCs, there is a large gap between countries' the unconditional commitments and their conditional commitments that would make the 1.5°C objective achievable. In least developed countries, international technical and financial support remains critical to bridge this gap, but it has yet to materialize at the necessary scale.

Cross-border electricity grids can increase the share of renewable energy. A higher share of renewable energy also requires more flexible, responsive grid systems. Increased cross-border connectivity and multilateral energy trading would enable the increased use of wind and solar power. These grids would expand the area in which electricity supply and demand are balanced, thereby making renewable energy more affordable and accessible. Such crossborder electricity markets require enabling frameworks, including intergovernmental agreements on energy cooperation and interconnection, and the coordination and harmonization of institutional policies and regulatory regimes, which can be supported by a regional green power corridor framework.

The heavy reliance on fossil fuels in the industrial sector is a major hurdle, particularly in steel and cement production. Electrification is critical, including the use of electric furnaces to process recycled steel or a shift to hydrogen-based production methods. Across industrial sectors, Governments should incentivize research and development, and the uptake of low-carbon technologies.

Improved energy efficiency can reduce greenhouse gas emissions while meeting growing energy demands. In 2020, the region's carbon intensity was higher than all other regions and 27 per cent more than the global average, according to data from the IEA and the World Bank.[6] Improved energy efficiency is a cost-effective way to

[5] World Energy Statistics and Balances database. Available at www.iea.org/data-and-statistics/data-product/world-energy-statistics-balances (accessed on 5 December 2022).

[6] See https://asiapacificenergy.org/apef/index.html#main/lang/en/graph/10/type/0/sort/0/time/

reduce greenhouse gas emissions, meet growing energy demand, lower exposure to energy price fluctuations and support energy security. Broader application of and more ambitious minimum energy performance standards could significantly improve the energy efficiency of lighting, appliances and equipment, and result in ousting inefficient technologies from the market. The harmonization of minimum energy performance standards and standardized labelling are being pursued by the Association of Southeast Asian Nations (ASEAN); the rest of the region could build on these initiatives.

Climate risk analysis and planning are needed to build greater climate resilience within existing and future energy systems. Power plants and electrical grids across the region are exposed to multi-hazard risks, and climate change is shifting environmental conditions, which have longer-term implications for regional energy systems. Hydropower, which holds the largest share of the region's installed renewable energy capacity, is becoming increasingly unreliable. Climate risk analysis and planning is, therefore, necessary for all economies. Using it to modernize existing infrastructure can help to improve climate-proof energy systems, increase generation efficiency and capacity, and attain greater grid flexibility.

3.2 Towards low-carbon mobility and logistics

Putting the transport sector on a low-carbon pathway remains challenging. The sector is fragmented and powered primarily by oil. To reach net-zero carbon by 2050, carbon dioxide emissions from transport need to decrease by at least 3 per cent annually. In Asia and the Pacific, transport emissions have increased by 200 per cent over the past three decades due to the rapidly growing demand for passenger and freight transport. Transport carbon dioxide emissions constitute 27 per cent of the region's total emissions and are above the global average. According to estimates by the International Transport Forum (ITF), demand for transport is forecast to increase by 150 per cent between 2015 and 2050, which would lead to a rapid increase in transport-related carbon dioxide emissions in the absence of a rapid transition to low-carbon transport solutions (ITF, 2021).

Nonetheless, it is possible to put the transport sector on a low-carbon pathway in Asia and the Pacific by reducing transport distance through integrated land use and transport planning and changes in route choice, shifting to sustainable transport modes with low-carbon or net-zero carbon emissions and improving vehicle and fuel efficiency. Policies must focus on five broad areas: (a) improved design, operations and planning of transport systems; (b) electrification; (c) low-carbon fuels and energy;

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(d) changing transport modes; and (e) innovation and upscaling. Ultimately, policies must change travel behaviour for passenger transport and logistics operations for freight transport, while improving vehicle, fuel and system efficiencies.

Immediate action is needed to develop and integrate a broad set of transport-related climate action policies into NDCs and to guide the transition of the sector to net-zero emissions. Integrated land use and transport planning needs to take into account expanding public transport options, linking public transport services to improved walking and cycling infrastructure and making advanced vehicle technologies powered by renewable fuels. This integration would encourage public transport use and improve the efficiency of transport networks.

Improved fuel efficiency of motor vehicles is crucial to reducing carbon dioxide emissions. Tighter fuel economy standards are needed as a transitional step prior to electrification. The electrification of two- and threewheelers in Asia and the Pacific is already well under way, led by China and India. Policy interventions and technological advancements have reduced the cost of owning an electric vehicle, extended vehicle range and enabled faster battery charging. The electric bus market is also growing. According to IEA (2022), China has almost 600,000 electric buses, and electric bus sales in India, Japan and the Republic of Korea have increased exponentially.

The freight transport sector, especially long-haul freight, is harder to put on a low-carbon pathway than the passenger transport sector. While some countries in the region have begun implementing climate action in this area, freight transport needs to be given greater priority. The right incentives for the private sector are essential to reduce freight emissions. Road freight is the main type of freight transport in most countries and the second-largest contributor of global transport carbon dioxide emissions after passenger road transport. Reducing road freight transport emissions requires improved energy and vehicle efficiency and performance standards.

Innovative transport technologies should complement measures to increase energy efficiency and electrification. These include passenger information systems, automatic toll payment, congestion charging, digitally enabled real-time route planners, and contactless and paperless border crossing. Investment in digital infrastructure would enhance the flexibility and responsiveness of transport systems, and, in turn, reduce energy consumption and carbon dioxide emissions, along with road congestion and air pollution.

Decarbonizing the transport sector requires cross-sectoral partnerships involving all governance levels and the private sector, as well as regional cooperation in exchanging best practices and relevant data and information, which will support countries in aligning low-carbon transport policies to achieve climate goals at a faster rate. With this goal in mind, ESCAP has launched two initiatives in 2022: (a) the regional cooperation mechanism on low-carbon transport, which is aimed at promoting low-carbon mobility and contributing towards transport emission reductions by helping countries develop relevant policies and technologies and (b) the AsiaPacific initiative on Electric Mobility, which supports developing countries in the region by providing expertise, technological know-how and the financial means to transition to net-zero-carbon transport.

3.3 Building low-carbon industries

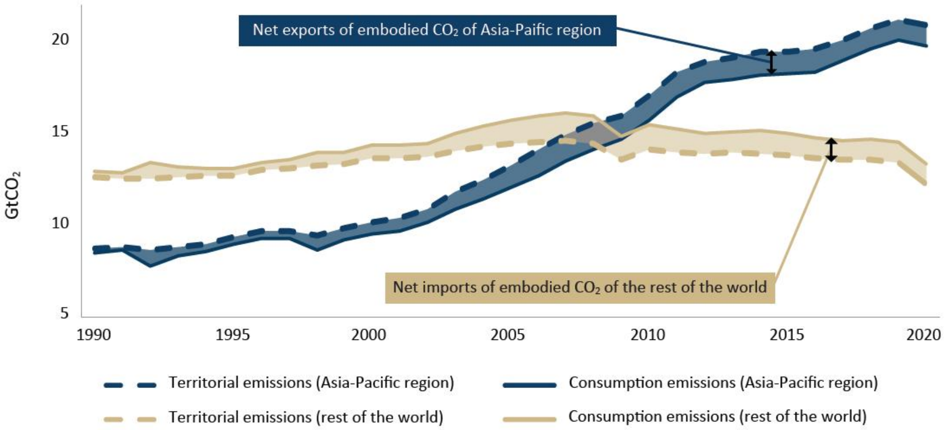
The industrial sector, especially manufacturing and construction, is the largest greenhouse gas emitter in the region if emissions are attributed based on where energy is consumed. The region accounts for nearly three quarters of global emissions in manufacturing and construction, reflecting its central role in global value chains. Climate-smart trade and investment can accelerate the transition of energy-intensive industries and energy-intensive processes in manufacturing and construction to a low-carbon future. Within a global rulesbased framework, international trade and investment can support this transition, including through the dissemination of technologies to make production less carbon intensive.

In recent years, the gap between consumption- and production-related emissions has widened internationally. Carbon leakage – production displaced from countries with stringent environmental policies to countries with more lenient requirements – is occurring from the rest of the world to Asia and the Pacific. This is leading some major trading partners, such as the European Union, to introduce carbon border adjustment taxes, which is expected to affect production practices and trade flows.

Eliminating fossil fuel subsidies and establishing carbon-pricing mechanisms internalize the environmental costs of greenhouse gas emissions and disincentivize carbon leakage. This must be complemented by introducing lesser-emitting production technologies and removing barriers to trade in environmental goods, including vital climate action technologies, such as solar panels and wind turbines. Many countries have set mandatory emission standards for imported vehicles, require energy ratings labels and certification for sourcing legal and sustainable timber, and have banned trade in chlorofluorocarbons – the gaseous compounds most to blame for stratospheric ozone depletion. Such non-tariff measures should be built on and supplemented by eco-labelling.

Figure 5. Territorial and consumption emissions in the Asia-Pacific region

Source: Friedlingstein and others (2022) and World Bank (n.d.)



It is crucial to integrate climate considerations into regional trade agreements. These considerations can incorporate precise, replicable and enforceable environment- and climate-related provisions to ensure that trade is climate smart. Eighty-five per cent of the regional trade agreements signed since 2005 to which at least one Asia-Pacific economy is party contain climaterelated provisions. These measures have promoted trade in environmental goods, services and technologies and have not been detrimental to developing country exports. Expanding regional trade agreements to include a maximum amount of goods with climate benefits could unlock further benefits. Binding commitments to guard against fossil fuel subsidies must be included.

Although climate-smart foreign direct investment (FDI) can help combat climate change, such investment in climate mitigation and adaptation has been unevenly distributed across the region. Developed countries and large developing countries in the region have been the principal destinations of FDI. Least developed countries and small island developing States have received no climate-related FDI since 2011. Investment promotion agencies of least developed countries and small island developing States need support in attracting and facilitating climate-related FDI. Tailored indicators are needed to assess, evaluate and measure the climate-relevant characteristics of investments.

IV. FINANCING CLIMATE ACTION AND MEASURING PROGRESS

4.1 Financing the transition to net zero

Finance is the enabling factor that allows policymakers to implement climate action. A bold financing programme could increase the resilience of developing countries in Asia and the Pacific to climate-related disasters and repair the damage done to the natural environment and biodiversity. To this end, considerable scaling up of financing and reprioritization of scarce capital are needed in the context of depleted fiscal space, rising debt vulnerabilities, high inflationary pressure and tighter financial conditions.

The climate action financing needs in Asia and the Pacific are sizeable. A rudimentary estimate suggests that the annual average financial needs to meet NDCs in selected developing countries in Asia and the Pacific are approximately $362 billion per year, consisting of $258 billion for mitigation and $104 billion for adaptation.[7] Current financial flows fall well short of this amount. The success of new sustainable financial instruments, such as green and sustainability-linked bonds, which channel capital to support climate action, is encouraging, as are the green norms increasingly adopted by banks and investors in response to climate-related regulations.

A wholeofgovernment approach at the national level and concerted regional action are needed to deliver adequate financing for climate action.

Coherent national financing policies are required across different sectors of the economy to develop environmental standards, incentivize the energy transition and encourage the adoption of green technologies. A greater level of convergence is needed between countries' private- and financial-sector applications of climate standards, while opportunities for regional harmonization and the cross-listing of debt and equity instruments should be explored. Domestic collaboration involving private financial institutions and project developers must be encouraged in the pre-investment phase to jointly develop investment-ready projects that support the energy transition.

The banking sector, capital markets and their regulators need to integrate climate science, carbon disclosure, and environmental, social and governance standards into lending and investing practices. For most least developed countries and small island developing States, the commercial banking sector is likely to remain the main tool for financial intermediation. Accordingly, reducing the cost of capital for banks embracing sustainable finance should be considered by regulators. Multilateral development banks and bilateral development finance institutions also have a critical

[7] Calculation based on data from the Nationally Determined Contributions database of the Institute for Global Environmental Strategies, version 7.7. Available at www.iges.or.jp/en/pub/iges-indc-ndc-database/en (accessed on 21 October 2022).

role in mobilizing finance in countries with underdeveloped capital markets. The concessional credit they can provide to national private or public finance institutions should be linked to sustainable finance.

National public and private financial institutions need to be incentivized to support research and development in new green technologies and make the uptake of such technologies less risky. Regional cooperation in developing coherent standards, reporting frameworks and policy environments to scale up climate finance and to use innovative financing instruments are urgently needed in order to redirect capital towards climate action. This would help Governments assess climate risks adequately and ensure that financing and projects are priced appropriately, and comply with international capital regulations and sustainability principles.

The creation of a regional fund that defrays the costs of member States to prepare low-carbon-transition or energy-transition projects for private financing is necessary, particularly for smaller projects. This is important given the challenges faced by many member States in gaining access to global climate funds. Smaller projects need to be proven and then scaled up to attract more financing. This must be recognized as a major hurdle to attracting climate financing at the necessary scale.

4.2 Measuring challenges and progress

The identification of climate challenges and the undertaking of effective climate actions by national, regional and global stakeholders must be underpinned with internationally comparable climate-related information and data. This includes data on the drivers of climate change, its impacts and the vulnerabilities it creates, as well as data on mitigation and adaptation efforts and the implementation of commitments. Effective multilateral climate action requires evidence that is internationally consistent to support informed negotiations, investments and interventions. Only reliable, comparable data can shape effective action to reverse the climate crisis and enable progress to be tracked.

Relevant data, statistics and indicators are collected and held by various government agencies and scientific and research institutions, which often use different approaches to data production. This fragmentation makes it challenging to provide coherent evidence as the basis for national climate decisions or internationally comparable information to inform multilateral climate negotiations and action. The production and policy use of climate change-related information will greatly benefit from internationally agreed concepts and frameworks. To date, the flexibility in international reporting requirements under the Paris Agreement has posed a challenge to global data comparability and aggregation, which is necessary to track progress in climate action.

A unified reporting system for developed and developing countries will be put in place in 2024 to support greater consistency in data and statistics. New biennial transparency reports under the Paris Agreement will be required to ensure the transparency of mitigation and adaptation actions and related support. The Global Set of Climate Change Statistics and Indicators was adopted by the Statistical Commission in March 2022 to assist countries in preparing national sets of climate change statistics and indicators based on their individual concerns, priorities and resources. Compliance with the enhanced transparency framework and the Global Set of Climate Change Statistics and Indicators is critical, as is greater involvement of national statistical offices in the data submissions required by international frameworks.

As data inform progress towards national and international climate commitments, decisions related to data investment should take into account the cross-cutting and interlinked nature of climate change-related data within entire national data ecosystems. A system-wide inter-institutional approach to improving the capacity of national statistical systems, with national statistical offices playing a driving role, should be considered. This is important in the context of the midterm review of the Sustainable Development Goals in 2023. In Asia and the Pacific, there are insufficient data on one quarter of the indicators to monitor progress on climate change-related goals and targets. Such data gaps undermine successful interventions in the areas of climate change impacts and adaptation.

Fundamentally, there is an urgent need to invest in and strengthen statistical capacity. National statistical offices and policy communities should join forces to agree on data priorities and implement plans informed by climate-related commitments. They should set the course to improve climatechange data ecosystems, multi-stakeholder engagement and climate data governance. Existing data and knowledge can be maximized to inform climate action by using new data technologies in line with internationally recognized statistical frameworks and guidelines.

V. ENHANCING REGIONAL COOPERATION FOR FASTER, MORE EFFECTIVE ACTION

Low-carbon and resilient development requires cooperation between countries to support policy frameworks for economy-wide emission reductions. To set major sectors on a low-carbon pathway, boost climate financing to the required scale and improve monitoring, ESCAP recommends strengthening regional cooperation by doing the following:

(a) Promoting regional cross-border electricity grids to scale up the share of renewable energy. Efforts should be focused at the subregional level through a regional green power corridor framework under which a set of scenarios could be developed for the increased deployment of renewable energy through a cross-border power system and a set of principles to align power system connectivity with national sustainable development and climate action goals;

(b) Promoting the transition to low-carbon mobility and logistics through the exchange of best practices and information facilitated by a regional cooperation mechanism on low-carbon transport and the Asia-Pacific initiative on electric mobility;

(c) Supporting the transition of manufacturing industries to a low-carbon future by promoting climate-smart trade policies, such as including climate-related provisions in regional trade agreements, and advancing nontariff measures and national capacities to implement climate-smart investment;

(d) Promoting regional cooperation to develop coherent standards and disclosure requirements to scale up climate finance. This is needed to support the energy transition, redirect capital to climate action and disseminate best practices on how to best mobilize private finance;

(e) Promoting cooperation for strengthening national capacity to monitor climate change impacts, adaptation and mitigation actions, following the operationalization of the enhanced transparency framework under the Paris Agreement and the adoption of the Global Set of Climate Change Statistics and Indicators;

(f) Developing a regional platform and partnership on the lowcarbon and climate-resilient transition to support national processes on long-term low-emissions development strategies and nationally determined contributions, as well as sectoral policies. This platform would be open to governments and other stakeholders, including the private sector. It would facilitate policy dialogue, technical cooperation, and technology and knowledge transfer, with a particular focus on multisectoral initiatives on energy, transport and industry.

The race to achieve net-zero emissions is on. A resilient and sustainable future depends on regional resolve. Now is the time to step up regional collaboration in Asia and the Pacific and join forces to accelerate climate action to keep global warming within 1.5°C.

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THEMATIC SECTION: GREEN TRANSITION AND NATIONAL EFFORTS TOWARDS NET-ZERO TARGET

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Thematic Section: Green Transition and National Efforts towards Net-Zero Target

ANALYSIS OF THE 2030 EMISSIONS REDUCTION TARGETS OF THE PREVIOUS AND CURRENT NATIONALLY DETERMINED CONTRIBUTIONS OF JAPAN, AND A COMPARISON BETWEEN COUNTRIES USING ENERGY-TECHNOLOGY AND ENERGY-ECONOMIC MODELS

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The Paris Agreement requires each participating country to prepare its nationally determined contributions (NDCs). In 2020, Japan submitted a 26 per cent emissions reduction target for 2030, and resubmitted a 46 per cent target (relative to 2013) in 2021. This paper provides an assessment of the Japanese emissions reduction efforts vis-à-vis other NDCs and international comparisons among countries using several different indicators. The carbon dioxide marginal abatement costs in Japan are expected to be approximately \$450/tCO2 eq in 2030, which is consistent with the 1.5°C pathways. Costs in the European and North American countries are at similar levels.

Keywords: climate change mitigation, greenhouse gas emission, marginal abatement cost, nationally determined contributions, climate policy of Japan

JEL classification: C61, D58, Q41, Q43, Q54

I. INTRODUCTION

The Paris Agreement was adopted at the twenty-first Conference of Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) on 12 December 2015 (UNFCCC, 2015) and took force in 2016. The rule book for its operation was completed at the twenty-sixth Conference of Parties (COP26) in 2021. According to the Agreement, all countries are expected to submit their own emissions reduction targets as nationally determined contributions (NDCs) every five years, and more progressive targets than the previous ones, within a "pledge and review"-type framework.

Article 2 of the Paris Agreement "aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty" by "holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C," "increasing the ability to adapt to the adverse impacts of climate change," and "making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development."

Many countries submitted their intended nationally determined contributions (INDCs) before COP21 in 2015 and prior to the 2020 deadline for the first NDC submissions. According to the Emissions Gap Report of the United Nations Environment Programme (UNEP), issued in 2020, the expected global greenhouse gas emissions of the unconditional NDC targets were 56 $GtCO_2eq$ (estimated range: 54–60 $GtCO_2eq$) in 2030, and those of the conditional targets were 53 $GtCO_2eq$ (51–56 $GtCO_2eq$) (UNEP 2020). These expected global emissions have large gaps relative to the emission pathways, not only for the 1.5 °C goal, but also for the 2 °C goal.

The Intergovernmental Panel for Climate Change (IPCC) assessed the expected global greenhouse gas emissions in 2050 for the NDCs submitted by 11 October 2021. According to IPCC (2022), global greenhouse gas emissions in 2030 based on the unconditional NDC targets were 53 $GtCO_2eq$ (estimated range: 50–57 $GtCO_2eq$), while those for the conditional targets were 50 $GtCO_2eq$ (47–55 $GtCO_2eq$). The assessments do not include the revised submissions of the NDCs by China, Japan and the Republic of Korea, for example, which had been submitted just after 11 October 2021. The required global emissions reductions by 2030 from 2019 were 27 per cent and 43 per cent for limiting warming to 2 °C (>67% probability) or 1.5 °C (>50% probability) with no or limited overshoot, respectively. The gap between the unconditional NDC target and the 2 °C emission pathways is 1016 GtCO2eq in 2030, and that for the 1.5 °C is 1926 $GtCO_2eq$. Many developed countries and some developing countries changed the emissions reduction targets in their NDCs to deepen their emissions reductions before COP26 in 2021 and adjusted their long-term emissions reduction targets to achieve net-zero emissions by around 2050. According to the 2022 UNEP report, which considers the NDCs submitted by 23 September 2022, global greenhouse gas emissions in 2030 based on the unconditional NDC targets were 55 $GtCO_2eq$ (estimated range: 52–57 $GtCO_2eq$), while those for the conditional targets were 52 $GtCO_2eq$ (49–54 $GtCO_2eq$) (UNEP, 2022). Still, the estimated emissions in 2030 fall far short of the 2 °C and 1.5 °C emission pathways. The gaps between the unconditional NDC target and the 2 °C (>67% probability) or 1.5 °C (>67% probability) emission pathways are 15 (1216) and 23 (2024) $GtCO_2eq$ in 2030.

In addition to the gap between the NDC emissions reduction targets and the United Nations long-term temperature goals, there are also large differences between actual historical emissions and the stated NDC targets (Victor and others, 2017). den Elzen and others (2019) assessed the gaps between the expected emissions from current policies and the NDC targets for the G20 countries and concluded that the expected emissions from current policies failed to meet the NDC targets for some of the countries. Global emissions, in particular, continue to increase, while many countries have introduced various climate change mitigation policies. Global CO_2 and greenhouse gas emissions continue to increase and in 2019, they were 45 $GtCO_2$/yr and 59 $GtCO_2eq$/yr, respectively (IPCC 2022). The actual emissions are near their upper levels in all of the emissions scenarios, including the non-climate policy scenarios, which were assessed by IPCC in 2007 (IPCC, 2007) and again in 2014 (IPCC, 2014) based on peer-reviewed papers, although the emissions in many developed countries have decreased. Carbon leakages among countries remain concerning.

Given these conditions, the assessment of the emissions reduction targets of the various NDCs is important to enhance emissions reductions, effectively reduce global emissions and avoid carbon leakages. The Government of Japan submitted its revised NDCs in October 2021, changing its greenhouse emissions reduction target from -26 per cent to -46 per cent relative to 2013 levels (Japan, 2020; 2021). To put this in a proper perspective requires a comparative assessment of the emissions reduction efforts of other countries that have submitted NDCs. While assessments of the previous NDCs submitted by participating countries, including a comparison of their emissions reduction costs, have been conducted (Akimoto, Sano and Shoai-Tehrani 2017; Aldy and others, 2016), and the costs associated with the previous Japanese NDCs have been estimated (Oshiro, Kainuma and Masui, 2017; Sugiyama and others, 2019), this article presents an assessment of the most recent NDCs, including those that were resubmitted by the Government of Japan. In addition to a comparison of the NDC emissions reduction efforts of Japan to those of other countries, the emissions reduction costs of the resubmitted Japanese NDCs (specifying a 46% reduction) are assessed by comparing those of the previous NDCs

(26% reduction). The assessments are expected to support efforts to develop deeper emissions reduction targets, avoid carbon leakages and achieve resulting effective global emissions reduction.

The remainder of the article proceeds as follows: Section 2 contains a description of the emissions reduction target of the NDCs submitted by Japan and the energy mix targets based on the emissions reduction target. The method used for evaluating NDC emissions reduction efforts is discussed in section 3. An assessment of the reduction efforts of not only Japan but also those of various other countries is presented in section 4. The estimated emissions reduction costs of the most recent NDCs submitted by Japan, under its 46 per cent reduction target, are compared to the costs of the country's previous NDCs, which targeted a reduction of 26 per cent. Section 6 includes a discussion of the economic impacts associated with changing the Japanese reduction target from -26 per cent to -46 per cent. Finally, the article is concluded.

II. THE EMISSIONS REDUCTION TARGETS OF JAPAN AS THE NATIONALLY DETERMINED CONTRIBUTION

The Government of Japan submitted its INDCs prior to COP21 in 2015. The document included a 26 per cent reduction in emissions compared to 2013 levels. In 2018, the Government adopted the Fifth Strategic Energy Plan (Japan, Ministry of Economy, Trade and Industry, 2018), which sets its energy mix in 2030 consistent with the 26 per cent reduction target and the 80 per cent reduction target for 2050. The electricity mix consists of, for example, the shares of renewable energy, nuclear power, and fossil fuel power in the total electricity supply would be 2224 per cent, 2220 per cent, and 56 per cent, respectively (Japan, 2020).

In October 2020, Yoshihide Suga, the Japanese Prime Minister at that time, stated that Japan aimed to achieve carbon neutrality by 2050. By roughly the time of the leaders' summit on climate in April 2021, the NDC emissions reduction targets of many of the participating countries had been deepened, especially among the developed countries. Japan also deepened its emissions reduction target for 2030, revising it to -46 per cent from the previous target of -26 per cent. Japan further declared its intention to pursue an even more ambitious goal of -50 per cent by 2030. In response to this new emission reduction target, the Sixth Strategic Energy Plan (Japan, Ministry of Economy, Trade and Industry, 2021) was formulated, including the revised energy mix proposal, and the plan for global warming countermeasures was revised (and confirmed by the Cabinet in October 2021). Under the new plan, the shares of renewable energy, nuclear power, and fossil fuel power in the total electricity supply are to be 3638 per cent, 2220 per cent, and 41 per cent, respectively.

In addition, the share of hydrogen/ammonia power is set at 1 per cent. The share of renewable energy in the new strategic energy plan increases greatly relative to its share in the previous plan. Importantly, however, such numbers are being treated not as targets but as “ambitious outlooks.” Specific policies to achieve the revised emissions reduction target and the proposed energy mix are still under discussion.

III. EVALUATION OF EMISSION REDUCTION EFFORTS OF THE NATIONALLY DETERMINED CONTRIBUTIONS

Appropriate reviews of the processes of the Paris Agreement are important to the realization of global emission reductions. Clearly, the methods used to measure and evaluate the emission reduction efforts described in NDCs are a crucial part of ensuring their effectiveness. Aldy and Pizer (2015) and Aldy, Pizer and Akimoto (2016) examined the various indicators to be reviewed and argued that to be effective, the indicators must be comprehensive, measurable, replicable and universal. Some of the indicators are easily replicable but not comprehensive, while others include model estimations that are comprehensive in evaluating the emission reduction efforts, but are not easily replicable.

Possible measures of emissions reduction efforts are the absolute level and the improvement rate of greenhouse gas emissions per unit of gross domestic product (GDP), emission reduction ratios from baseline emissions, carbon dioxide (CO_2) marginal abatement costs and emission reduction costs per unit of GDP. No silver bullet indicator exists, however, and each indicator has its merits and drawbacks, as shown in table 1. An indicator can only be used effectively if its meaning and limitations are recognized; moreover, multiple indicators are needed to ensure a comprehensive evaluation.

Table 1. Indicators employed for measuring emissions reduction efforts

CategoryIndicators for emission reduction efforts	Overview and notes
Emissions reduction ratio from the base year	When baseline emissions are expected to stagnate, it is more relevant to simply compare the projected reduction rates, which makes it possible to avoid uncertainties in the estimation for baseline emissions can be avoided.

Table 1. *(continued)*

CategoryIndicators for emission reduction efforts	**Overview and notes**
Emissions per capita	As this indicator is highly dependent on the country's level of economic activity and situation in general, assessing emissions reduction efforts through this indicator can be difficult. On the other hand, this indicator could be used to assess responsibilities and emissions reduction efforts through changes in the indicator from the base year.
CO_2 intensity (greenhouse gas emissions per unit of GDP)	While this indicator reveals what level of CO_2 emissions corresponds to what degree of economic activity, it is determined by the country's industrial structure and is, therefore, not closely related to emission reduction efforts. On the other hand, the rate of change of this indicator might be assessed as an aspect of the emissions reduction efforts.
Emissions reduction ratio compared to baseline emissions	While this indicator takes into account differences in economic growth, among other factors, it excludes past efforts in energy saving and the abatement potential of renewables.
CO_2 marginal abatement cost (carbon price)	This is a particularly relevant indicator for assessing reduction efforts, as it reflects national differences in terms of economic growth, energy savings efforts and the abatement potential of renewables. However, uncertainties are high, as this is a model-based estimation.
Emission reduction costs per GDP	While marginal abatement costs do not take into account the economy's ability to bear the necessary burden, this indicator is sensitive to that. However, uncertainties are high as this is a model-based estimation.
Retail prices of energy (electricity, city gas, gasoline, diesel)	While marginal abatement costs show the additional effort required, this indicator also includes the efforts made in the baseline. Market data are available for ex-post evaluation, but for ex-ante evaluation, only model-based estimates are available, which inevitably generate high degrees of uncertainty.

Table 2 shows the assessed emissions reduction targets of NDCs used for our international comparison. All of those NDCs were submitted prior to 23 December 2021 (UNFCCC. 2021a; 2021b). To understand the ambition level and the required emissions reduction efforts represented in the NDCs submitted by relative to those of other major countries, the emissions reduction targets (only the unconditional targets) for the countries listed in table 2 were assessed using the multiple indicators described in table 1. For the international comparison, countries with large emissions or a large GDP were assessed. The historical emissions of the International Energy Agency (IEA) statistics (IEA, 2021) are used, while the EDGAR database (European Commission, 2021) is used for non-CO_2 greenhouse gas emissions in developing countries. While the emissions reduction rates of NDCs may be considered based on the original estimations for historical emissions for some countries, for this study the amounts of emissions and emissions reduction rates are assessed based on the IEA and EDGAR databases, which are consistent with the assessment models employed in this study.

Table 2. Nationally determined contribution emissions reduction targets in 2030

	Submitted emissions reduction targets in 2030 of NDCs
Japan	-46% compared to 2013
United States	-50% to -52% compared to 2005
European Union (27)	-55% compared to 1990
United Kingdom	-68% compared to 1990
Switzerland	-50% compared to 1990
Australia	-26% to -28% compared to 2005
Canada	-40% to -45% compared to 2005
Republic of Korea	-40% compared to 2018
Mexico	-22% compared to business as usual emissions (business as usual in 2030: 991 MtCO2eq/yr)

Table 2. *(continued)*

	Submitted emissions reduction targets in 2030 of NDCs
Türkiye	No unconditional targets[1]
South Africa	350 to 420 MtCO2eq/yr in 2026-2030
Russian Federation	-30% compared to 1990
Ukraine	-65% compared to 1990
Kazakhstan	-15% compared to 1990
China	-65% of CO2/GDP compared to 2005
India	-33% to -35% of greenhouse gas/GDP compared to 2005
Saudi Arabia	-278 MtCO_2eq/yr compared to 2019
Pakistan	-15% compared to business as usual emissions (business as usual in 2030: 1603 MtCO_2eq/yr)
Thailand	-20% compared to business as usual emissions (business as usual in 2030: 555 MtCO_2eq/yr)
Malaysia	-45% of greenhouse gas/GDP compared to 2005
Singapore	-36% of greenhouse gas/GDP compared to 2005, Emission peak (65 MtCO_2eq/yr) around in 2030[2]
Brazil	-43% compared to 2005
Indonesia	-29% compared to business as usual emissions (business as usual in 2030: 2869 MtCO_2eq/yr)

IV. EVALUATION OF EMISSIONS REDUCTION EFFORTS OF THE NATIONALLY DETERMINED CONTRIBUTIONS

The international comparisons using the indicators described in section 3 are presented below.

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1 Unconditional targets are not provided; the emissions without climate mitigation policies are assessed only with the DNE21+ model.

2 According to the authors' outlook for GDP, the emission peak constraint in 2030 is lower than that of the greenhouse gas/GDP reductions.

Figure 1 shows a comparison of the emissions reduction rates for 2030 relative to 2013, the base year for the NDCs submitted by Japan, as contained in NDCs submitted by the studied countries. (2013 is the year in which Japan experienced a major increase in emissions due to the shutdown of most of the country's nuclear power plants following the Fukushima-Daiichi nuclear accident in 2011). As shown, with 2013 as the base year, the reduction rate of the United Kingdom of Great Britain and Northern Ireland is the highest among all the countries listed. If the emissions reduction rates of Japan are converted to base years 1990 and 2005, the rates are -40 per cent and -44 per cent, respectively. If 2013 is used as the base year, the emissions reduction rate for Japan is greater than that of the United States of America and the European Union countries however, if 1990 is used as the base year, the rate for Japan is less than that of European Union countries, and if 2005 is used as the base year, the rate for Japan is below that of the United States. Large increases in greenhouse gas emissions relative to 2013 are expected in India, Indonesia, Pakistan and the Russian Federation. This comparison shows that it is difficult to measure emissions reduction efforts by using reduction rates from any particular base year.

Figure 1. International comparison of emissions reduction rates in 2030 compared to the base year of 2013 for nationally determined contributions

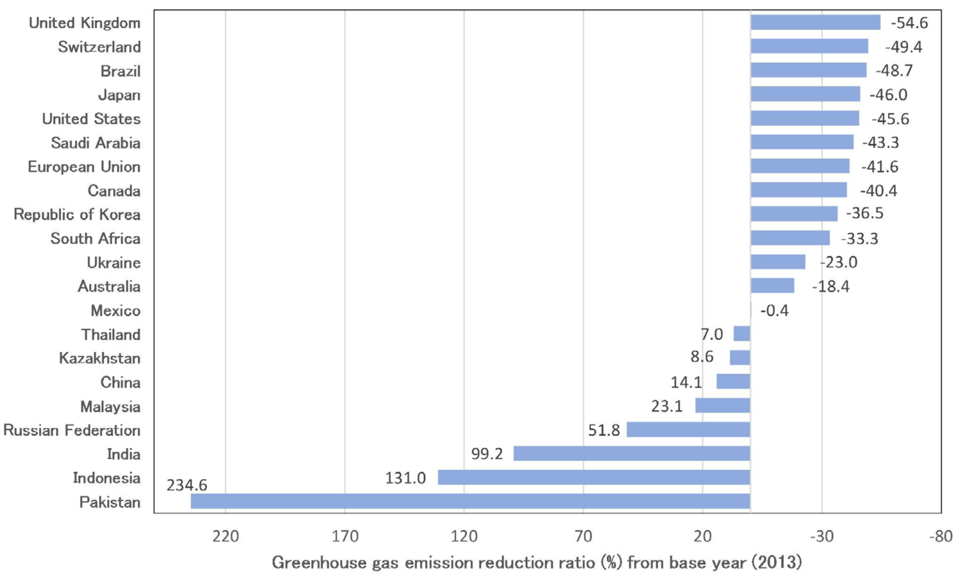
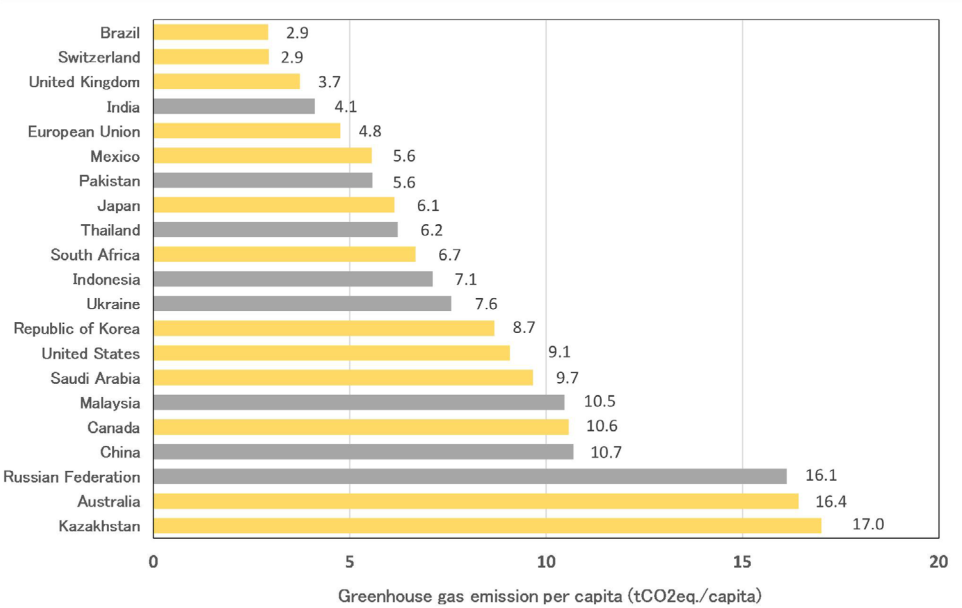


Figure 2 shows greenhouse gas emissions per capita while figure 3 shows greenhouse gas emissions per unit of GDP. Some developing countries, such as India, have not yet reached the decent living standard, so their per-capita emissions are expected to increase. Greenhouse gas emissions per capita under the NDC target of Japan is 6.1 tCO_2eq. in 2030; in 2015, it was 10.0 tCO_2eq.

Greenhouse gas emissions per unit of GDP in 2030 will be nearly the same for Japan, the European Union countries and the United States under the GDP outlook used in this study. In principle, lower emissions are better with both indicators; however, this is determined not only by a shift to ambitious energy savings and less intensive energy consumption, but also by the potential and accessibility of low-carbon or decarbonized energy sources.

It should be noted that the emissions shown in figures 1 and 2 are production-based and depend greatly on the industrial structure and its allocation among countries. Accordingly these indicators can only partially be used to assess emissions reduction efforts.

Figure 2. International comparison of per-capita greenhouse gas emissions in 2030 for the nationally determined contributions



Note: The grey bars show the increase in per-capita emissions compared to 2015, even if the submitted NDC emissions reduction targets were to be achieved.

Figure 3. International comparison of per-gross domestic product greenhouse gas emissions in 2030 for the nationally determined contributions

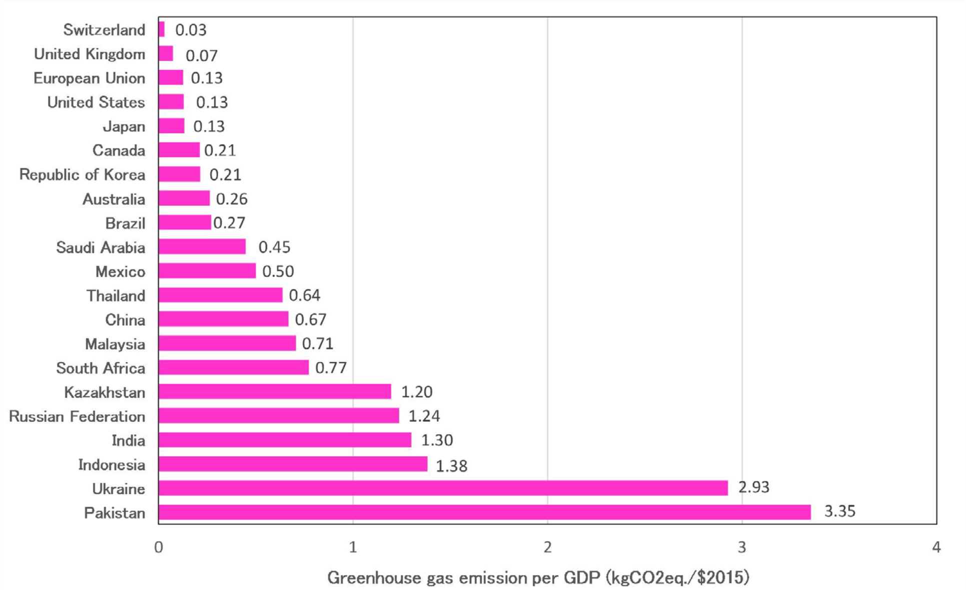


Figure 4 shows the CO_2 marginal abatement costs (MAC) corresponding to carbon prices; figure 5 shows the emissions reduction costs per unit of GDP. The emissions reduction costs are estimated using the global energy systems model DNE21+ (see appendix 1). The DNE21+ model is an intertemporal linear optimization model extending to 2100. The notable features of the model are that (1) it recognizes regional differences among the 54 regions into which all countries are aggregated, (2) the global warming response measures of approximately 500 specific technologies are evaluated in detail, and (3) facility replacements over the entire period are explicitly considered. With this model, the costs and potential of emissions reduction can be assessed across countries with a high level of consistency, as it accounts for differences in economic growth, energy efficiency levels and energy resources, among other attributes. Although the emissions reduction targets of Brazil and Indonesia anticipate significant emissions reductions through land-use changes, the associated cost estimates are highly uncertain. Consequently, the cost estimates for the targets of Brazil and Indonesia are omitted from figures 4 and 5. The emissions reduction costs estimated to achieve the emissions reduction targets of the NDCs are more comprehensive indicators for measuring emissions reduction effort, however, it should be noted that estimation of the costs involves relatively large and unavoidable uncertainties.

In 2030, MAC of Japan is projected to be approximately 450 USD/tCO_2eq., similar to the costs in Western European countries (European Union member countries, the United Kingdom and Switzerland) and North America countries (Canada and the United States). MACs for the Republic of Korea and China are approximately 180 and 40 USD/tCO_2eq, respectively. For India and Pakistan, the MAC is projected to be nearly 0 USD/tCO_2eq, which means that the emissions targets are almost the same as the estimated baseline emissions. Such large differences in MAC are bound to induce carbon leakages, while the DNE21+ model assumes scenarios of production and services by region/country based on historical trends and the future assumed population and GDP, which are not factors directly affecting carbon prices (MAC). In addition, the implementation of strong climate mitigation policies can be extremely challenging in terms of industrial competitiveness in countries with high costs.

The aggregated global greenhouse gas emissions according to the submitted NDCs are estimated to be approximately 50 GtCO_2eq/yr in 2030, which is consistent with the UNEP estimates (UNEP, 2021; 2022). According to the least cost measures estimated with DNE21+, the globally uniform MAC in 2030 for meeting the 50 GtCO_2eq/yr is 47 USD/tCO_2eq. Meanwhile, if MAC for achieving the emissions reduction target in the Japanese NDC (452 USD/tCO_2eq) is implemented in all countries, global greenhouse gas emissions in 2030 are expected to be 32 GtCO_2eq/yr, which is reasonably consistent with the emissions for the 1.5 C pathways with no or limited overshoot (31 GtCO_2eq/yr having the range of 2136 GtCO_2eq/yr) in the IPCC report (2022).

On the other hand, the emissions reduction cost per GDP in Japan is approximately 1 per cent, a middle value among the countries included in the study. This level is similar to that of China. Countries that export or import large amounts of fossil fuels have a negative or positive impact via the fossil fuel price decreases associated with the global emissions reduction indicated by NDCs. To be useful, emissions reduction efforts should be evaluated using multiple indicators.

Figure 4. International comparison of carbon dioxide marginal abatement costs in 2030 for the nationally determined contributions

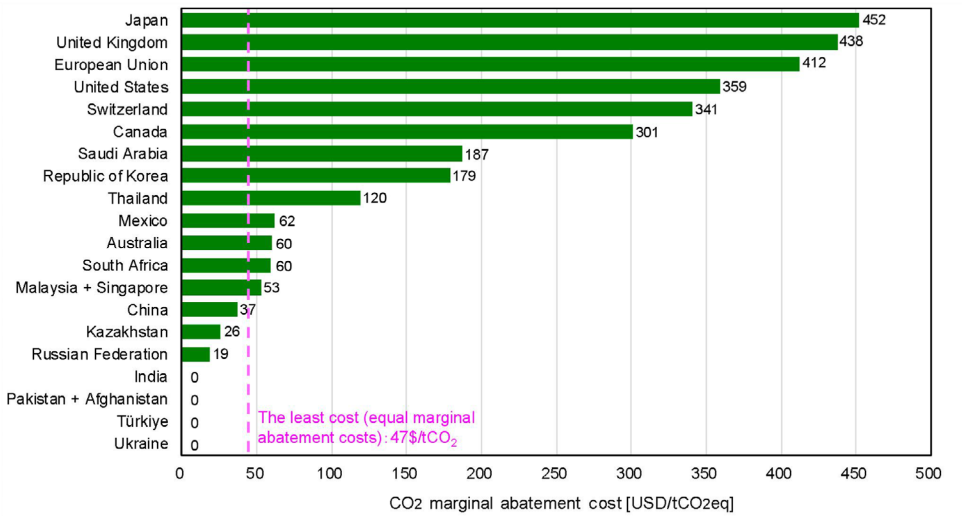
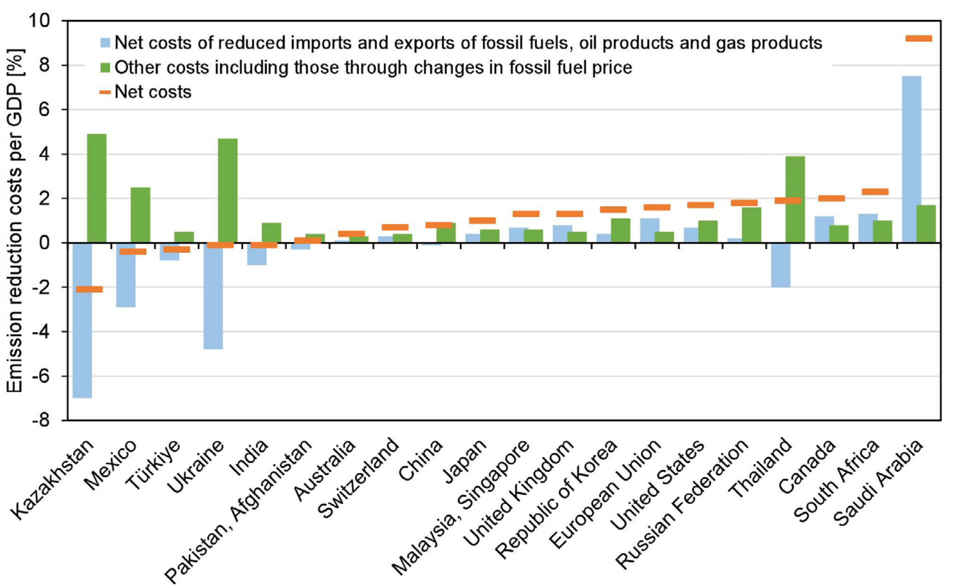
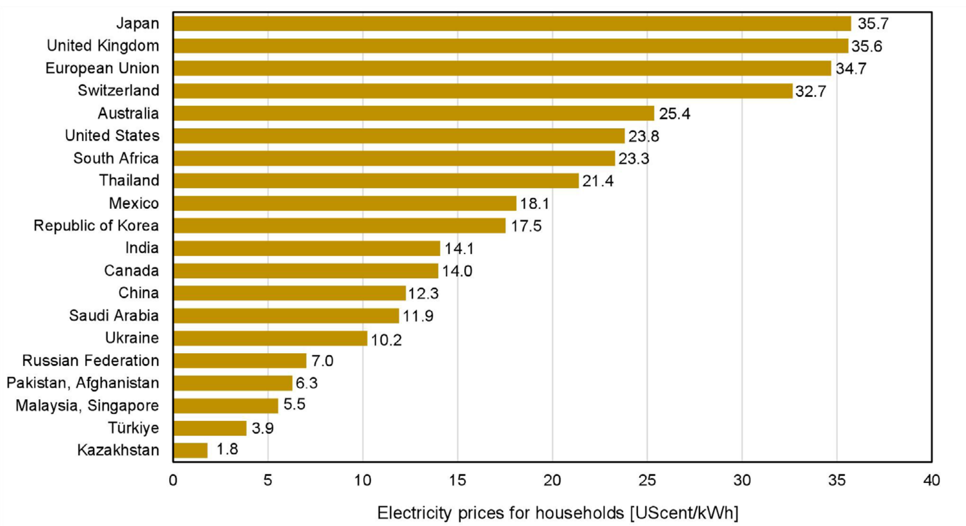


Figure 5. International comparison of emissions reduction costs per gross domestic product in 2030 for the nationally determined contributions



The emissions reduction costs shown in figures 4 and 5 are the additional costs associated with achieving the emissions reduction targets. However, the low energy production or low energy services that result are affected not only by additional climate polices, but also by other factors, such as existing energy policies and existing energy prices associated with energy accessibility. Consequently, the retail prices of final energy are also important indicators. Figure 6 shows the final retail prices of electricity (residential uses) in 2030 for NDCs estimated by the DNE21+. The 2030 prices in Japan, the United Kingdom, the European Union and Switzerland are expected to be particularly high. In addition, it should be noted that there are large differences among countries.

Figure 6. International comparison of final retail prices of electricity (residential uses) in 2030 for the nationally determined contributions



V. FACTORS IN CHANGING THE EMISSIONS REDUCTION COSTS FROM 26 PER CENT TO 46 PER CENT REDUCTIONS

In this section, the factors for the changes in the CO2 MAC induced by the change made by Japan from its earlier NDC target of -26 per cent to its latest NDC target of -46 per cent are analysed. MAC increases are not only the result of the more ambitious reduction target, but also reflect such factors as socioeconomic conditions and cost reduction outlooks, as well as differences in the 2015 and 2021 energy mixes. Figure 7 shows the changes in MAC by factor.

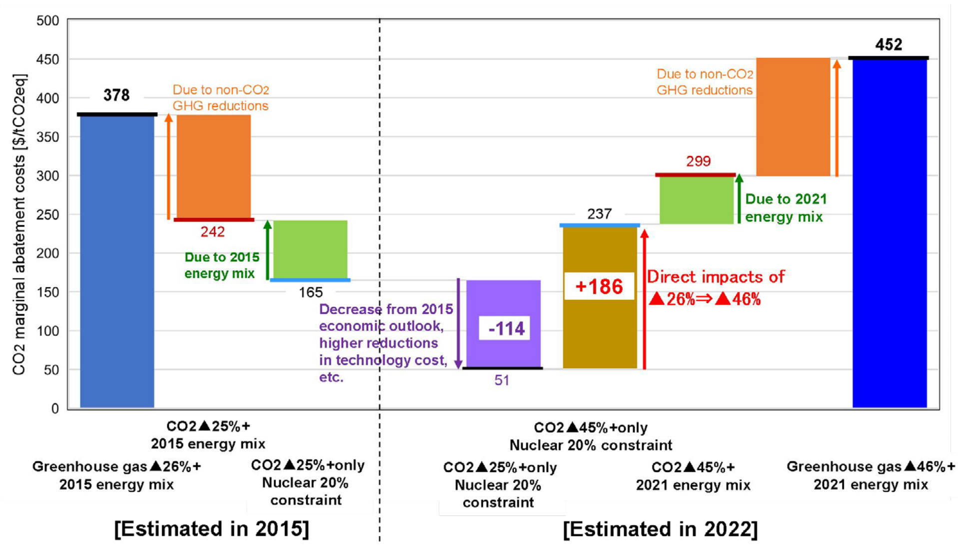
The GHG (CO_2) emission targets of NDCs submitted by Japan changed from -26 (-25) per cent to -46 (-45) per cent in which non-CO_2 reduction targets are expressed as the difference between the GHG reduction targets and CO_2 reduction ones, respectively. In this study, the abatement costs for non-CO_2 greenhouse gas emissions are estimated by using a non-CO_2 greenhouse gas model (Akimoto and others 2010) based on the cost and database provided by the United States Environmental Protection Agency (2006); Then, the MACs for GHG reductions are estimated through iterative calculations between the DNE21+ and non-CO_2 GHG models.

Comparing the costs only for CO_2 emission reduction targets, MAC for the CO_2 emissions reduction of -45 per cent is 299 USD/tCO_2, while that for the previous estimate for the -25 per cent reduction is 242 USD/tCO_2. The revised NDC target (greenhouse gas GHG: -46%; CO_2: -45%) assumes a different electricity mix from that for the previous target. If the energy mixes are not considered and only nuclear power share targets (20% of total electricity supply, which is the same in the previous and new energy mix targets) are considered, MACs in the 2015 and 2022 estimates are 165 and 237 USD/tCO_2eq., respectively. On the other hand, the economic outlooks for 2030 estimated in 2015 are different from those in 2022. The outlook for GDP growth from 2015 to 2030 was 1.9%/yr, but considering the historical GDP growth, the revised GDP growth of 1.4%/yr is more reasonable. In addition, the cost outlooks of some technologies are also different. The aggregated impact of the decrease in MAC from the 2015 estimate to the 2022 estimate is projected to be 114 USD/tCO_2. Accordingly, the direct impact on the increase in MAC for deepening CO_2 emissions reductions by 20 percentage points is approximately 186 USD/tCO_2, based on the analyses using the DNE21+ model.

According to the model comparison study conducted by Sugiyama and others (2019) for the previous NDCs (-26% relative to 2013), the range of MAC is 44.3345.6 USD/tCO_2, with a median of 149.8 USD/tCO_2. While MAC including the effects of the energy mix and non-CO_2 greenhouse gas reductions is 378 USD/tCO_2, the least cost measure to respond to CO_2 emissions reduction is 165 USD/tCO_2, which is similar to the median value of the comparison study.

For the least cost measures responding to the 46 per cent reduction, MACs should be uniform among sectors. Under the least cost measures, the required emissions reduction rates in hard-to-abate industrial sectors, such as the iron and steel, cement and residential/commercial sectors, are relatively small, and those in power and less-energy intensive sectors are relatively large. However, it is necessary to consider not only the cost-efficient emissions reductions, but also the response measures intended to stabilize the energy supply and provide energy security. As Japan, in particular, depends heavily on overseas energy sources, energy security issues are extremely important, and should be taken into account in the strategic energy plans with targeted energy mixes. When these issues are considered, larger emissions reductions in non-power sectors are needed, and the cost increases from the least cost are unavoidable.

Figure 7. Factor analysis of the changes in the carbon dioxide marginal abatement costs associated with changing the emission reduction targets from -26 per cent to -46 per cent

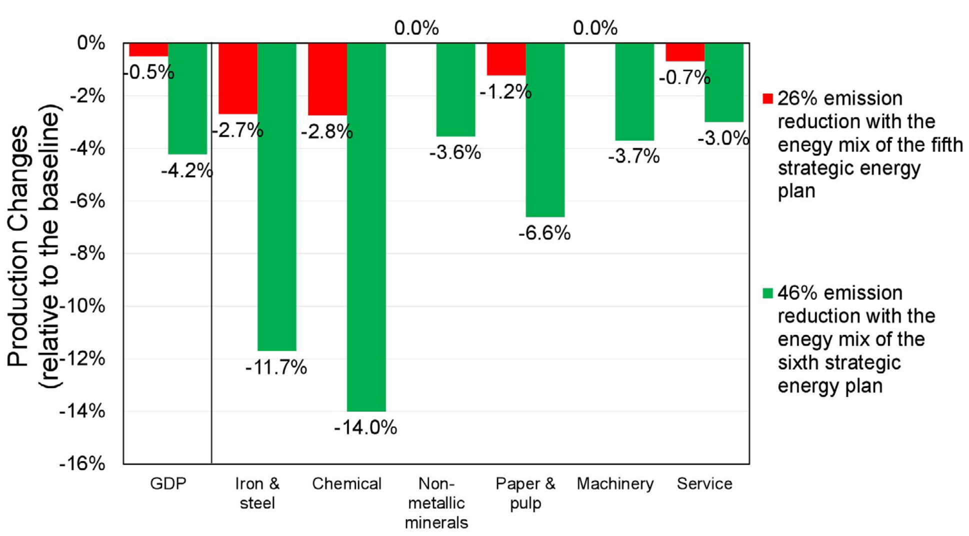


VI. THE ECONOMIC IMPACTS OF A 46 PER CENT EMISSIONS REDUCTION

The economic impacts of the emissions reduction target in NDCs submitted are estimated using the global energy-economic model DEARS, which is one of the Computational General Equilibrium (CGE)-type models (see appendix 2). DEARS can assess the impacts on an entire economy, including disaggregated sectors, rather than the impacts on only the energy system. In this analysis, both emissions reduction targets and energy mixes are considered. Under the current economic outlook, the GDP impacts for the 26 per cent reduction are estimated to be 0.5 per cent, while those for the 46 per cent reduction are 4.2 per cent as shown in figure 8 (Homma and Akimoto, 2022). The economic impacts include the effects of increases in investment, decreases in consumption and net reductions in exports due to higher energy costs associated with the differences in MAC among countries. For the 46 per cent reduction, the economic impacts on the CO_2 intensive sectors, such as the iron and steel and chemical sectors, will be much higher than the average impact as reflected in the national GDP.

In order to maintain international competitiveness in CO_2-intensive sectors, such as iron and steel and to avoid carbon leakage, the European Union plans to introduce a carbon border adjustment mechanism (CBAM). However, in Japan, the volume of exports from the CO_2-intensive sectors is large relative to the volume for the European Union. Accordingly, the impacts of CBAM on mitigating international competitiveness issues would be rather small if the export rebate, for which there is significant concern regarding its compatibility with World Trade Organization (WTO) rules, is not implemented. The possible options for addressing international competitiveness issues may be very limited in Japan.

Figure 8. The economic impacts in Japan for 26 per cent and 46 per cent reductions



CONCLUSIONS

The Paris Agreement calls for all participating countries to submit their own emissions reduction targets as NDCs, and most of them have complied. The NDC process is a "pledge and review"-type scheme, which means it is important to implement appropriate reviews for the submitted NDCs. However, under the UNFCCC framework, there are few mechanisms for measuring the emissions reduction efforts among countries. The role of measurement is expected to fall outside the purview of UNFCCC.

In 2020, the Government of Japan submitted a NDC target of a 26 per cent reduction in emissions by 2030. In 2021, it submitted revised NDCs, changing the target to a 46 per cent reduction. In this article, the emissions reduction efforts of the new target set by Japan relative to those of other countries using several indicators are evaluated. Given that no single indicator is without its deficiencies, such an evaluation can best be conducted by applying a combination of indicators. While emissions reduction costs are relatively comprehensive indicators for measuring emissions reduction efforts, the uncertainty associated with their estimation is relatively high. According to the analyses using the technology-oriented energy systems model DNE21+, the CO_2 marginal abatement costs of the Japanese NDCs is one of the highest among all the countries studied. The costs for the European and North American countries are at similar levels.

The marginal abatement costs for the NDC reduction target set by Japan of 46 per cent matches the ranges of MAC for global greenhouse gas emissions to achieve the long-term goal of keeping the global temperature increase below 1.5 °C. The 46 per cent reduction target was decided upon politically in a top-down manner without detailed scientific assessments; however, the assessed MACs were found to be similar to those of other major developed countries, but there were large differences in costs between developed countries and many developing countries.

Achievability and induced carbon leakages are a concern. Large differences in MAC (carbon price) among countries makes it difficult to implement domestic climate policies that avoid substantial economic damages, especially in the more CO_2-intensive industries. According to the CGE-type model DEARS, the estimated macroeconomic impacts of NDCs in Japan will be substantial, particularly in the CO_2--intensive sectors, such as iron and steel, and in the chemical sectors. While investment is greatly increased, domestic consumption and net exports decrease significantly due to the increases in energy costs. Narrowing the policy gaps between current policy and the policies needed to achieve the NDC target is a great huge challenge for Japan. Limiting the negative impacts on the international competitiveness of its industries, particularly in the CO_2-intensive sectors, and avoiding the risks of carbon leakages is a major concern. The European Union plans to introduce CBAM to avoid carbon leakages due to large differences in carbon prices (MAC) associated with NDCs. The United States is also considering the introduction of in CBAM with different schemes from the European Union CBAM. However, CBAMs cannot deter carbon leakages sufficiently, particularly for exports of CO_2-intensive products and could lead to some world trade conflicts. Accordingly, NDCs with more coordinated carbon prices among countries should be pursued as well as reductions in MAC through several kinds of technological and social innovations.

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APPENDIX 1

Overview of the global energy and greenhouse gas emission reduction assessment model DNE21+

The DNE21+ model (Akimoto and others, 2010; 2014; 2021) is an intertemporal linear programming model for the assessment of global energy systems and global warming mitigation in which the worldwide costs are to be minimized. The model represents regional differences and assesses detailed energy-related CO_2 emission reduction technologies up to 2100. When any emission restriction (such as an upper limit on emissions, emission reduction targets, targets for energy or emission intensity improvements or carbon taxes) is applied, the model identifies the lowest cost energy systems that meet all the assumed requirements, including the assumed production in industries, such as iron and steel, cement, and paper and pulp, transportation by automobile, bus, and truck, and other energy demands. The energy supply sectors are hard-linked with the energy end-use sectors, including energy exporting/importing, and the lifetimes of facilities are taken into account so that the assessments are made with complete consistency over the various energy systems. Salient features of the model (1) an analysis of regional differences among 54 world regions as well as 77 regions resulting from a further disaggregation in some of the larger countries, (2) a detailed evaluation of global warming response measures based on the modelling of approximately 500 specific technologies expected to help suppress global warming, and (3) explicit facility replacement considerations over the entire time period. Based on plausible ranges derived from the relevant literature, the model assumes energy efficiency improvements in several kinds of technologies and cost reductions in renewable energies and CO_2 capture and storage, among others.

APPENDIX 2

Overview of the global energy-economic model DEARS

The DEARS (Dynamic Energy-economic model with multi-regions and multi-sectors) model is a global energy-economic model based on dynamic intertemporal optimization (Homma and Akimoto, 2013), which integrate a top-down economic module and a bottom-up energy system module dividing the world economy into 18 regions and 16 industrial sectors. The model has an objective function of discounted global consumption utilities up to 2030 in ten-year steps, with 2010 as the initial year. The model explicitly represents industrial and trade structures by region and by sector. The economic module has a computational general equilibrium modelling structure, with structures of capital accumulation by sector and by region. The initial values of the module are based on the international input-output tables, with the datasets of the Global Trade Analysis Project (GTAP) ver.9 (GTAP, 2015) have been adjusted to meet the GDPs and energy balances in 2010 in the IEA statistics (IEA, 2019). The energy system module represents simplified energy system flows explicitly under the physical energy unit in which the initial values of the energy balance tables in 2010 are based on the IEA statistics (ver.2019). The energy module has eight types of primary energy (coal, crude oil, natural gas, hydro and geothermal, wind, photovoltaic, nuclear and others) and four types of secondary energy (solid, liquid, gaseous and electricity), with bottom-up modelling for technologies in energy supply (such as power generation) and carbon capture and storage; the use of carbon capture and storage technology is not assumed in this analysis. The links to the economic module for energy demand by the secondary energy type are based on price and income elasticities. Autonomous energy efficiency improvements are assumed in the baseline energy intensities by sector, region, and secondary energy type.

Thematic Section: Green Transition and National Efforts towards Net-Zero Target

ASSESSMENT OF THE ENHANCED NATIONALLY DETERMINED CONTRIBUTIONS OF THE REPUBLIC OF KOREA AND THE STRATEGIES FOR THE 2050 NET-ZERO TARGET

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The Republic of Korea has made a net-zero pledge and submitted enhanced nationally determined contributions (NDCs), targeting a 40 per cent reduction in gashouse emissions by 2030 compared to 2018 levels. This article provides a review of the country's mitigation progress by evaluating its NDCs and 2050 net-zero commitments. Three key challenges are identified: limited time window to meet the targets; energy transition difficulties; transforming carbon-intensive industries. A SWOT analysis informs strategic directions in four areas: accelerating low-carbon transitions in key sectors; enhancing mitigation policy effectiveness in building stakeholder consensus on transition costs; bolstering international cooperation for carbon neutrality.

Keywords: SWOT analysis; low-carbon transition; emission trading scheme; stakeholder involvement; international cooperation

JEL classification: O53, Q48, Q54

I. INTRODUCTION

The Republic of Korea has recently announced its net-zero pledge and submitted enhanced nationally determined contributions (NDCs), which included the ambition to reduce emissions by 40 per cent by 2030 compared to the 2018 level. This demonstrates the country's willingness to contribute to a global warming pathway way below 2°C degrees and within 1.5°C degrees. The present article includes a review of the current status of the country's mitigation efforts in order to critically assess if they are contributing towards achieving the enhanced NDC commitments and the 2050 net-zero pledges. Through the initial research, three key challenges pertaining to the commitments have been identified: (i) short-time window to meet the reduction target; (ii) difficulty in the energy transition, and (iii) difficulty for the industrial sectors to carry out the transition because of their carbon-intensive structures. A SWOT analysis was conducted to shed light on the current situation of the Republic of Korea in its efforts to achieve the net-zero target. Based on the results of the analysis, a strategic propulsion direction was drawn in the following four areas: (i) accelerating the low-carbon transition in the power and industrial sectors, (ii) strengthening the efficiency and efficacy of mitigation policies, particularly through an emission trading system (ETS), (iii) coordinating a consensus among stakeholders on payment for social, economic and environmental costs associated with the transition, and (iv) strengthening international cooperation in attaining carbon neutrality.

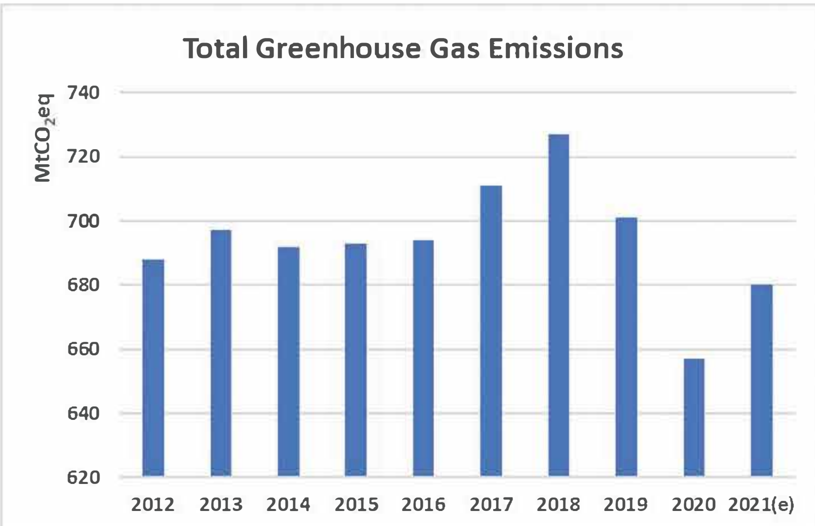
II. THE CURRENT STATUS OF THE REPUBLIC OF KOREA AND THE REVISED NATIONALLY DETERMINED CONTRIBUTIONS

2.1 Greenhouse gas emissions from the Republic of Korea

The greenhouse gas emissions of the Republic of Korea peaked at 727 MtCO2eq in 2018. Since then, the country has reduced its greenhouse gas emissions from various sources in the energy and industrial sectors. For example, it successfully cut electricity demand, fuel demand for heating and electricity generation from coal-fired power plants, and focused on lower-emitting industrial processes. In 2020, the global COVID-19 pandemic significantly reduced economic activities, which lowered electricity demand. Additionally, policies intended to reduce the use of coal-fired power plants has led to significant reductions in greenhouse gas emissions. The greenhouse gas emission level in 2020 was 656 MtCO2eq,, which is similar to the emission level of 2010. However, the recovery of economic activities and the increase in transportation resulted in a slight uptick in the national gas emissions in 2021 to 680 MtCO2eq. Although the country has not steadily cut its greenhouse gas emissions, the recent rise of 3.5 per cent is lower than the global average of 5.7 per cent and when compared to other major economies, such as China, the United

States of America and the European Union. (Korea, Ministry of Environment, 2021; 2022a; 2022b)

Figure 1. Total Greenhouse Gas Emissions (2012–2021) of the Republic of Korea



Source: Korea, Greenhouse Gas Inventory and Research Center (2022) and Korea, Ministry of Environment, 2022a).

The greenhouse gas emissions from the Republic of Korea are heavily concentrated in the energy-related sector, which accounted for 86.9 per cent of such emissions in 2021. Electricity and heat generation accounted for approximately 32.7 per cent of total greenhouse gas emissions, while the transportation, steel and chemicals accounted for a sizeable portion of the emissions, at 14.4 per cent, 14.3 per cent and 7.8 per cent, respectively, The country's heavy reliance on fossil-fuel for its energy-intensive industries and power generation presents a challenge to its goal to decouple greenhouse gas emissions and economic growth.

2.2 2050 emissions development strategies and the updated 2030 nationally determined contributions

The Government of the Republic of Korea submitted its 2050 long-term low greenhouse gas emission development strategies (LEDS) at the end of 2020 (Republic of Korea, 2020). The strategies specifically and explicitly set the vision to achieve carbon neutrality by 2050, with an emphasis on green and digital components for achieving carbon neutrality. The key elements of the strategies are as follows: use clean power and hydrogen; improve energy efficiency; commercial development of carbon removal and new technologies; scale up the circular economy; and enhance of carbon sinks. In addition, achieving carbon neutrality is highlighted in the robust and sustainable institutional framework The Government has outlined the plan for aligning climate and energy policies and incorporating climate change with policy setting, including for fiscal policies.

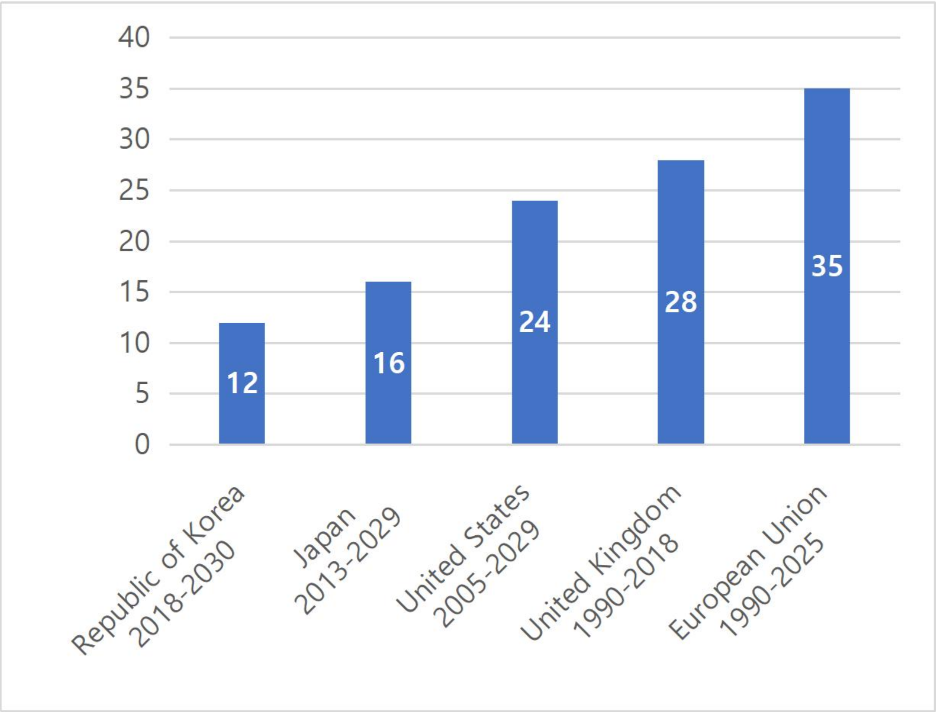
In late 2021, the Government of the Republic of Korea announced its updated NDCs with enhanced climate actions and targets (Republic of Korea, 2021). Previously, the Government had committed to reduce greenhouse gas emissions by 24.4 per cent relative to the 2017 level (equivalent to a 26.3 per cent reduction relative to the 2018level). Under the updated plan, the commitment is raised to 40 per cent from the 2018-level. This enhancement is in line with the country's carbon neutrality declaration and the enactment of the Carbon Neutrality Act. The updated NDCs include an implementation plan with various measures, including the utilization of ETS, collaboration with international carbon markets and the development of sectoral strategies. The updated 2030 NDCs can serve as an important milestone to transform the country's economy into a low-carbon economy for achieving the net-zero target by 2050.

III. THE CHALLENGES IN IMPLEMENTING THE ENHANCED NATIONALLY DETERMINED CONTRIBUTIONS

3.1 Challenges with reduction the target and achievement period

Gas emissions in the Republic of Korea peaked in 2018, which is relatively late compared to other major economies. Because of the more recent peak year, to achieve the 40 per cent reduction in greenhouse gas emissions target, the country has to mobilize action at a pace that is 2-3 times faster than other major economies. The European Union countries, the United Kingdom of Great Britain and Northern Ireland and the United States have either achieved a 40 per cent reduction from their emission peak or are close to achieving the target. However, for the developed economies of Japan and the Republic of Korea, whose emissions peaked at later dates, it would take 12-16 years to successfully achieving the target, to reduce emissions by 40 per cent from their peaks as shown in figure 2 (Choi and others, 2021).

Figure 2. Years required to cut emission by 40 per cent from the emission peak (unit: year)



Source: Choi and others (2021).

Notes: Original source came from the “Historical GHG emissions” from the Climate Watch Database and government documentations; [Year A – Year B] indicates the peak year (Year A) while “Year B” is the year reaching 40 per cent emission reductions (Year B)

3.2 Challenge in the energy transition sector

Under the updated NDCs, the power sector plays the most important role in achieving the 2030 NDCs. In fact, this sector should account for at least half of the actual domestic reductions, excluding forest sink and foreign abatement. Specifically, power generation in 2030 is expected to increase by approximately 7.3 per cent compared to 2018, but greenhouse gas emissions emanating from the power sector are targeted to decrease by 44.4 per cent, compared to the 2018 level, to 149.9 million tons (Lee, 2021). This means major changes in the current power supply system is required to achieve the 2030 NDCs target. In particular, among the power generation sources, changes in coal and new renewable energy, which will decrease by 44.3 per cent and increase by 5.2 times, respectively, compared to 2018 levels, are noticeable as in indicted in figure 3 (Republic of Korea, Joint Government, 2021; Lee, 2021). Accordingly, more audacious investment and policy foundations are essential for a cleaner energy transition.

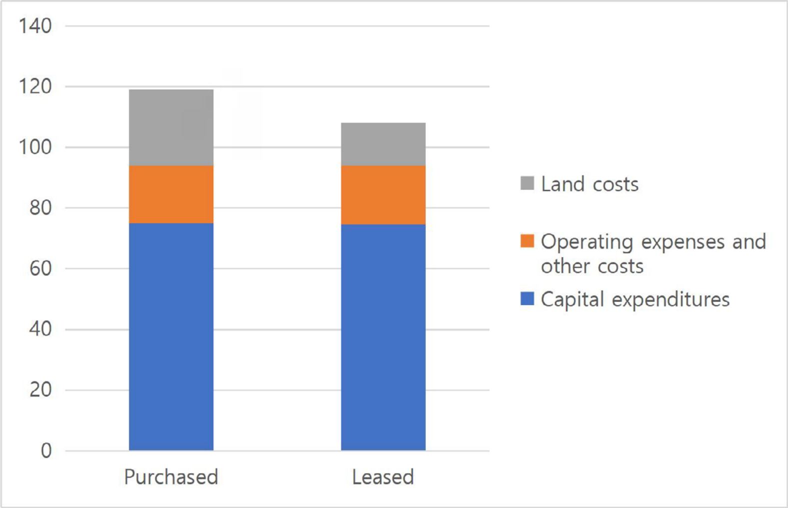
Figure 3. Power generation by energy sources (unit: 1,000 GWh)

Source: Republic of Korea (2021).

Notes: LNG, liquefied natural gas.

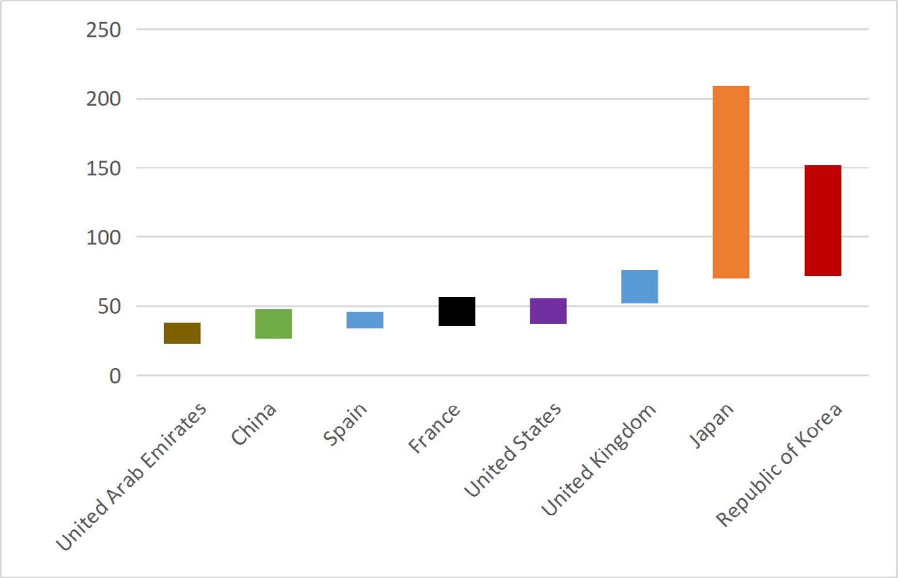
The high levelized cost of electricity (LCOE) in renewable energy-based generation for the Republic of Korea can be attributed to the high costs to acquire land, which includes dealing with civil complaints and licensing for the land use, as shown in figures 4 and 5. To address this challenge, it is advisable to expand the use of renewable energy, develop technologies that overcome location restrictions, and for the production of renewable energy (Lee, 2021;). In addition, developing large-scale offshore wind farms or other renewable energy sources that are appropriate in the Republic of Korea context should be implemented.

Figure 4. Comparison of levelized cost of electricity (purchased land versus leased land) unit: $/MWh)



Source: Lee(2021)

Figure 5. Levelized cost of electricity by economy (unit: $/MWh)



Source: Lee (2021)

The Republic of Korea relies heavily on coal-based power generation. In the power generation sector, coal accounted for 38 per cent of the of energy source in 2018; natural gas 24 per cent; nuclear, 31 per cent; oil, 2.5 per cent; hydro 0.6 per cent, and non-hydro renewables 2.7 per cent. In terms of fuel type, coal accounted for 48 per cent of the greenhouse gas emissions from fossil fuels in 2018; oil; 33 per cent; and natural gas, 19 per cent (IMF, 2021). The Seocheon Thermal Power Plant and Goseong High Thermal Power Plant, which were launched in 2021 added 3.1 GW of power, which was recorded as the third largest increase in the world (Park, 2022). Seven coal-fired power plants set in the Sixth Basic Plan for Electricity Supply and Demand in 2013 are either under construction or have been completed. As private companies have obtained business licences in accordance with legal process, the thermal plants cannot be shut down by force. If early closure of the plants takes place, the workers and local businessmen need to be compensated while acknowledging the project owner's property rights (Deloitte, 2021).

3.3 Challenges in the industrial sector

A sharp reduction in carbon emissions is expected to put a significant burden on the industrial sectors of the Republic of Korea, where the proportion of carbon emissions in the industrial sectors is high (Deloitte, 2021). The country's greenhouse gas emissions have a strong correlation with the manufacturing industry, which accounts for 30 per cent of the national gross domestic product (GDP). Expansion of the manufacturing industry has not only led to an increase in direct emissions from the relevant industries, but also an increase in indirect emissions from the power generation sector due to the higher demand for electricity (Lee, 2021). Moreover, the overall value chain of the manufacturing industry, such as transportation and distribution, waste generation in operation and energy-related activities has also contributed to greenhouse gas emissions (KBCSD and KOSA, 2021). In addition, if renewable energy generation were to be expanded to reduce carbon emissions in the power sector, the competitiveness of the manufacturing industry would be weakened due to an increase in electricity rates (Jung, 2021).

IV. SWOT ANALYSIS CONDUCTED FOR THE REPUBLIC OF KOREA 2050 TARGET

For this study, a SWOT analysis was conducted to shed light the ability of Republic of Korea to realize its 2050 net-zero target, taking into account all sectors, and environmental and regulatory policies. Using results from the analysis, the strengths, weaknesses, opportunities and threats that could affect meeting the 2050 target can be assessed by drawing a strategic propulsion direction in the following areas:

- Accelerating a low carbon transition in power and industrial sectors;
- Strengthening the efficiency and efficacy of mitigation policies, particularly in its ETS;
- Coordinating consensus on payment for social, economic, and environmental costs from the transition by stakeholders;
- Strengthening international cooperation.

SWOT analysis is a structured planning method adopted to assess various strengths (S), weaknesses (W), opportunities (O), and threats (T) and other factors that affect a certain topic. It investigates both advantageous and disadvantageous elements, which are derived from internal and external factors (Shi, 2016). Strengths and weaknesses are internal factors that are supportive or hindering the achievement of the 2050 target in the Republic of Korea. Opportunities and threats are external helpful or harmful factors that affect the 2050 net-zero plan, respectively. SWOT assessment results can be used to formulate the corresponding strategies, plans, and countermeasures by creating the scenario (Jasiulewicz-Kaczmarek, 2016). The method used for the SWOT analysis is effective to identify helpful and harmful conditions, solve issues in a specific manner, spot current obstacles, and guide science-based decisions (Wang and Wang, 2020). The results of the analysis indicate the following:

4.1 Strengths

First, the Republic of Korea has a high level of digitalization and advanced low-carbon technologies. It was one of the first countries to include the concept of green growth as a national development agenda item and announce its commitment to develop a green information and communications technology (ICT) in the 2000s. Applications of digital technologies in sectors, such as energy, urban transport, and agriculture, can create new opportunities for climate change mitigation (World Bank, 2022b). In terms of low-carbon technology in the energy sector, the Republic of Korea has a **competitive edge in technology for nuclear power generation.** The country's nuclear stature has been promoted by its foreign partners. The war in the Ukraine has resulted in energy scarcity to Europe, which is now eagerly looking for alternatives to Russian gas. For example, Finland plans to adopt the technology used for the Republic of Korea reactors to wean itself off Russian energy supplies. Furthermore, countries in the Middle East, including Saudi Arabia, are potential buyers of Republic of Korea reactor, and the United Arab Emirates, as a current partner, has praised the nuclear technology of the Republic of Korea as enabling clean energy for the Asia-Pacific region (Lee, 2022). In addition, in the transport sector of the Republic of Korea, **eco-friendly vehicles (electric, hydrogen, and hybrid)** have increased exponentially, by 41.3 per cent (+339,000 cars) compared to the previous year. To date, 1,160,000 of these types of cars are registered in the Republic of Korea. The number of electric vehicles in the country has grown rapidly to 231,442 at the end of 2021, up 71.5 per cent (+96,481 cars) from the previous year. By category, 185,000 of the cars were registered for passenger vehicles, 43,000 cars for cargo vehicles, 3,100 cars for vans, and 130 cars for special vehicles (Republic of Korea, Ministry of Land, Infrastructure and Transport, 2022).

Second, the Republic of Korea has a large-scale ETS market with abundant knowledge of operations, which will support efforts to achieve the 2050 target. The K-ETS market, launched in 2015, is the second largest national emission trading market globally, followed by the one in China, and the third largest market (when including the European Union ETS) in the world (World Bank, 2022a). K-ETS was established in 2012 through an act on the allocation and trading of greenhouse gas emission permits (Korean Law Information Center, 2012). Phase I (2015–2017) included five sectors (power, industry, buildings, waste and transportation), 23 subsectors, and 100 per cent free allocation of allowances was given (average greenhouse gas emissions between 2011 and 2013). During Phase II, coverage was expanded to six sectors (heat and power, industry, buildings, transportation, waste, and public) and 62 subsectors. In Phase I, 97 per cent of the allowances were distributed for free and 3 per cent (26 subsectors) by auction. The sector-specific benchmark was applied to seven subsectors (International Carbon Action Partnership, 2022; Republic of Korea, Ministry of Trade, Industry and Energy, 2017). The Phase III (2021–2025) of K-ETS covers six sectors (industry, buildings, heat and power, transportation, waste, and public sector) and 69 subsectors, accounting for 73.5 per cent of the country's total greenhouse gas emissions. More than 10 per cent of allowances will be auctioned from the 41 eligible subsectors, and more advanced fuel-specific benchmark methods for electricity generation will be applied (International Carbon Action Partnership, 2022). In the Conference of Parties 26 (COP26), held in 2021, the principles for international carbon market mechanism in Article 6 of the Paris Agreement built a consensus among the stakeholders, setting the groundwork for K-ETS to contribute more for achieving the emission target of the 2050 net zero goal.

Third, the Republic of Korea gas has ample experience in the area of green growth, which incorporates "green" components into economic growth strategies. Since the announcement of the concept of "low-carbon green growth" in 2008, the country has introduced a series of institutional frameworks and policies to transform the national economy into a low-carbon economy. The Republic of Korea established its institutional basis for promoting green growth through the National Strategy for Green Growth (2009–2050" and Five-Year Plan (2009–2013) in 2009. To facilitate green growth, the Presidential Committee on Green Growth was established in 2009, and the Framework Act on Low Carbon Green Growth was enacted in 2010

(Global Green Growth Institute, 2015). Moreover, during the COVID-19 pandemic, the Korean New Deal, which is an economic package combining green and digital components, was announced. In the package, the "green" component is considered to be an important pillar for economic growth. The country has ample experience and know-how based on a long history of establishing institutional frameworks and implementing policies to facilitate the low-carbon transition. The Enforcement Decree of the Framework act on low carbon, green growth became effective in March 2022, and the 2050 Presidential Commission on Carbon Neutrality and Green Growth is leading the efforts aimed at achieving carbon neutrality and green growth (Republic of Korea, Ministry of Environment , 2022c). These solid institutional frameworks and know-how are helping to accelerate national efforts to achieve carbon neutrality goals as well supporting other developing countries' low-carbon transitions.

4.2 Weaknesses

First, lacking alignment of mitigation policies and NDC targets, and weak cooperative governance. The domestic policies covering greenhouse gas mitigation are not aligned with the updated NDCs of the Republic of Korea. Previously adopted national energy policies before the amendment, such as the 9th Basic Plan for Electricity Supply and Demand and the Third Energy Master Plan need to be updated to keep up with the enhanced NDC target. As already indicated, because the greenhouse gas emissions in the Republic of Korea peaked relatively recently compared to other major countries, the country must reduce these emission by 40 per cent at a rate that is 2-3 times faster than the rate for other advanced economies. In addition, insufficient horizontal governance among the governmental department or vertical cooperation between central and local governments for policy implementation remains a challenge for achieving the 2050 net-zero mitigation target. Stronger partnerships with the private sector to align with new NDC targets should also be considered. That said, the Government is expanding support for greenhouse gas reduction facilities (from 97.9 billion Korean won in 2022 to 138.8 billion Korean won in 2023) and plans to introduce Carbon Contracts for Difference to encourage further investment among companies in innovative technologies for greenhouse gas mitigation (Invest Korea, 2023). Engagement of young people in the policy decision process should also be considered.

Second, energy transition to renewable energy is happening slowly in the Republic of Korea due to the inertia of having heavily relied on fossil fuel-based power generation. Coal-based power generation is still widely used in the country, and new coal-fired power plants are still under construction. Another impediment for the energy transition to renewable energy is grid parity has not been met and LCOE in the renewable energy sector is high because of the high cost to purchase land. In addition, the country's heavy dependence on energy imports, especially fossil fuels, and energy and carbon-intensive economic structure are impediments to reaching NDC targets and net zero. The manufacturing sector accounted for 27.9 per cent of greenhouse gas emissions in 2021, and this share has remained steady over the past decade (Statistics Korea, 2022). Moreover, the country's major industrial sectors include energy and carbon-intensive industries, such as semiconductors, petrochemical and steel, so the decoupling of economic growth from carbon emissions requires a significant shift of the economic structure towards a low-carbon economy.

Third, relatively low-carbon pricing and cheap electricity prices cannot provide enough motivation to ensure sufficient effort to achieve carbon neutrality. The Republic of Korea been operating an ETS since 2015, but its carbon market and carbon pricing are still not enough to curtail carbon emissions and achieve a low-carbon transition. Compared to the EU ETS, where the permit price was EUR 87.55/ton, as of Aug 11, 2022 (EMBER, 2022), the country's carbon price remained at a relatively low level at approximately $21/ton as of 11 August 2022. In addition, the limited carbon pricing mechanism is due to various reasons, such as high free allowances and no consideration of the carbon price in power dispatch. Moreover, relatively low electricity bills for consumers does not provide enough motivation for them to cut their electricity consumption, making it hard to reduce electricity demand.

4.3 Opportunities

First, the potential for regional or bilateral carbon trading provides an opportunity to enhance cooperative mitigation actions. Recently, many emerging economies started to develop or prepared to introduce a domestic ETS. The adoption of Article 6 of the Paris Agreement provides a foundation for international carbon markets. At COP26, which was in Glasgow, Scotland, from 13 to 21 October 2021, new agreements were reached regarding Article 6 allowing the transfer of carbon credits from mitigation while avoiding double counting. Specifically, in Article 6.2, the bilateral efforts to reduce greenhouse gas emissions are noted and suggested guidelines for internationally transferred mitigation outcomes between countries are given (Di Leva and Vaughan, 2021). This allows the Republic of Korea to not only acquire carbon credits at lower costs, but also to investment in and provide low-carbon technologies to emerging economies.

Second, a potential regional power trade among East Asian countries (China, Japan and the Republic of Korea) presents an opportunity to reduce the country's heavy fossil-fuel dependence. The Republic of Korea is geopolitically an "island'' country due to the Democratic People's Republic of Korea; therefore, energy security and stable energy supply are key agendas. A vast amount of liquefied natural gas (LNG), which is considered as a relatively clean fossil fuel ,has been imported from other countries to ensure a stable energy supply, as well as lessen greenhouse gas emissions. Accordingly, the potential regional power trade would not only improve energy security, but it also could reduce the dependence on fossil-fuels, as the Republic of Korea purchases renewable-based electricity from neighbouring countries.

Third, the rapidly decreasing cost of low-carbon technologies, especially renewable technologies, and technology innovation, such as small modular reactors, can accelerate the low-carbon transition in the energy sector. According to IPCC (2022), unit costs of low-carbon technologies, such as solar, wind, and lithium-ion batteries, fell sharply in 2010s and reached grid parity globally and nationally. Moreover, the development of large-scale offshore wind farms, a promising technology globally, provides additional mitigation options to countries, including the Republic of Korea.

Finally, the rapid expansion of the global green mobility market could provide the impetus for the Republic of Korea to further mitigate greenhouse gas emissions. Globally, the penetration of electric and hydrogen vehicles is growing exponentially, and many global car manufacturers have announced plans in 2021 to produce only electric vehicles (IEA, 2022). In the Republic of Korea, more than 5 per cent of newly registered vehicles were electric vehicles, and clean vehicles, including hybrid, electric, and hydrogen vehicles, accounted for approximately 4.7 per cent of the total number of vehicles in 2021 (Republic of Korea, Ministry of Land, Infrastructure and Transport, 2022). The global transition to green mobility along with domestic support offers a great opportunity for the Republic of Korea to reach the global mitigation target.

4.4 Threats

First is international pressure, such putting in place a Carbon Border Adjustment Mechanism (CBAM), renewable energy deployment and similar policies imposed by major economies that have already reached their emission peaks. The burden on domestic companies is expected to increase considerably according to the CBAM amendment of the European Union. Originally, there were five CBAM-applied items: steel; aluminum; fertilizer; cement; and electricity, but after it was modified, organic chemicals, plastics, hydrogen, and ammonia were added, increasing the total to nine items. In addition, the implementation schedule has been brought forward. Regarding renewable energy deployment, domestic renewable power generation in 2020 accounted for 5.6 per cent of the total. To achieve the NDC target of 30 per cent, an increase of 24.4 per centage points is required within 10 years and to do this, as already noted, the timeframe involved would be 2-3 times faster compared to the gradual expansion of renewable energy required by major countries (Choi and others, 2021). Moving at such a rapid pace could result in economic and social burdens on the national economy and the society in general.

Second, the COVID-19 pandemic and the war in Ukraine has posed mounting challenges to achieve the greenhouse gas mitigation goals. These two crises have resulted in macroeconomic turbulence and instability in international politics, forcing countries to make myopic decisions, which drag down the mitigation efforts, rather than implement long-term and sustainable policies. In addition, they have caused an unprecedented rise in commodities and labour pricing, and further consequential impacts on global supply chains for mitigation technology (Allam, Bibri and Sharpe, 2022).

Third, implementation of Article 6 of the Paris agreement has been delayed globally. The short-time window to achieve NDCs was not practical to establish the institutional frameworks and introduce carbon-pricing mechanisms in many countries. Notably, the globally sluggish adoption of carbon pricing, including ETS and other difficulties in implementing Article 6 of the Paris Agreement is presenting hurdles in meeting the net-zero goal for the Republic of Korea.

Table 1. Strengths, weaknesses, opportunities and threats affecting the achievement of the 2050 2050 net-zero target of the Republic of Korea based on the SWOT analysis

	Helpful	Harmful
Internal	[STRENGTHS] • High-level of digitalization and low-carbon technologies -Long-history of digital green growth experience -Competitive nuclear technology -Competitive eco-friendly vehicle market • Well-established, national-wide ETS market • Ample experience and know-how in green growth	[WEAKNESSES] • Lacking alignment of mitigation policies and NDC targets and weak cooperative governance • Slow energy transition to renewable energy and heavy dependence on fossil-fuel based power generation -Relying on coal-based power generation -Unmet grid-parity and high LCOE -Carbon intensive economic structure • Relatively low carbon price and electricity bills

Table 1. *(continued)*

	Helpful	Harmful
External	[OPPORTUNITIES] • Potential regional or bilateral carbon trading in accordance with Article 6 of the Paris Agreement • Regional power trade among the East Asian countries • Significant reductions of promising low-carbon technologies • Rapid transition towards green mobility	[THREATS] • Global pressure on mitigation as a newcomer -EU CBAM -Renewable energy deployment • Macroeconomic turbulence and unstable international politics, in particular the COVID-19 pandemic and the war in Ukraine • Global delay in the implementation of Article 6 -Sluggish adoption of carbon pricing mechanisms

V. DISCUSSION: STRATEGIES FOR THE 2050 NET-ZERO TARGET OF THE REPUBLIC OF KOREA BASED ON THE SWOT ANALYSIS

5.1 Low-carbon transition through renewable energy and hydrogen

To realize the 2050 target, applying realistic greenhouse gas reduction technologies is important. Conventional mitigation options in the industrial sector and improving energy efficiency would not be enough; nor would it be cost-effective. The country has already adopted many cheap low-hanging fruit options, so it needs to go beyond the current actions and find a breakthrough action to further accelerate the low-carbon transition, in order to achieve the 2050 net-zero target. A clear road map for the development, demonstration, and industrial application of innovative technologies for the reduction of greenhouse gas emission should be formulated. Accelerating the investment and deployment of renewable energy, as well as establishing a stable supply infrastructure for hydrogen to be used as fuel and raw material in the future are essential.

As renewable sources become more and more cost-effective, policies aimed at supporting renewable sources and facilitating competition of energy sources in the market should be considered, while taking into account the circumstances in the Republic of Korea. The country can benchmark Germany and the United Kingdom, which are considered as leading countries for reducing carbon emissions. These two countries have successfully deployed renewable energy and have been actively promoting the hydrogen economy. The United Kingdom set a target of supplying 30 per cent of electricity generation with renewable energy by 2020 under the National Renewable Energy Action Plan. The development of low-carbon energy technologies, including renewables, are seen as an important option to achieve its ambitious 2050 net-zero emissions target (Korea Energy Agency, 2019). In particular, the United Kingdom has been promoting wind power, especially offshore wind, which accounted for 27 per cent of the power generation in 2020 (United Kingdom, Department for Business, Energy and Industrial Strategy, 2021). By retiring feed-in-tariffs in 2019, the country is supporting renewable energy through market mechanisms, such as the smart export guarantee and the contract for difference (United Kingdom, Department for Business, Energy and Industrial Strategy, 2022). Germany, a leading country in terms of renewable penetration, has announced plans to increase the share of power generation from renewable sources, from 50 per cent to 65 per cent in 2020 (Korea Energy Agency, 2020). The country promotes the deployment of renewable energy through mixed policy options comprising feed-in-tariffs, feed-in-premiums and auctions. In addition, hydrogen, especially if produced by electrolysis with renewable sources, could lead the energy transitions in the transportation, buildings and industrial sectors in which there are lingering challenges pertaining to decarbonization. The United Kingdom and Germany have been promoting the development of hydrogen. Germany adopted a national hydrogen strategy in June 2020, and the United Kingdome promotes a hydrogen economy by investing in the installation of carbon capture and storage technology, building hydrogen networks in industrial parks and developing blue hydrogen for the transportation sector (Deloitte, 2021). To promote renewable and alternative sources, such as hydrogen, the Republic of Korea could consider introducing a more market-based approach, which facilitates competition among various energy sources, and consider providing incentives to develop hydrogen as a long-term energy strategy.

To reach the enhanced NDC proposal within a limited time, the Republic of Korea should strengthen its national energy policies, and offer incentives for the development and deployment of renewables and hydrogen. In particular, it is necessary to consider restructuring the energy and electricity market to create an enabling environment for renewable energy operators to compete in the market and reach grid parity. Moreover, it is necessary to reorganize government organizations to increase the efficiency of efforts to achieve the goals by coordinating and integrating the opinions of government departments and local governments (Choi, H. and others, 2021). In addition, it is necessary to reform the fossil-fuel subsidies. According to the G20 Scorecard (Tucker, 2020), the overall score the Republic of Korea in terms of fossil fuel funding put it at a ranking of 8th out of 11 countries; the country recorded the fourth highest international total public finance for fossil fuels among G20 countries. Setting pledges and commitments for reducing fossil-fuel subsidies and enhancing transparency of information is required to accelerate the country's efforts to meet NDCs and net zero targets.

5.2 Strengthening the emission trading system

The Republic of Korea has been operating a nation-wide ETS for years. Its coverage is approximately 73 per cent, which is higher than other such systems. The country's ETS (K-ETS) is the second largest ETS outside of the European Union. In the third stage (2021–2025) of the system, only 10 per cent of the allowances will be auctioned; the remaining 90 per cent are being freely allocated. K-ETS must be strengthened to achieve the updated NDC target. The International Monetary Fund (IMF) has argued that strengthening the carbon price signal using fiscal policy is required for the country to achieve its climate goals. Several specific measures have already been implemented or announced to achieve carbon neutrality in the country. In particular, improvements to its carbon-pricing system through more effective implementation of the plans to upgrade the functioning of the K-ETS to have greater coverage compared to other countries can become a central tool used to improve carbon pricing. Although there are limitations on implementation of the current stage of the K-ETS, this can be improved in the fourth stage of the K-ETS. According to IMF, in the fourth stage, K-ETS should set a total amount of emission permits that is consistent with the country's 2030 reduction target and gradually raise the upper and lower limits of the price of emission permits. In addition, K-ETS needs to carry out fully paid allocations (auctions) instead of grandfathering to distribute emission rights. Owing to its higher share of coal, the Republic of Korea is more sensitive to higher carbon prices compared to other G20 countries. Accordingly, to achieve the 2030 NDCs through carbon prices, the price of emission permits needs to be raised from approximately $18 per ton to $75 per ton (based on $1 = 1,111.10 won). The issue of acceptability to rising energy prices can be overcome by taking a comprehensive package approach, which combines sectoral mitigation measures with complementary means, such as supporting the vulnerable segments of society and providing various incentives (IMF, 2021).

5.3 Building a mechanism for coordinating stakeholder opinions

As the cost for achieving the NDCs goal is gradually increasing, social discussions and plans should be promoted on how the reduction they should be shared. For example, with the well-established national-wide ETS in the Republic of Korea in place, a road map must be prepared by 2030 to predict corporate reduction costs. Accordingly, the payment of environmental costs, such as for reforming electricity rates, introduction of a carbon tax and expansion of paid allocation of ETS, should be discussed in advance (Choi and others, 2021). One of the weaknesses to carbon neutrality, mentioned above, is impeding the energy transition to renewable energy due to unmet grid parity and high LCOE in the renewable energy sector The high proportion of land acquisition costs in developing renewable infrastructure is a concern. Accordingly, it may be advisable to establish a public mechanism that can share costs and coordinate stakeholder opinions through a deliberative democratic approach.

Moreover, a just transition should be carefully considered because the enhanced NDCs and the carbon neutrality require a significant shift of the economy of the Republic of Korea. Failing to carry out a just transition would incur economic and social conflicts, such as labour reallocation and stranded assets. Without a proper mechanism for coordinating stakeholders' opinions, continued conflicts among groups would drag down the efforts related to the low-carbon transition.

5.4 Strengthening international cooperation

Overseas reductions have increased to 33.5 million tons of CO_2eq, therefore, considering the situation in the Republic of Korea, using the international carbon market is inevitable. Carbon trading with other emerging economies with a lower abatement cost would enable the Republic of Korea to reduce the greenhouse gas emissions more cost effectively while contributing towards global greenhouse gas mitigation. Moreover, the success of carbon neutrality with hydrogen depends on a large amount of hydrogen imports, so international cooperation is becoming more and more important. In addition, the provision of bilateral green official development assistance (ODA) and participation in multilateral cooperation through international organizations can support low-carbon development and climate resilience in developing countries. This would support efforts to achieve global carbon neutrality and would enhance the international status of the Republic of Korea (Choi. and others, 2021).

The OECD Development Assistance Committee (DAC) has confirmed that only 19.6 per cent of aid extended by the Republic of Korea was used for Green ODA over the period 2015–2019, which was lower than the average of OECD DAC countries, at 28.1 per cent. Accordingly, the Green New Deal official ODA strategy became a part of the country's foreign aid strategy in accordance with the Committee for International Development and Cooperation. To confirm the role of the Republic of Korea as a leader in the global climate response, it is noteworthy to highlight the Green New Deal ODA strategy as follows: first, the Republic of Korea increases the share of green ODA above that of the OECD DAC average by 2025 and supports partner countries' green transition by building a green new deal ecosystem and through flagship projects. Second, the Republic of Korea increases contributions to green-related international organizations. Third, the Republic of Korea builds mutually beneficial partnerships with partner countries and the private sector by aligning the partner countries' development needs and the country's strengths, such as green energy and green mobility (World Bank, 2022s). In addition, by utilizing a regional or bilateral carbon and power trade, the Republic of Korea leverages the opportunity to achieve the country's ultimate goal of carbon neutrality.

VI. CONCLUSION

The announcement of 2050 LEDS, the enhanced NDCs, and carbon neutrality as a 2050 goal shows the strong intention and efforts of the Republic of Korea to reduce greenhouse gas emissions and transform to a low-carbon economy. To push the country to achieve the net-zero goal more effectively and efficiently, relevant strengths, weaknesses, opportunities and threats must be identified. By setting the enhanced NDCs as an interim goal for reaching the ultimate target of carbon neutrality, the country must cope with several challenges, including a very limited time to achieve the 40 per cent emissions reduction, the slow pace of its energy transition from fossil-fuel based system to low-carbon energy sources and the carbon and energy-intensive industrial structure.

A SWOT analysis was conducted to clarify possible strategies for achieving the 2050 net zero and review the current situation in the Republic of Kores.

The findings indicated that the country strengths in this regard are its high-level of digitalization, low-carbon technologies, well-established, nation-wide ETS, decade-long experience in green growth, solid institutional foundation, and accumulated knowledge, which collectively can be a strong enabler in supporting the country to reach the target.

As for weaknesses, which are impeding the transition efforts, the findings indicated the following: sluggish transition due to unmet grid parity; the carbon- intensive economic structure and low carbon-pricing and electricity bills, which limits motivation to cut energy usage.

There are also opportunities to overcome the challenges and reinforce the country's strengths. At COP 26, Article 6 of the Paris Agreement, which enables international carbon trading, was approved. The Republic of Korea has already implemented various mitigation measures that have relatively low costs, including a nation-wide ETS. Accordingly, the international carbon market highlighted in Article 6 is a good opportunity to obtain carbon credits at lower costs while supporting mitigation efforts in developing countries. In addition, the costs of low-carbon technologies have declined significantly, and some technologies, such as renewables, have become competitive against traditional technologies in some regions and countries. As new technologies are developed, more options to reduce greenhouse gas emissions and accelerate mitigation efforts will become available. Implementing a low-carbon transition in the mobility sector is very difficult, but the global trend shows faster penetration of green mobility; this is a positive signal for achieving the global 2050 target.

However, the current macroeconomic turbulence and unstable international politics caused by the COVID-19 pandemic and the war in the Ukraine has had adverse effects on the Republic of Korea, specifically with regard to funding low-carbon technologies, facilitating international cooperation and accelerating the low-carbon transition. In addition, global pressures, such as the European Union Carbon Border Adjustment Mechanism has increased the burden on the country's economy.

To achieve its enhanced NDCs and the 2050 net-zero target, the Republic of Korea consider implementing the following strategies:. The first one is to impose a carbon tax as it is the most efficient market-based mitigation instrument to stimulate the transition among green gashouse-emitting industries. Countries, such as Denmark, Finland, the Netherlands. Norway and Sweden, have adopted a carbon tax scheme. Lessons learned from them about the implementation of the tax could provide practical insight and caution for the Republic of Korea on levying the tax (Lin and Li, 2011).

Second, the Republic of Korea needs to facilitate the deployment of renewable energy and hydrogen across all sectors as a long-term solution. A system-wide integration of electric vehicles, energy storage systems and hydrogen technologies, for example, can be a feasible plan, which is achievable by adopting advanced ICT and Industry 4.0 technologies. Although the Republic of Korea supports the use of renewable energies through a renewable portfolio standard, the country could benefit from restructuring the energy and electricity market to facilitate competition of various energy sources. In addition, more coordinated action among governmental departments and regional governments is necessary to strengthen policy measures for developing and deploying renewable and hydrogen.

Third, the Republic of Korea needs to strengthen K-ETS to enhance its efficacy and efficiency. Despite its vast coverage, a very large portion of allowances are still freely allocated, and the market is not fully functioning. Accordingly, the country must set K-ETS to be consistent with the emission targets and restructure the market to determine efficient and optimal carbon pricing. Moreover, a just transition and a mechanism for coordinating stakeholder opinions should be introduced to ease social tensions and conflicts incurred by transforming the country's economic structure. Inevitably, the low-carbon transition creates social and economic challenges, such as unemployment, labour reallocation and stranded assets. If these challenges are not addressed, the transition towards a low-carbon society would be hindered.

Finally, regional and international cooperation has become more and more critical in the Republic of Korea. In addition to the long-term plan to import green hydrogen, carbon trading with other countries could benefit the country greatly in its effort to achieve mid-term and long-term mitigation goals. In addition, green ODA and knowledge-sharing on green growth can contribute towards reaching the global 1.5°C-degree pathway.

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Thematic Section: Green Transition and National Efforts towards Net-Zero Target

THE TRANSITION OF CHINA TO A LOW-EMISSION FUTURE: THE ROLE OF CLEAN COAL TECHNOLOGIES

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The "30-60" catchphrase in China refers to the commitment of China to reduce greenhouse gas emissions after the peak by 2030 and achieve carbon neutrality before 2060. The 30-60 goal is a challenge, but it offers opportunities for the country's sustainable future. By using Integrated energy and environment policy assessment modelling, an assessment of the energy strategies and policy regimes for the country's energy transition by 2050 is conducted. Based on the results, it can be argued that coal will remain an important part of the transition pathway, and hence clean coal technology development is critical.

Keywords: clean coal, carbon neutrality, coal-based chemistry, carbon capture and storage, energy transition

JEL classification: Q47

I. INTRODUCTION

China emits 27 per cent of the global carbon dioxide (CO_2) and one third of the world's greenhouse gases (World Bank, 2022). Accordingly, the achievement of global climate goals critically depends on the country's successful transition to a low-carbon economy. China is vulnerable to climate change-induced extreme weather and natural disasters, such as frequent coastal flooding, storm surges, costal erosion and saltwater intrusion. These climate change-induced disasters threaten its densely populated and economically critical low-lying coastal cities, home to an estimated one fifth of the population, which contributes one third of the gross domestic product (GDP) (World Bank, 2022). Unabated climate change could lead to estimated GDP losses of between 0.5 and 2.3 per cent annually as early as 2030 (World Bank, 2022).

Accordingly, the transition to a low-carbon economy is crucial for sustained economic progress in China. This transition requires a massive shift in resources and innovation, as well as new technologies to enhance energy efficiency and resource productivity. Nevertheless, as World Bank (2022) notes, the country is well positioned to meet its climate commitments and transition to a greener economy, while meeting its development goals. Its advanced technological capabilities mean the pathway to carbon neutrality will open new avenues for development.

In this paper, the country's energy strategies, policy regime, and energy transition pathways are reviewed. Based on the results, it can be argued that coal will continue to be part of the energy mix in the foreseeable future and hence the development of clean coal technology is critical for the energy transition to a low carbon economy by 2050. The paper begins with an assessment of energy development in China since 1990; it then includes a discussion of the energy strategies and policies of China. A snapshot of coal supply and use in the country is followed by a discussion on clean coal technologies. Energy transition pathways for the carbon neutrality goal are assessed by using the Integrated Energy and Environment Policy Assessment model for China (IPAC). The concluding section reflects on the future of clean coal in China.

The Integrated Energy and Environment Policy Assessment model for China is an energy modelling system comprised of (a) general energy supply and demand models, (b) an emissions model, (c) a disaggregated set of energy supply models that focus on technologies and regions of China (in particular Beijing) and (d) air and health impact models. The model's main relevance to the suggested response measures is its detailed treatment of energy technologies. It is mostly used to (a) forecast greenhouse gas emissions, (b) assess the impact of new technologies, (c) analyse the impact of different energy and environmental policies and (d) forecast energy demand.

II. ENERGY DEVELOPMENT IN CHINA

2.1 Energy trend

Total primary energy consumption in China was 691 million tonnes of oil equivalent (toe) in 1990, 1.029 billion toe in 2000, 2.525 billion toe in 2010, and 3.486 billion toe in 2020[1] (NSB, 2022) (figure 1). The most rapid increase occurred from 2000 to 2010; the annual growth rate reached 9.39 per cent, as compared to 4.06 per cent from 1990 to 2000, and 3.28 per cent from 2010 to 2020. Coal has dominated energy use in China; it share of the primary energy mix was 79 per cent in 1990, 68.5 per cent in 2000, 69.2 per cent in 2010 and 56.8 per cent in 2020. Before 2010, there was only a modest change in the share of coal in total primary energy use, mainly because the commodity is the cheapest energy source and the largest fossil fuel resource in China. This changed in 2013 when the Air Pollution Prevention and Control Action Plan was announced, under which controlling coal use was one of the top measures to improve air quality (State Council, 2013). Following the release of the Plan, several strong policies were set to control coal use in China, including an energy revolution strategy announced in 2014. In the same year, the State Council announced the desire for CO_2 emissions to peak prior to 2030 and the country's commitment to the United Nations Framework Convention for Climate Change (UNFCCC) to control CO_2 emissions from China in 2015 to support the Paris Agreement (China.Org.CN, 2015). Another significant factor supporting the change is the rapid increase of installed capacity of wind power and solar power (NSB, 2022).

Figures 2 and 3 present the installed capacity and power generation from renewable energy in China (NEA, 2022). They show that after 2013. wind and solar started to be developed rapidly in China, especially solar photovoltaic (PV) in 2016. After 2016, annual newly increased capacity for solar and wind power has accounted for nearly half of the global newly installed capacity. Consequently, China has become a global leader in developing solar and wind power. By 2021, solar and wind accounted for 12.1 per cent of the country's power generation, as compared to 3.9 per cent in 2015, and 1.2 per cent in 2010. Power generation totalled 49.5TWh in 2010, 223.8TWh in 2015, and 981.5TWh in 2021.

Nuclear power has also been increasing rapidly in China. Installed capacity of nuclear energy was 10.82GW in 2010, 27.17GW in 2015 and 53.26GW in 2021. After 2018, the construction of nuclear projects were restarted in six units annually; in 2022, a total of 10 new units began operating with total capacity of 12GW.

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[1] Primary energy is calculated based on the method applied the by National Statistics Bureau of China (NSB) in which renewable energy and nuclear energy are added based on efficiency of fossil fuel power generation.

Figure 1. Primary energy demand in China from 1990 to 2021

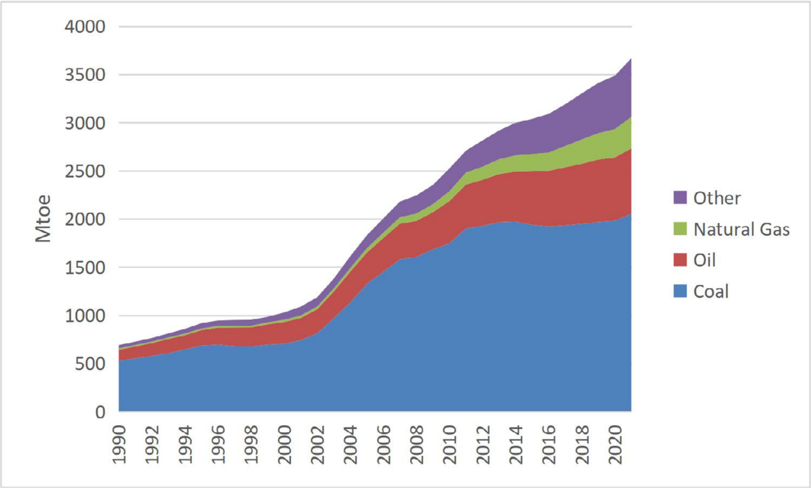


Figure 2. Zero carbon power development in China

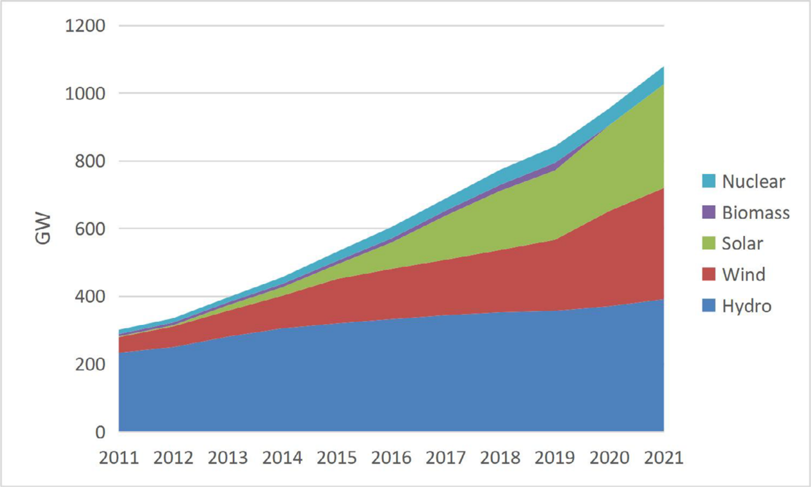
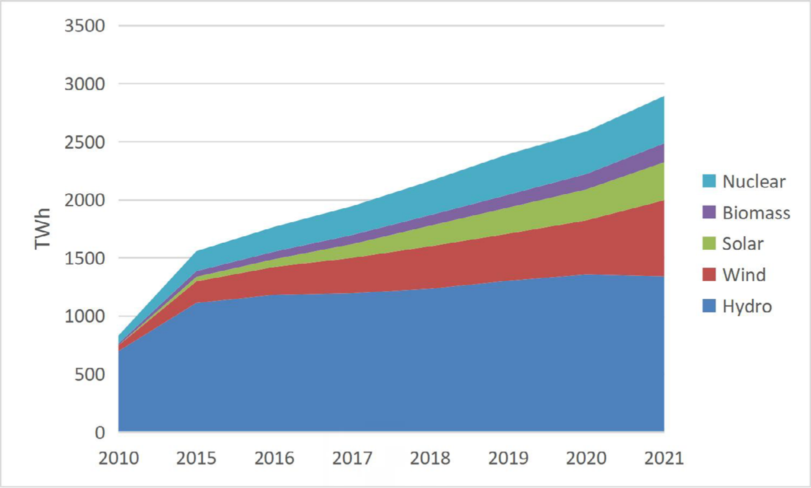


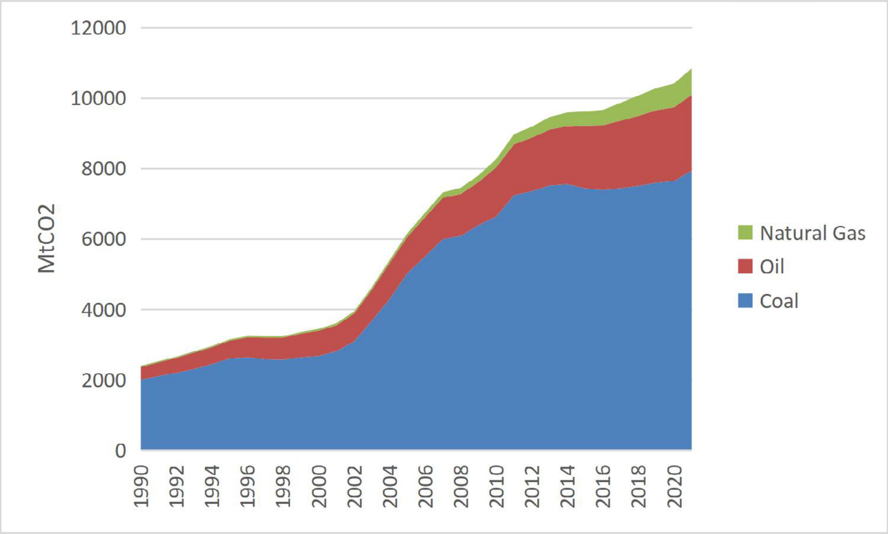
Figure 3. Power generation from zero carbon power in China



2.2 Carbon dioxide emissions

Carbon dioxide emissions in China are calculated by using emission factors from the IPAC model. Figure 4 presents the CO_2 emissions from energy activities from 1990 to 2021. Due to the rebound in coal use, carbon emissions reached a record high in 2021 and may enter a carbon emissions plateau in the next few years. Driven by economic growth, these emissions had trended higher starting in the 1990s until 2013 when it reached a plateau. However, since 2017, coal consumption has ticked higher as the economy faced headwinds and the Government sought to stimulate industrial growth. Since 2020, greenhouse gas emissions has increased by approximately 13 $GtCO_2$-equivalent (CO_2-eq), equating to 9 tCO_2-eq per capita. This accounts for about a quarter of global emissions, up from 10.2 per cent in 1990. Nevertheless, the carbon intensity of GDP dropped from a peak of approximately 810 gCO_2 in 2005 to 450 gCO_2 in 2020 (IEA, 2022). The 790 TWh increase in electricity demand was half met by coal, as the CO_2 emissions reached a record high of 11.9 billion tonnes in 2021, accounting for 33 per cent of the global total in 2021 (IEA, 2022).

Figure 4. Carbon dioxide emissions in China, 1990–2021



III. ENERGY STRATEGY OF CHINA

3.1 Energy security

Energy is a fundamental sector in socioeconomic development in China. From 1950 to 1970, the key work for the energy sector of China was to provide enough energy to support economic development. Starting in the 1970s, energy conservation policies were promoted in order to make the country environmentally friendly. By 2000, overcapacity of coal-fired power plants had become a key issue for energy supply, prompting the Government took steps to control newly installed capacity and investment. With the surge in energy-intensive production after 2003, energy supply shortages became the driving factor for energy policies. In the Air Pollution Prevention and Control Action Plan announced in 2013, coal use was strictly controlled with the objective to improve air quality.

Based on reaching a peak in CO_2 emissions prior to 2030 and the drive to achieve carbon neutrality before 2060 targets (the 30-60 targets), the energy development strategy was revised. In December. 2020, the white paper ” Energy development: energy in China’s new era”, was published by the State Council, which included new strategies on energy development and energy security.

As set in the white paper, China has adopted a new energy security strategy, vowing to promote reforms in energy supply and consumption, market building and innovation, while strengthening international cooperation. The strategy, which features reform in four aspects and comprehensive international cooperation, endeavours to adapt to domestic and international changes and meet new requirements.

3.2 30-60 carbon targets and policies

In September 2020, President Xi pledged that CO_2 emissions in China would peak before 2030 and that the country would strive to achieve carbon neutrality before 2060. In April 2021, he announced the country's plan to strictly limit the increase in coal consumption over the fourteenth Five-Year Plan and phase it down in the fifteenth Five-Year Plan. In September 2021, President Xi made further pledges that China would stop building new coal-fired power plants overseas. Throughout 2021, President Xi and other high-level Chinese officials reiterated and reinforced the country's commitment to the "30/60" goals on multiple occasions, signalling the country's intention to accelerate the low-carbon transition.

Energy security is among the top priorities of the country's development strategy. The current situation poses new challenges to its energy and economic development. For example, as a consequence of the war in the Ukraine, global energy markets are in turmoil amid rising oil and gas prices, and China, as an energy importer, has been experiencing higher energy costs and commodity prices.

Domestically, China struggled with several power shortages in 2021 and 2022, making stable and reliable energy supply the country's prime concern.

Starting in 2020, the country's economy has entered a new era featured by the "Dual Circulation" strategy (Xinhuanet, 2020). This strategy emphasizes an expanded domestic market (domestic circulation) and growing exports (international circulation). The carbon neutrality goal aligns with this strategy of greater self-reliance through more clean energy resources and advanced clean technologies, and facilitates the country's complete transformation of its economy and the energy system. In the early years of this transformation, new trends have emerged, including rapid expansion of renewables, an uptick in coal consumption and a relatively steep increase in carbon emissions.

The fourteenth Five-Year Plan (2021–2025) began in 2021, which also marks the first year of the country's efforts to peak carbon emissions since the announcement of the Dual Carbon Strategy, "30/60". Throughout the year, the political will in advancing the dual-carbon agenda remained high, as important policy signals during national and international meetings, and the "1+N" series of policies directing carbon neutrality and carbon emissions peaking efforts were released.

3.3 Policies on coal development

In past decades, the rapid growth of the Chinese economy and population led to extensive consumption of fossil energy, which has resulted in not only increasing depletion of traditional fossil energy, but also serious ecological and environmental issues. By 2021, fossil energy consumption (coal, oil, natural gas) was 4.37Btce, which accounted for approximately 83.4 per cent of total energy consumption in China; the shares of coal, oil, natural gas were 56 per cent, 18.5 per cent and 8.9 per cent, respectively. In 2016, China set a cap on annual primary energy consumption of less than 5.0 btce by 2020, and strived to increase the ratio of non-fossil energy from 12 per cent to 15 per cent.

Because coal is the lowest cost source of energy in China, development of the commodity has dominated energy development, accounting for 76.2 per cent of the energy produced in 1990, 68.5 per cent in 2000, 69.2 per cent in 2010, and 56 per cent in 2021. As coal is the largest fossil fuel resource, the supply of it plays a key role in energy security in China. Before 2005, the use of coal was driven by the demand side. However, with the environment emerging as a prominent concern, especially air pollution control, coal usage has become an issued tied with environment protection. For example, controlling coal use was referred to in planning by the city of Beijing, in its commitment to improve the city's air quality ahead of the Olympics Game in 2008. More and more Chinese cities are taking actions to improve air quality and control coal use .One noted development in this regard, as noted earlier, is the Air Pollution Prevention and Control Action Plan released by the State Council in 2013, which made control of coal use, and regulations on clean coal use part of a national strategy.

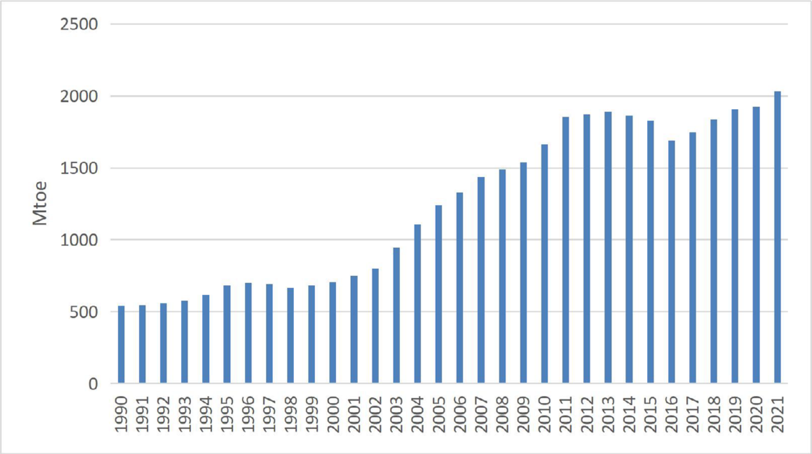
IV. COAL SUPPLY AND USE IN CHINA

4.1 Coal supply and consumption

A description of the energy resource structure in China as being "rich in coal resources, less resource of gas, and lack of oil" in China, clearly indicates that coal occupies the dominant position in terms of energy demand and consumption. This position will be difficult to change substantially in the coming decades.

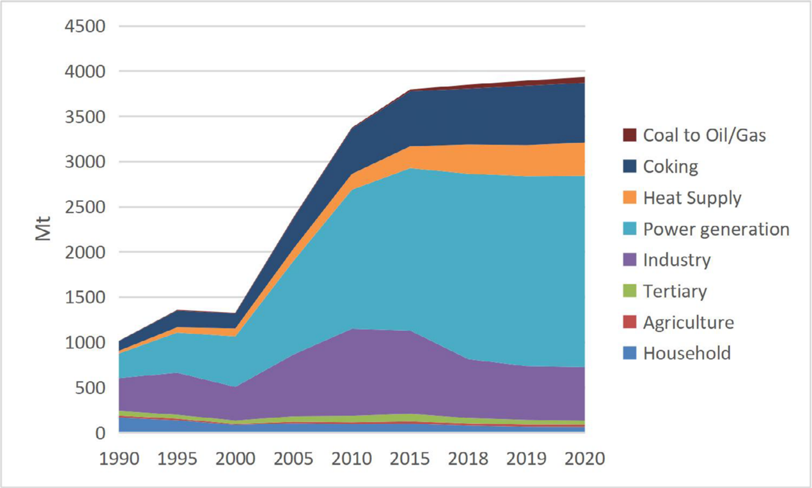
In 2020, raw coal output in China expanded by 0.9 percent year-on-year, while coal imports increased by 1.5 per cent and 3.84 billion tonnes of raw coal were, registering a year-on-year growth of 90 million tonnes. The country imported 304 million tonnes of coal in 2020, an increase of 4 million from a year earlier. In December, coal imports increased to 27.32 million tonnes from November to reach 39.08 million tonnes. Figure 5 presents coal production in China.

Figure 5. Coal production in China



The power generation sector is the country's largest user of coal. It accounted for 53.8 per cent of coal usage in 2020. Other large users are coke-making, heat supply and industry. After 2013, the increase of coal use slowed on the back of a shift in the country's economic structure and polices to reduce air pollutants were introduced.

Figure 6. Coal use by sectors in China, 1990–2020



Large users, such as coal-fired power plants are becoming more prominent consumers of coal and the commodity is becoming more environmentally friendly. Due to the policies announced in 2013, coal consumption in small households has become more strictly regulated. As a result, coal use in households, and small industries has declined significantly. Almost all large coal-fired boilers and power generation were required to be equipped with PM2.5, sulfur dioxide (SO_2) and nitrogen oxide (NOx) emission reduction facilities. However, it should be noted that after being retrofitted with these emission reduction facilities, there is not much difference between coal-fired power generation and natural gas fired power generation. In fact, the only real difference is in CO_2 emissions. Currently, ultra-low emission standards are being extended to cover steel and cement factories.

Starting in 2010, as part of the effort to promote clean coal technologies, ultra-clean standards to coal-fired power plants and large boilers were applied, and a model to develop a coal based chemical industry was developed quickly.

However, in line with the shifting of the economy and more control on air pollution, in recent years, traditional coal and coal chemical industries in China have suffered from overcapacity. Although the development of new coal chemical industries is receiving increasing attention, the constraints of new environmental laws and carbon emission reduction targets continue to increase. Consequently, it is necessary to judge the developmental scale trend of the industries and to provide guidance to businesses and governments. Based on research on coal and coal chemical industries, the following factors are affecting industrial development market and enterprise reform, policy, technology and industrial structure adjustments.

The projected trends in the coal and coal chemical industries in China are based on the IPAC model. The results show that the Shanxi coal industry will have to emerge from a difficult period of industrial development, and that the development of the coal chemical industry in China will greatly depend on the price ratio between crude oil and coal. Ultimately, based on this research, a number of suggestions pertaining to the sustainable development of the two industries in terms of circular economies, technical breakthroughs and policymaking are provided.

4.2 Coal-based chemical industry

The coal chemical industry is divided into the traditional coal-based chemical and new coal-based chemical industries. The traditional coal-based chemical industries include, for example, coal-to-synthetic ammonia, coal-to-methanol and calcium carbide and coke, Calcium carbide and coke production are not involved in the subsequent processing of chemical industrial products. Thus, they are not considered in this research. The new coal-based chemical industries mainly include coal-to-gas, coal-to-liquid and coal-to-olefin.

In this current phase of rapid development of the new coal chemical industry, it is important to judge the developmental prospects for the coal and coal-based chemical industries. By creating a driving force model and applying it to the coal and coal-based chemical industries, the research not only can reproduce industrial historic development curves but also predict future trends.

By 2021, in China, capacity for coal-to-gas was 5.1BCM. coal-to-oil 9.06 million tons, coal-to-alkene 16.72 million ton and coal-to- ethylene glycol 5.97million tons. Total production output was 26.47 million tons, and 93.8 million tons coal in the production process..

By 2020, there were approximately 520 million tonnes of CO_2 emissions from coal-based chemical industries, and approximately 50 per cent of the CO_2 emission were high concentration CO_2, which could be captured at a cost of approximately RMB100/ton CO_2. This presents a great opportunity to use CO_2 with green hydrogen from renewable energy or nuclear energy.

V. CLEAN COAL TECHNOLOGIES

5.1 Coal technology development

Coal is and will remain the world's most abundant and widely distributed fossil fuel. Burning coal, however, can pollute and it produces CO_2. Clean coal technologies address this problem. The widespread deployment of pollution-control equipment to reduce SO_2, NOx and dust emissions from industry is an example of initiatives that have brought cleaner air to many countries. Since the 1970s, various policy and regulatory measures have created a growing commercial market for these clean coal technologies, resulting in declining costs and improved performance. More recently, the need to tackle rising CO_2 emissions to address climate change means that clean coal technologies now extend to include those for CO_2 capture and storage (CCS). A report from the IEA Coal Industry Advisory Board (CIAB) offers recommendations on how to accelerate the development and deployment of this important group of new technologies and to grasp their very significant potential to reduce emissions from coal use. It stresses the urgent need to make progress with demonstration projects and prove the potential of CCS through government-industry partnerships. The commercialization of CCS depends on a clear legal and regulatory framework, public acceptance and market-based financial incentives. For the latter, the IEA Coal Industry Advisory Board favours cap-and-trade systems, price supports and mandatory feed-in tariffs, as well as inclusion of CCS in the Clean Development Mechanism of the Kyoto Protocol to create demand in developing economies where coal use is growing the most rapidly.

Efficiency improvements at existing power plants is an important option for clean coal technologies. The World Coal Institute has noted the scope for efficiency improvements at existing power plants. For, example, achieving thermal efficiencies of up to 40 per cent could reduce CO_2 emissions by as much as 22 per cent, especially in non-Organisation and Economic Co-operation and Development (OECD) countries. This potential has been validated by the improvements achieved and projected in European Union countries. In developing countries, funding for such improvements, which should entail equipment upgrading and the systematic performance monitoring and diagnostic testing of boilers, turbines, condensers and auxiliary equipment, could come from a combination of development aid, export credits and electricity revenues. The global potential to reduce CO_2 emissions through efficiency improvements at existing power plants is the subject of a forthcoming IEA report for the Group of Eight (G8) countries. According to CIAB, because of the complexity of determining power plant efficiency, for comparisons to be valid, they must account for local conditions and fuel quality

Advanced technologies research and development in support of supercritical and ultra-supercritical technologies has allowed their deployment for new construction such that they are now considered mainstream for power generation. There is a growing base of high-efficiency supercritical coal-fired units in operation. The supercritical status for hard coal plants is defined as achieving outlet steam temperatures of 540-566°C (1 000-1 050°F) and a pressure of 250 bar (3 600 psi). Ultra-supercritical units are defined as those with outlet steam temperatures above 590°C (1 100°F) and pressures above 250 bar. Higher operating temperatures, of up to 700°C (1 300°F), should make it possible to achieve an even higher level of efficiency.

5.2 Near-zero emission technologies

Near-zero emission technologies until the mid-1990s, before global climate change gained a high profile, were aimed primarily at the first three tiers of technologies. Subsequent to the signing of the Kyoto Protocol in 1997, attention shifted from controlling emissions of particulates, sulphur dioxide, smog precursors and mercury, to efficiency and CO_2 capture and storage. Although many CCT projects – especially in developing countries – continue to target conventional pollutant emissions, the focus of CCT development in OECD countries has turned to “near-zero” emission technologies intended to decarbonize coal combustion. The research, development and deployment efforts for these systems are being implemented, with some governments, multilateral agencies and industrial entities taking steps to move their focus away from conventional pollutant emissions and economic performance to focus on meeting greenhouse gas emission reduction targets.

VI. ENERGY TRANSITION IN THE 30-60 TARGETS

6.1 General pictures

To meet the temperature rise target of the Paris Agreement, a deep reduction of CO_2 emissions must be achieved in China and the energy as well as social and economic development pathway has to be transformed (Jiang and others, 2021). The 30-60 targets are consistent with the Paris Agreement targets. The development pathway with carbon neutrality emphasizes the paralleling abilities to address the impact of climate change and to coordinate with other social development targets while implementing the emission reduction pathway.

The strict carbon budget constraints under the temperature warming targets of 2°Cor 1.5°C mean that the global remaining carbon emission budget will be exhausted soon (IPCC, 2022).

According to the latest global CO_2 emission data, CO_2 emission from energy combustion and industrial processes was 38.0 $GtCO_2$ in 2020. Hence, if global emissions remain at the level of 2020, the remaining global carbon budget will only support emissions for less than 30 years under the temperature warming target of 2°C If the target is 1.5°C, the remaining time will be approximately10 years. The following should be emphasized: Although the approximate linear relationship exists between temperature warming and cumulative emission, there is large uncertainty in terms of its proportion parameters. The difference between the upper and lower limits may be more than twice.

Only a few domestic studies have the same carbon neutrality targets as the ones in China (Jiang and others, 2018a). Scenarios for carbon neutrality before 2060 share some similarities: the proportion of renewable energy in primary energy increases significantly. By 2050, this proportion will be 43-81 per cent. Nuclear power will increase in all the scenarios, but the extent of the increase differs greatly. The nuclear power installed capacity will be 140-5610GW in 2050. In some scenarios, warming is limited to 1.5°C and the nuclear power installed capacity will be higher than 510GW in 2050, accounting for 30 per cent of the total power generation (Jiang and others, 2018b). Under a scenario developed by the Energy Research Institute, National Development and Reform Commission in which there is a high proportion of renewable energy, in 2050, renewables will account for more than 70 per cent of the overall primary energy, while the nuclear power will only be 1750GW.

To achieve carbon neutrality and a peak in CO_2 emissions, a strong energy transition is required. Net-zero emissions from energy systems around 2050 will provide support for carbon neutrality before 2060. Main approaches for the energy transition are as follows: to improve energy efficiency; to reduce the need for energy services through the energy transition and sustainable consumption; and to raise the end-use electrification rate in all sectors and decarbonization of the power system.

Too realize the 30-60 targets, the period from 2020 to 2030 is crucial. The transition requires an early start point; the fourteenth Five Year Plan period is the starting point for the transition. It is important to develop low-carbon energy and begin to change the domination of fossil energy and promote a low-carbon mode of traditional energy and the industrialization of low-carbon energy; these efforts aim to make the fossil energy consumption reach its peak before 2030. It is necessary to control the total carbon emissions and promote the low-carbon transformation of the energy system and industrial structure. A business model for large-scale promotion of non-fossil energy is becoming more and more practical. It is also essential to reduce the cost of non-fossil energy through marketization, build a power grid system suitable for large-scale renewable energy access and promote the consumption and supply of green electricity. Another aspect to consider is the promotion of energy conservation, which, for different sectors, will reach global leading levels and promote the popularization of advanced energy-saving technologies, for example, the promotion of ultra-low energy consumption buildings and the implementation of an energy consumption standard for buildings. Finally, greater international energy cooperation is required to lay the foundation for the transformation of the energy import and export mode Zhang and others, 2022; Dahe, 2021; Jiang, 2022).

From 2030 to 2050, energy technology innovation, industrial innovation and business model innovation need to be accelerated to increase the proportion of non-fossil energy significantly. Low-carbon energy will dominate the energy consumption. The following are efforts required to lay the foundation for building a climate-friendly energy system. First, it is necessary to decouple economic development from fossil energy consumption. New energy consumption needs will be basically met by non-fossil energy. Second, build infrastructure network for large-scale non-fossil energy development. The electricity from fossil energy will be substituted on an enormous scale and the use of low-carbon energy will increase significantly. Electricity from non-fossil energy will account for more than 680 per cent and more than 860 per cent of installed capacity and power generation capacity, respectively. The carbon emission factor per unit power generation will decline significantly. Third, build an advanced energy interconnection system; promote the construction of infrastructure, such as a smart grid, a smart gas network, a smart heat network, smart transportation and smart buildings; strengthen the integration and interaction of multi-networks and based on information technology, also enhance smart grid technology and energy storage technology; build a cross-region power system that is flexible that can interact with other systems and is compatible The fourth point is about full electrification in the end use of terminal sectors and the popularization of energy-saving technology.

6.2 Energy transition by Integrated Energy and Environment Policy Assessment model

Energy supply plays the most important role in the drive to achieve carbon neutrality. Recent IPCC reports clearly presents that a rapid transition in the energy system is occurring. By 2050, renewable energy and nuclear power will dominate energy supply (Jiang and others, 2021; Xiao and Jiang, 2018). Figure 7 shows the primary energy demand in China based on the IPAC model results. The energy industry will shift largely to renewable energy and nuclear. Figure 8 depicts power generation in the carbon neutrality scenarios. Both figures indicate that the energy sector transition is significant; they present one part of the economic transition.

Figure 7. Primary energy demand in China, 1.5 scenario

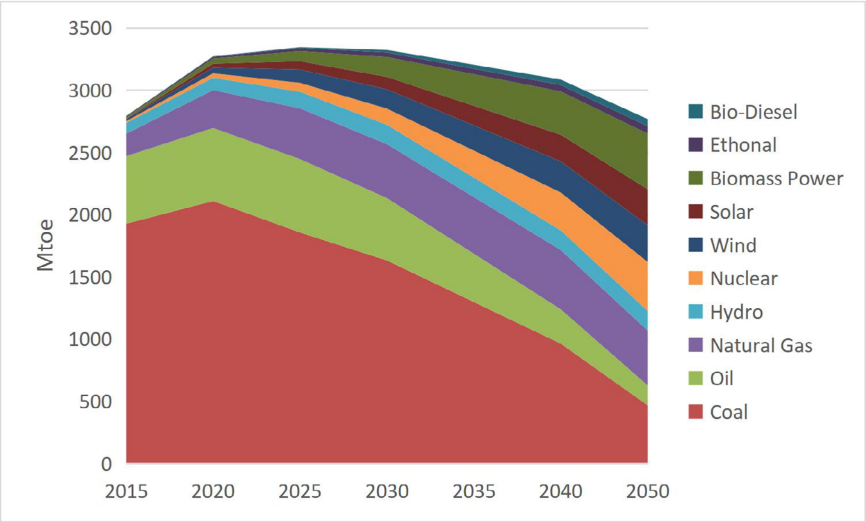
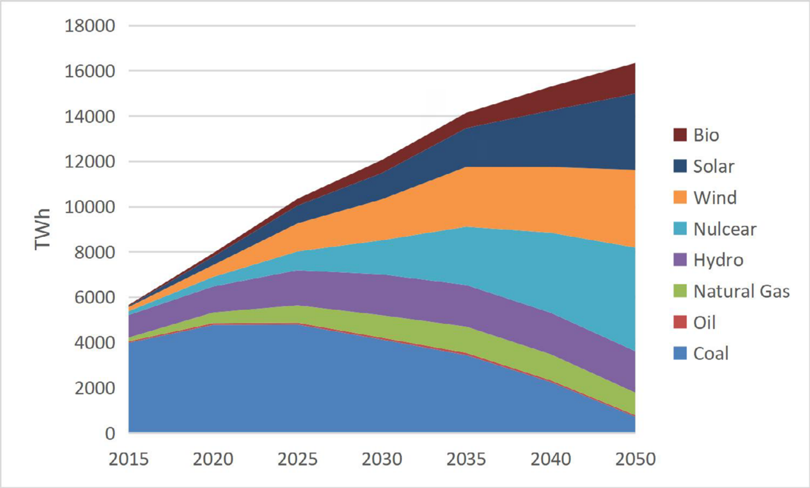


Figure 8. Power generation scenario for China, 1.5 scenario



Clear reduction targets require a response from industries and consumers. Policies targeting emissions reductions could change the production structure. The new industry process includes hydrogen as a feedstock and reduction materials to make steel and chemical products; new technologies include an advanced battery for vehicles and power storage and advanced nuclear power generation, among others; new materials could replace high-emission products, such as plastic, with renewable materials; new consumption behaviours, including carbon labelling and carbon footprints can change the manufacture industry significantly; new energy use pattern to be zero emission energy supply, or even negative emission energy supply. To achieve a reduction in greenhouse gas emissions, the whole economic system has to make the transition to match the requirements for deep cuts in greenhouse gas emissions.

The power generation sector plays a key role in the carbon neutrality scenario. Basically, emit zero greenhouse gas emissions or negative emissions by 2050, are required from power generation and a greater amount electricity use must be pushed to the end-use sector.

Figure 9 presents the installed capacity of the power generation sector in China. Due to greater electricity use in the end use-sector, power generation is expected to increase to be more than 14000TWh by 2050, with per capita 10320kWh.

Among the power generation sources, renewable energy and nuclear is expected generate 80 per cent of total power generation in 2050, Wind power, 21 per cent, solar, 16.6 per cent, hydro, 14 per cent, biomass, 7.6 per cent, nuclear power, 28 per cent,, while the corresponding percentages would be 3.3 per cent, 0.7 per cent, 17.7 per cent, 0.3 per cent and 3 per cent in 2015. Coal-fired power and natural gas-fired power are expected to account for 5.3 per cent and 7.1 per cent of energy generation in 2050, as compared to 71 per cent and 3 per cent in 2015, respectively. This is a significant transition in 35 years. By considering that the life span for these fossil fuel-fired power plants normally does not exceed 35 years, for this transition to occur, the decision to proceed must be made now.

From figure 9, it can be observed that installed power capacity for wind is expected to increase from 129GW in 2015 to 1634GW by 2050, solar from 43GW to 3060GW, hydro from 319GW to 573GW, biomass power from 11GW to 301GW and, nuclear from 26GW to 610GW. The average increase in power capacity from 2015 to 2050 is expected to be 43GW for wind power, 86GW for solar power, 7.2GW for hydro, 8.3GW for biomass power, and 16.7GW for nuclear power, while coal-fired power needs to be reduced by 20GW per year.

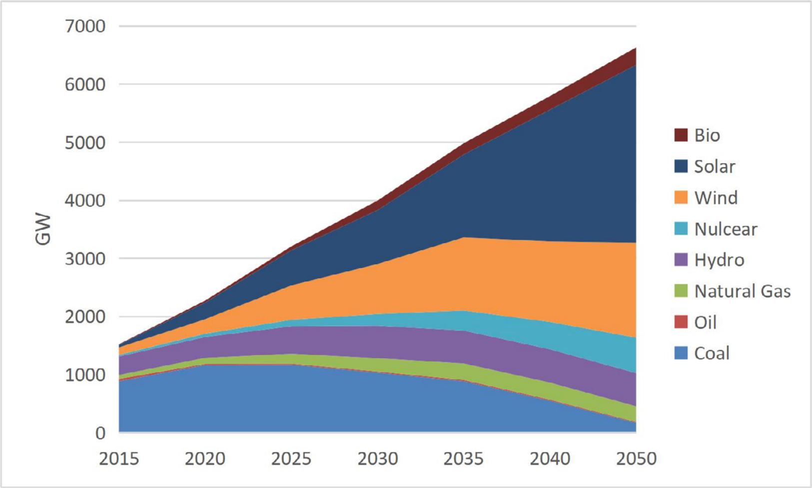
This means that the power generation sector will be a mixed power supply system, not dominated by single type of power generation, unlike the current situation in which coal-fired power generation comprises 71 per cent of total power generation.

Fossil fuel generation power will need to complemented by CCS in order for emissions to be as low as possible. By 2050, 100 per cent of coal-fired power and natural gas-fired power will be equipped with CCS.

Bioenergy with carbon capture and storage (BECCS) is a crucial option for the low emission scenario in the power generation sector. By 2050, installed capacity for biomass will be 250GW, and equipped with CCS. Biomass for power generation will mainly come from firewood from planted trees. Total biomass demand will be 420Mtce, with power generation efficiency of 32 per cent while using with CCS.

Altogether, CO_2 emissions from power generation will be -414 million tonnes in 2050.

Figure 9. Installed capacity for power generation in China



VII. FUTURE OF CLEAN COAL DEVELOPMENT

The future of coal in the energy transition depends on the carbon neutrality target and the development of renewable energy and nuclear energy. In the short term, coal will remain a component that supports energy security. Based on the IPAC model results, coal use could peak quickly but with some uncertainty whether coal would replace some of the natural gas demand. In 2022, natural gas demand decreased because of high prices and increased use of coal .Due to the ongoing discussion on energy security in 2022, many countries, including China, put energy security as a top priority. However, amid progress towards achieving carbon neutrality targets, zero-carbon energy, including renewable energy and nuclear energy are being developed rapidly in China, and the future of fossil energy depends on the growth of these zero-carbon energies. Approximately 200 GW solar PV and wind power were installed in 2022, which is very surprising growth. In the meantime, the rapid development of nuclear power is the current trend; construction of 10 units with capacity 12GW began in 2022. With the expected rapid development of solar PV, wind and nuclear power, fossil fuel usage may peak sooner than expected. Accordingly, the future of coal use is much more dependent on the competition between coal and natural gas.

Transitioning to consuming coal with the application of CCS is difficult due the costs involved compared with other energies, such as solar PV, wind and nuclear. However, there is still need for carbon to produce petrochemical products; one option is to use coal or natural gas and oil only for feedstock.

In general, use of clean coal technologies are likely to increase. To deal with growing health problems associated with nitrogen oxides (NOx), SOx and particulate matter emissions, leading Chinese coal-fired power companies invested extensively from 2014 to 2019 to retrofit their domestic fleet with new pollution abatement equipment. As this sector is characterized by high debt levels and very thin margins, this was a major capital expenditure burden that the companies hope to be able to recover through longer asset lives and improved dispatch—neither of which are a sure thing.

Basically, coal is dirty and any effort to make it "clean" raises costs and reduces operational efficiency. Unfortunately, it also has lower energy value. The Institute for Energy Economics and Financial Analysis estimates that a coal-power plant would have to burn 26 per cent more "Envirocoal" to generate roughly the same amount of power that can be produced using domestically sourced Shanxi coal before considering the added handling, storage, or transport costs for increased coal requirements.

The economics of coal is hard to figure out. It reinforces the case for accelerated decommissioning of older and subscale coal units. It also tips the planning balance in the direction of investments that can accelerate the construction of grids in China to increase the dispatch of renewables. A grid that can integrate clean deflationary renewables provides a hedge against coal price volatility and reduces the need to pass pollution remediation costs on to price-sensitive consumers.

There is one final flaw in the "clean" coal narrative of China, which equates to "clean" with pollution and air brushes carbon emissions out of the equation. Investors have seen evidence of this disconnect for years. Leading coal-fired power companies in China are enthusiastic to report to investors about the dramatic improvements they have achieved with their new ultra-low emission coal-fired generating units.

There could, however, be one opportunity for coal use to be clean. That is the case of green hydrogen, which had been developed in China rapidly, and it is expected to cost less than hydrogen from coal and other process before 2030. Low-cost CO_2 from coal- based chemical industry was approximately 260 million tons in 2021, together with green hydrogen, it could significantly reduce CO_2 emission from the coal-based chemical industry, and result in reduced emissions of air pollutants at the same time. Green hydrogen could make the coal-based chemical industry emit less CO_2a and thus, enable it to cut the emissions of air pollutants. This is one option to consider before developing clean coal in the energy transition.

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Thematic Section: Green Transition and National Efforts towards Net-Zero Target

WHAT TO FOCUS ON IN ORDER TO ACCELERATE ACCESS TO MODERN ENERGY SERVICES AND ENERGY USE EFFICIENCY IN BANGLADESH

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How can a rapidly growing country, such as Bangladesh, overcome the barriers to realizing Sustainable Development Goal 7? The present study includes an analysis of the barriers to achieving 24x7 access to modern energy and the required improvements to make energy more efficient to overcome them in Bangladesh. Interpretive structural modeling (ISM) is applied to identify the interactions among the barriers as laid out in context-relevant scientific literature. The Cross-impact matrix multiplication applied to classification (MICMAC) is applied to classify the barriers. The results indicate that the barriers can be addressed through a systematic packaging and prioritization approach.

Keywords: Sustainable Development Goal 7; barrier analysis; interpretive structural modeling, rapidly growing economy, developing country

JEL classification: O13, Q49, Q56

I. INTRODUCTION

Bangladesh, one of the most rapidly growing economies in South Asia, recorded annual gross domestic product (GDP) growth of 7.9 per cent in 2019 (World Bank, 2020). To put into context, in Asia, the Republic of Korea and Singapore recorded a GDP annual growth rate that exceeded 8 per cent from1966 to 1990; China recorded annual GDP growth of 9.8 per between 1978 and 2009; Malaysia recorded annual GDP growth of 7.37 per cent from 1961 to 1997. (Mahmud and Roy, 2020). Bangladesh aspires to achieve developed nation status by 2041. Under the national government initiative entitled "Vision 2021" Bangladesh had set a goal of universal access to energy by 2021 (Bangladesh, Ministry of Planning, 2020) and achieved 96.2 per cent access in 2020 (SDG Cell, 2020). More than 88 per cent of the Bangladeshi households have access to electricity; 82 per cent get it from the grid and 6.1 per cent get it from off-grid sources, but 65 per cent of the households experience more than 14 outages per week. For 47 per cent of the households that can use medium- to high-load appliances, electricity is available for at least 8 hours per day and 3 hours per evening. Only 2.6 per cent has 23 hours of electricity service per day with 4 hours of outages per evening and is capable of using very high-power load appliances (Samad and others, 2019).

Over the past forty years, innovations, policies and implementation of energy efficiency initiatives have been proven to be highly effective across various country contexts. Energy efficiency programmes in many countries and sectors have successfully reduced energy use per unit of economic output and led to net improvements in welfare or emission reductions, or in both of them (Saunders and others, 2021). In many countries and many sectors, however, energy efficiency improvements are possible, but gaps persist due to multiple barriers. Among the Asian countries, China, India and Singapore, were able to keep their energy/GDP ratio at less than one during their rapidly growing economic phase whereas the economies of Bangladesh, Malaysia and the Republic of Korea had been expanding while at the same time increasing their energy use per GDP (Roy and others, 2021). Energy efficiency is a critical component of societies' response to the challenges of climate change, economic development and energy security (IEA, 2013). The existing energy efficiency at various industrial activities vis-à-vis the international benchmark and saving potential in Bangladesh show that there is plenty of room for improvement in many industries in this regard, including, among them, those engaged in textiles and steel. (Hartley-Louis and Islam, 2018).

Sustainable Development Goal 7 (affordable and clean energy) is focused on three areas: renewable energy penetration; modern energy access; and energy efficiency improvement by 2030.[1] For this analysis, a comprehensive list of barriers to the accelerated penetration of renewable energy in Bangladesh was developed and the hierarchy among the various individual barriers was analysed (Mahmud and Roy, 2021). Many researchers have attempted to identify specific barriers to 24/7 modern energy access and energy efficiency improvements in Bangladesh, however, no comprehensive literature covering the country exists. However, it is available in other country contexts (Zhao, Chen and Li, 2019), and can be used to illuminate the interconnections and hierarchy among these barriers to help in formulating policy recommendations (Mahmud and Roy and others, 2021). Specific contributions of this present study are to fill this gap in the literature in the context of Bangladesh through the following:

(a) Identification of a list of barriers through a literature review that have been hindering the improvement of 24/7 modern energy access and overall energy efficiency.

(b) Understanding the hierarchical structure of the barriers to obtain a clear understanding of the various layers of the barriers.

(c) Categorizing the barriers as driving barriers, dependent barriers, independent barriers and autonomous barriers to help in guiding actions for overcoming these barriers systematically.

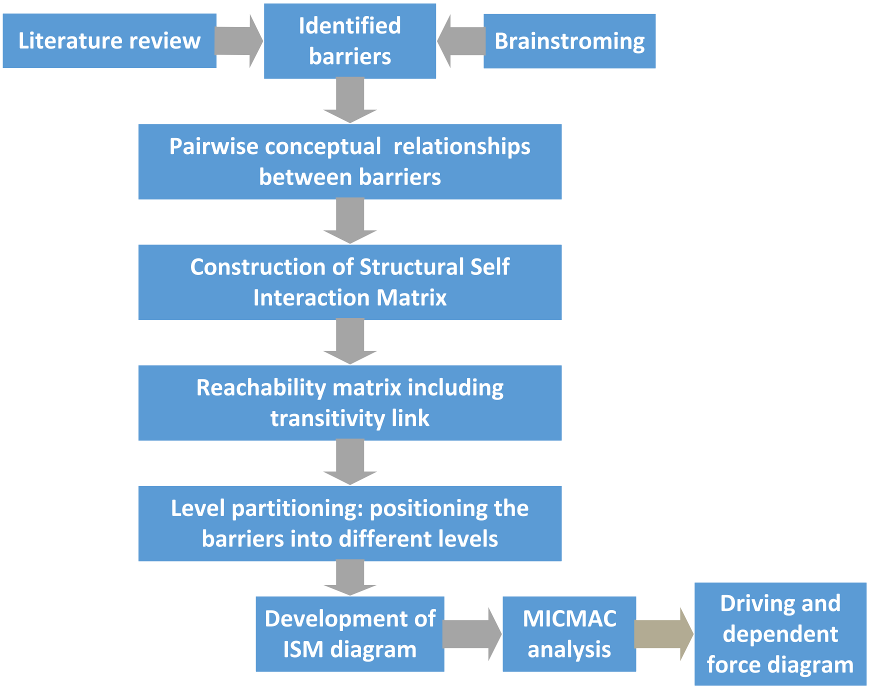
Section 2 gives a description of the methods, materials and research tools used for the analysis the results and discussion are presented in section 3, followed by the conclusions in section 4.

II. METHODS, MATERIALS AND RESEARCH TOOLS

A review of methods in the literature (Mahmud and Roy, 2021) clearly shows the advantage of applying the interpretive structural modeling (ISM) method supplemented by cross-impact matrix multiplication applied to classification (MICMAC) (Yadav and Barve, 2015). How a barrier system works is critical to understand what level of packaging or sequencing needs to adopted overcome them. The steps followed in the ISM process are shown in figure 1.

[1] A/RES/70/1.

Figure 1. Steps followed in interpretive structural modeling



Source: Adapted from Mahmud and Roy (2021)

- Step 1: (a) A comprehensive list of barriers are identified from peer reviewed literature (boxes 1 and 2) and various official reports.
- Step 2: A pairwise conceptual relationship is established between the barriers to develop a structural self-interaction matrix (SSIM).
- Step 3: An initial reachability matrix is formed using SSIM through binary numbers. The final reachability matrix is developed by using the transitivity concept to obtain higher-order links to incorporate the indirect relationships among the barriers using the following relation:
  - Element P related to Q;
  - Q related to R;
  - Implies R is necessarily related to P.

- Step 4: The barriers are positioned into different levels by using the final reachability matrix.
- Step 5: The ISM model is presented using the partitioned level and the relationship given in the reachability matrix.
- Step 6: Cross-impact matrix multiplication applied to classification analysis.
- Step 7: A final figure is developed to show clusters of barriers grouped by their driving power and dependence power.

Data for this study are qualitative in nature. Information about barriers are collected from published peer-reviewed literature on Bangladesh relevant to the objective of this study. From the literature review, an exhaustive list of 14 barriers for "'access to modern energy" ' (listed in box 1) and nine barriers to "energy efficiency improvement" (listed in box 2) are identified. The key applications for which the barriers are assessed are shown in table 1. The allocation of these barriers across eight major dimensions (Mahmud and Roy, 2021) are shown within parenthesis beside each barrier in boxes 1, 2 and 3. It is worth noting that each of the literature reviewed mentions one or the other, or a group of these barriers, but not the comprehensive list as compiled in this study, taking note of overlaps. The authors of this study have decided to identify the links among them without carrying out any further screening, as is sometimes performed by authors (Zhao, Chen and Li, 2019), and then conducted their hierarchy check following the steps mentioned in figure 1 for each of the focus areas.

Table 1. Key energy efficiency and energy access applications in Bangladesh to which the barriers apply

	Energy efficiency for	24/7 Energy access
	Power sector	**Power and energy supply**
1	High efficiency power generation by Combined cycle, tri-generation, multi energy output, among others.	Rural and urban distribution network modernization.
2	Transmission loss reduction, power factor Improvement, theft, leakage, among others.	Reducing peak demand through demand side management
3	Energy management in energy supply plants	Strengthening demand side energy conservation
4		Cross-border power trading

Table 1. *(continued)*

	Energy efficiency for	24/7 Energy access
	Industry sector	
5	Efficient industrial process, waste heat recovery, among others	Replacement of captive power by grid power
6	Use of energy efficient technology for industrial motor, boiler, chiller, textile weaving, among others	Improved coordination among electricity generation, transmission and distribution utilities.
7	encourage advanced technology brick kiln and use of non-fired brick	Making the power grid smart, reliable and resilient
	Transport Sector	
8	Penetration of high efficiency vehicle, hybrid car, electric car	Automatic load management and generation scheduling,
9	Mass transportation system in urban area	Appropriate information disclosure mechanisms
10	Improved and enhanced Inland Water Transport (IWT) system	Development of domestic energy resources including offshore exploration in newly acquired sea area
11		Reliable and affordable grid power
	End-use appliances	
10	Use of energy efficient appliances such as split type, inverter type AC with a high coefficient of performance, and variable speed compressor; refrigeration with inverters and variable speed compressor; efficient fans.	Increased use of clean cooking fuels and efficient cooking stoves.
11	Efficient fluorescent lamp, LED bulbs	
	Policy instruments and behaviour change	
12	Appropriate energy pricing, subsidy reduction, time of use based pricing	Proper pricing
13	Change the lifestyle, such as sleeping with the lights off	Consistent policy implementation
14	Awareness raising programme	

Table 1. *(continued)*

	Energy efficiency for	24/7 Energy access
15	Energy efficiency labelling programme, such as home appliance rating	
16	Energy Management Program involving, for example, an energy audit, benchmarking,, consumption reporting and large consumer dissemination	
	Finance	
17	Engage bank personnel on financing EE projects, stimulating investment in energy efficiency activity	

Source: Prepared from the literature listed in boxes 1 and 2

Box 1. List of barriers relevant to Bangladesh to accelerate access to modern energy

1. Inefficiency, complexity and unbalanced evaluation of the value chain: (institutional barrier 1)

A bureaucratic culture, complex administrative environment and lack of coordination among generation, transmission and distribution results in policy implementation delays. Value chains involving the electrical and energy sectors, as well as the production, distribution, and transmission sectors, are not adequately explored. Another hurdle is the institutions' insufficient negotiating power for cross-border agreements (Haque, Dhakal and Mostafa, 2020; Hossain, 2020; Islam and others, 2014; Moazzem and Ali, 2019; Sarker, 2017; Economist Intelligence Unit, 2018; Zaman and Brudermann, 2018).

2. Corruption (institutional barrier 2)

Such as illicit gas and electricity connections, meter manipulation, utility employee malfeasance, results in increased system loss and a low connection to bill ratio. These, in turn, increase consumer costs and reduce the energy sector's institutional efficiency (Haque, Dhakal and Mostafa, 2020; Hossain, 2020; Islam and others, 2014; Moazzem and Ali, 2019; Sarker, 2017; Economist Intelligence Unit, 2018; Zaman and Brudermann, 2018).

3. Unfavorable political environment (policy and governance barrier 1)

Over an extended period of time in Bangladesh, the unpredictability of the political environment and the blame culture has led to the frequent alteration in policy direction and the execution cost of energy and climate-related policies. Political intervention, impact of local politics delays consistent policy formation or results in the implementation of incorrect policies (ADB, 2009; Amin and others, 2019; Haque, Dhakal and Mostafa, 2020; Hossain, 2020; Islam and others, 2014; Moazzem and Ali, 2019; Sarker, 2017; World Bank, 2019; Zaman and Brudermann, 2018).

4. Top-down policymaking (policy and governance barrier 2)

Policies are developed using a top-down approach through a non-transparent centralized bureaucracy in which the participations of stakeholders are missing (ADB, 2009; Amin and others, 2019; Haque, Dhakal and Mostafa, 2020; Hossain, 2020; Islam and others, 2014; Moazzem and Ali, 2019; Sarker, 2017; World Bank, 2019; Zaman and Brudermann, 2018).

5. Inefficient policies (policy and governance barrier 3)

Absence of a suitable energy policy to discourage the use of fossil fuels in power generation in accordance with the nationally distributed commitment (NDC) to climate objectives. Instead, present regulations promote inefficient captive power generation and high-cost quick rental power plants. The tariff policy lacks competitive tariffs, and energy tariffs are influenced by power tariffs. Furthermore, categorizing tariffs for various users does not account for the impact of this pricing on the corresponding user's economic activity (ADB, 2009; Amin and others, 2019; Haque, Dhakal and Mostafa, 2020; Hossain, 2020; Islam and others, 2014; Moazzem and Ali, 2019; Sarker, 2017; World Bank, 2019; Zaman and Brudermann, 2018).

6. Unreliable grid power supply: (technical barrier 1)

Voltage fluctuations, insufficient capacity and failure to modernize the transmission and distribution system, lack of spinning reserves, inefficient dispatch procedures, and outages during peak hours all contribute to the unreliability of grid electricity. This encourages inefficient captive power generation, while also observing idle generation capacity (ADB, 2009; Amin and others, 2019; Hossain, 2020; Islam and others, 2014; Moazzem and Ali, 2019; Zaman and Brudermann, 2018).

7. Exploration and infrastructural limitation for primary energy supply (technical barrier 2)

Inefficient primary energy exploration leads to a deficit in primary energy supply. Offshore exploration activity is very restricted; exploration is delayed due to sporadic changes in contract choices for gas exploration, despite successful exploration in the same maritime region by neighbouring countries. Coal exploration and production has a relatively limited track record of success. Port capacity is insufficient to fulfil the demand for imports for new power plants (ADB, 2009; Amin and others, 2019; Hossain, 2020; Islam and others, 2014; Moazzem and Ali, 2019; Zaman and Brudermann, 2018).

8. Safety and efficiency (technical barrier 3)

The average efficiency of power plants is lower for low-efficient liquid-based power plants. The sluggish rate of smart prepayment meter installations increases system loss and decreases efficiency. The management safety and disposal of radioactive waste is a major problem associated with nuclear power plants that became operational by 2021 (ADB, 2009; Amin and others, 2019; Hossain, 2020; Islam and others, 2014; Moazzem and Ali, 2019; Zaman and Brudermann, 2018).

9. Inappropriate subsidy allocation and lack of appropriate tariff policy: (economic and financial barrier 1)

The energy subsidy is irrational and trapped in supporting fossil fuel; there is also no long-term tariff strategy for the subsidy. A market-based tariff is missing (ADB, 2009; Amin and others, 2019; Hossain, 2020; Islam and others, 2014; Moazzem and Ali, 2019; World Bank, 2019; Zaman and Brudermann, 2018).

10. Inefficient financing and donor dependent policy (economic and financial barrier 2)

Inadequate financing facility, shortage of long-term capital and dependency on donor agencies hinder progress for reliable excess to modern energy. The policy advice of a donor agency influences the development of energy infrastructure and imbalances the interests of local investors and stakeholders and national policymakers. Additionally, power sector entrepreneurs are more interested in investing in generation rather than transmission and distribution (ADB, 2009; Amin and others, 2019; Hossain, 2020; Islam and others, 2014; Moazzem and Ali, 2019; World Bank, 2019; Zaman and Brudermann, 2018).

11. High cost of grid power and increasing cost of doing business (economic and financial barrier 3)

Expensive liquid fuel, imported liquefied natural gas (LNG), and debt burdens increase the costs for energy-intensive heavy industry (ADB, 2009; Amin and others, 2019; Hossain, 2020; Islam and others, 2014; Moazzem and Ali, 2019; World Bank, 2019; Zaman and Brudermann, 2018).

12. Depleting local gas reserve and fossil dependency: (resource and environmental barriers)

Depleting local gas reserves creates dependency on imported costlier LNG and reduces the supply of primary energy at affordable prices. Limited supply of local gas promotes expensive liquid-based power generation. Fossil fuel dependency raise emissions over time (Hossain, 2020; Moazzem and Ali, 2019; Economist Intelligence Unit, 2018; World Bank, 2019; Zaman and Brudermann, 2018).

13. Limited disclosure and inaccurate information: (informational barrier)

Informational limitation is a significant barrier. The information disclosure mechanism is very limited. Asymmetric reporting and data variations are common for energy-related information. Absence of accurate demand forecasting in relation to economic activity results in idle generation capacity (Hossain, 2020; Zaman and Brudermann, 2018).

14. Limited cooperation and transactional complexity (geopolitical barrier)

Geopolitical complexity creates significant barriers for an energy-importing county, such as Bangladesh. Insufficient regional cooperation, possible tariff fluctuations and existing contractual limitations has impeded cross-border electricity trade, such as importing clean power from Nepal and Bhutan through India (Haque, Dhakal and Mostafa, 2020; Zaman and Brudermann, 2018).

Box 2. List of barriers relevant to Bangladesh in accelerating energy efficiency improvement

1. Shortage of trained manpower with right skills (human capacity barrier)

Shortage of skilled manpower, technical experts, professionally trained personnel in the industry and financial sectors, for conducting research and development and energy audits and effective energy management, among others (Haque, 2014; Hasan and others, 2019b; Islam and others, 2014).

2. Functional limitation (institutional barriers)

Complexity of collaboration among different energy-related public organizations. Complex bureaucratic system makes the situation worse and cannot influence energy management practices. Association of energy service companies with the relevant industries is very limited (Haque, 2014; Hasan and others, 2019b; Islam and others, 2014).

3. Absence of appropriate regulations (policy and governance barrier)

Lack of adequate regulations covering energy efficiency standards, implementation, financing, pricing, energy management practice and energy audits limits efforts to improve energy efficiency in Bangladesh. Moreover, unfavourable policies impose additional taxes and duties on energy-saving technologies and equipment (Haque, 2014; Hasan and others, 2019a, Hasan, 2019a; Hossain, Sarkar and Pargal, 2017; Islam and others, 2014; Hartley-Lewis and Islam, 2018).

4. Limited research and development and demonstration (technical barrier)

Technological uncertainty, very few research and development activities and limited technological demonstration of energy efficiency (Hasan and others, 2019a; Hasan and others, 2019b; Islam and others, 2014).

5. Limited capital and few private investments (economic and financial barrier 1)

Limited access to finance, high initial cost and difficulties in attracting attract private investment for energy efficiency projects are vital barriers (Haque, 2014; Islam and others, 2014).

6. Unfavourable energy price and future uncertainties (economic and financial barrier 2)

The current low price of energy does not encourage energy savings through energy efficiency measures. In addition, the complexity of non-uniform energy pricing, limited financial incentives and unpredictable future energy prices make it more difficult to implement such measures (Hasan and others, 2019a; Hasan and others, 2019b; Hossain, Sarkar and Pargal, 2017; Islam and others, 2014).

7. Investment preference for production over efficiency: (economic and financial barrier 3)

The preference of investors for production over energy efficiency projects is a barrier to promoting energy efficiency (Hasan and others, 2019a; Hossain, Sarkar and Pargal, 2019; Hasan and others, 2019b; Islam and others, 2014).

8. Lack of technological benchmarks, cost-benefit analysis and other relevant information: (informational barriers 1)

Absence of data collection and poor quality of the information about cost-benefits analysis, technological benchmarks, energy expenditure, opportunities regarding energy efficiency are significant barriers that are limiting efforts to improve energy efficiency (Hasan and others, 2019a; Hasan and others, 2019b; Islam and others, 2014).

9. Lack of awareness (informational barrier 2)

End users, financiers and industrialists are not sufficiently aware of the benefits of energy efficient technologies (Haque, 2014; Hasan and others, 2019a; Hasan and others, 2019b; Hossain, Sarker and Pargal, 2017; Islam and others, 2014).

III. RESULTS AND DISCUSSION

3.1 Barriers to modern energy access: interpretive structural modeling analysis

The findings of a step-by-step ISM analysis are presented in sections 3.1.1 to 3.1.5.

3.1.1 SSIM: structural self-interaction matrix.

The structural self-interaction matrix for modern energy access barriers is presented in table 2. ISIM is built using four types of barrier to barrier pairwise relations (1 through 14) using symbols V,A,X and O.

Table 2. Structural self-interaction matrix for modern energy access barriers

Barriers	14	13	12	11	10	9	8	7	6	5	4	3	2
1	V	O	O	V	O	O	O	V	V	O	O	O	A
2	O	O	O	V	O	O	O	O	V	O	O	A	
3	V	O	V	V	O	V	O	O	O	V	O		
4	O	O	O	O	O	V	O	V	V	V			
5	O	A	O	V	V	V	V	V	V				
6	A	A	A	V	A	A	O	A					
7	O	A	V	V	A	A	O						
8	O	O	O	O	O	O							
9	O	A	V	V	V								
10	O	A	O	V									
11	A	O	A										
12	A	O											
13	V												

For example, in the SSIM table 2, cell (1,14) is denoted by V because barrier 1 aids in the elimination of barrier 14; cell (1,2) is denoted by A because barrier 1 aids in the abatement of barrier 2; and cell (2,14) is denoted by O because barrier 2 and 14 are unrelated. As there is no barrier pair that helps to alleviate each other, the cell is indicated by X.

3.1.2 Reachability matrix.

Following the rules in table 3, the SSIM in table 2 is converted into the initial reachability matrix by replacing symbols V, A, X, and O with 0 and 1. Table 4 shows the resulting initial reachability matrix.

Table 3. Rules to follow in deriving reachability matrix from the structural self-interaction matrix

Sl. No.	Symbol of (i, j) Cell in SSIM	Substituted in initial reachability matrix	
		Cell (i, j)	Cell (j, i)
1	V	1	0
2	A	0	1
3	X	1	1
4	O	0	0

Source: Table compiled for the purpose of this study using information available from published literature (Ansari and others, 2013).

Table 4. Initial reachability matrix for modern energy access barriers

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1	0	0	0	0	1	1	0	0	0	1	0	0	1
2	1	1	0	0	0	1	0	0	0	0	1	0	0	0
3	0	1	1	0	1	0	0	0	1	0	1	1	0	1
4	0	0	0	1	1	1	1	0	1	0	0	0	0	0
5	0	0	0	0	1	1	1	1	1	1	1	0	0	0
6	0	0	0	0	0	1	0	0	0	0	1	0	0	0
7	0	0	0	0	0	1	1	0	0	0	1	1	0	0
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0
9	0	0	0	0	0	1	1	0	1	1	1	1	0	0
10	0	0	0	0	0	1	1	0	0	1	1	0	0	0
11	0	0	0	0	0	0	0	0	0	0	1	0	0	0
12	0	0	0	0	0	1	0	0	0	0	1	1	0	0
13	0	0	0	0	1	1	1	0	1	1	0	0	1	1
14	0	0	0	0	0	1	0	0	0	0	1	1	0	1

While the initial reachability matrix is based on direct links, the final reachability matrix incorporates indirect linkages through the use of the transitivity criteria, as indicated in step 3 of the ISM method discussed in section 2. The results show 17 indirect links after conducting first-order transitivity checks, and one additional indirect link after carrying out second- and third-order transitivity checks. For example, if barrier 2 is resolved/reduced, it aids in the mitigation of barrier 1, and barrier 1 aids in the reduction of barrier 14. As a result, overcoming barrier 2 significantly contributes towards the reduction of barrier 14. The resulting final reachability matrix is shown in table 5. In the final reachability matrix, the driving power is determined by counting and adding 1 in each of the barrier's rows, and the dependence is computed by counting and adding 1 in each of the barrier's column.

Table 5. Final reachability matrix for modern energy access barriers

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Driving Power
1	1	0	0	0	0	1	1	0	0	0	1	1	0	1	6
2	1	1	0	0	0	1	1	0	0	0	1	1	0	1	7
3	1	1	1	0	1	1	1	1	1	1	1	1	0	1	12

Table 5. *(continued)*

Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Driving Power
4	0	0	0	1	1	1	1	1	1	1	1	1	0	0	9
5	0	0	0	0	1	1	1	1	1	1	1	1	0	0	8
6	0	0	0	0	0	1	0	0	0	0	1	0	0	0	2
7	0	0	0	0	0	1	1	0	0	0	1	1	0	0	4
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
9	0	0	0	0	0	1	1	0	1	1	1	1	0	0	6
10	0	0	0	0	0	1	1	0	0	1	1	1	0	0	5
11	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
12	0	0	0	0	0	1	0	0	0	0	1	1	0	0	3
13	0	0	0	0	1	1	1	1	1	1	1	1	1	1	10
14	0	0	0	0	0	1	0	0	0	0	1	1	0	1	4
Dependence power	3	2	1	1	4	12	9	5	5	6	13	11	1	5	

3.1.3 Level partitioning.

From the reachability matrix, the reachability set and antecedent set for each of the barriers under consideration can be determined, followed by the intersection of the reachability set and antecedent set for each barrier. Barriers 8 and 11 are positioned in level I in the case of modern energy access barriers because they have the same element in the reachability set and intersection set (table 6). In the second iteration (table 7), these two barriers are omitted. This method is continued until all of the barrier levels are determined; the findings are presented in tables 8 to 12.

Table 6. Level partitioning of modern energy access barriers: stage 1

Elements	Reachability	Antecedent	Intersection	Level
1	1,6,7,11,12,14	1,2,3	1	
2	1,2,6,7,11,12,14	2,3	2	
3	1,2,3,5,6,7,8,9,10,11,12,14	3	3	
4	4,5,6,7,8,9,10,11,12	4	4	
5	5,6,7,8,9,10,11,12	3,4,5,13	5	
6	6,11	1,2,3,4,5,6,7,9,10,12,13,14	6	

Table 6. *(continued)*

Elements	Reachability	Antecedent	Intersection	Level
7	6,7,11,12	1,2,3,4,5,7,9,10,13	7	
8	8	3,4,5,8,13	8	I
9	6,7,9,10,11,12	3,4,5,9,13	9	
10	6,7,10,11,12	3,4,5,9,10,13	10	
11	11	1,2,3,4,5,6,7,9,10,11,12,13,14	11	I
12	6,11,12	1,2,3,4,5,7,9,10,12,13,14	12	
13	5,6,7,8,9,10,11,12,13,14	13	13	
14	6,11,12,14	1,2,3,13,14	14	

Table 7. Level partitioning of energy access barriers: stage 2

Elements	Reachability	Antecedent	Intersection	Level
1	1,6,7,12,14	1,2,3	1	
2	1,2,6,7,12,14	2,3	2	
3	1,2,3,5,6,7,9,10,12,14	3	3	
4	4,5,6,7,9,10,12	4	4	
5	5,6,7,9,10,12	3,4,5,13	5	
6	6	1,2,3,4,5,6,7,9,10,12,13,14	6	II
7	6,7,12	1,2,3,4,5,7,9,10,13	7	
9	6,7,9,10,12	3,4,5,9,13	9	
10	6,7,10,12	3,4,5,9,10,13	10	
12	6,12	1,2,3,4,5,7,9,10,12,13,14	12	
13	5,6,7,9,10,12,13,14	13	13	
14	6,12,14	1,2,3,13,14	14	

Table 8. Level partitioning of modern energy access barriers: stage 3

Elements	Reachability	Antecedent	Intersection	Level
1	1,7,12,14	1,2,3	1	
2	1,2,7,12,14	2,3	2	
3	1,2,3,5,7,9,10,12,14	3	3	
4	4,5,7,9,10,12	4	4	
5	5,7,9,10,12	3,4,5,13	5	
7	7,12	1,2,3,4,5,7,9,10,13	7	
9	7,9,10,12	3,4,5,9,13	9	
10	7,10,12	3,4,5,9,10,13	10	
12	12	1,2,3,4,5,7,9,10,12,13,14	12	III
13	5,7,9,10,12,13,14	13	13	
14	12,14	1,2,3,13,14	14	

Table 9. Level partitioning of modern energy access barriers: stage 4

Elements	Reachability	Antecedent	Intersection	Level
1	1,7,14	1,2,3	1	
2	1,2,7,14	2,3	2	
3	1,2,3,5,7,9,10,14	3	3	
4	4,5,7,9,10	4	4	
5	5,7,9,10	3,4,5,13	5	
7	7	1,2,3,4,5,7,9,10,13	7	IV
9	7,9,10	3,4,5,9,13	9	
10	7,10	3,4,5,9,10,13	10	
13	5,7,9,10,13,14	13	13	
14	14	1,2,3,13,14	14	IV

Table 10. Level partitioning of modern energy access barriers: stage 5

Elements	Reachability	Antecedent	Intersection	Level
1	1	1,2,3	1	V
2	1,2	2,3	2	
3	1,2,3,5,9,10	3	3	
4	4,5,9,10	4	4	
5	5,9,10	3,4,5,13	5	
9	9,10	3,4,5,9,13	9	
10	10	3,4,5,9,10,13	10	V
13	5,9,10,13	13	13	

Table 11. Level partitioning of modern energy access barriers: stage 6

Elements	Reachability	Antecedent	Intersection	Level
2	2	2,3	2	VI
3	2,3,5,9	3	3	
4	4,5,9	4	4	
5	5,9	3,4,5,13	5	
9	9	3,4,5,9,13	9	VI
13	5,9,13	13	13	

Table 12. Level partitioning of modern energy access barriers: stage 7

Elements	Reachability	Antecedent	Intersection	Level
3	3,5	3	3	VIII
4	4,5	4	4	VIII
5	5	3,4,5,13	5	VII
13	5,13	13	13	VIII

The level partitioning technique entails creating eight levels of hierarchy for the 14 barriers. The top ones in hierarchy are barriers 8 and 11 while barriers 3, 4, and

13 are at the bottom. As a bottom-level barrier has the greatest influence on all other barriers in the hierarchy above it, the barriers at level VIII in the analysis (barrier #3 – unfavourable political environment; barrier #4 – top-down policymaking, barrier #13 – limited disclosure and inaccurate information) require the most attention and highest priority in order to overcome all other barriers and accelerate modern energy access in Bangladesh. On the other hand, the top-level barriers (barrier #8 – safety and efficiency; and barrier #11 – high cost of grid power and increasing cost of doing business) do not affect the other barriers positioned in the lower-levels.

3.1.4 Barrier hierarchy.

Hierarchy of the ISM hierarchy model is built by utilizing the level partitioning and final reachability matrix (figure 2), top-level barriers, #8 –safety and efficiency, and #11 – high cost of grid power and increasing cost of doing business, and the bottom level (level VIII) barriers. #3 – unfavourable political environment, #4 – top-down policymaking, and #13 – limited disclosure and inaccurate information. Between the top and bottom levels, there are institutional, geopolitical, informational, resource, and environmental barriers in the ISM hierarchy.

3.1.5 The cross-impact matrix multiplication analysis.

MICMAC analysis is used to classify the barriers into four groups, namely autonomous, independent, linkage and dependent. There is no linkage barrier. The dependent barriers are #6 (unreliable grid power supply: technical barrier 1), #7 (exploration and infrastructural limitation for primary energy supply: technical barrier 2), #11 (high cost of grid power and increasing cost of doing business: economic and finance barrier 3), and #12 (depleting local gas reserve and future greenhouse emission rise: resource and environment barrier), which appear in the upper section of the ISM hierarchy. They are affected by the four independent barriers: #3 (unfavourable political environment: policy and governance barrier 1), #4 (top-down policymaking: policy and governance barrier 2), #5 (Inefficient policy: policy and governance barrier 2), and #13 (limited disclosure and inaccurate information: informational barrier 1). These independent barriers are the most important and are at the bottom of the ISM hierarchy. Barriers #1 (inefficiency, complexity and unbalance evaluation of value chain: institutional barrier 1), #2 (corruption: institutional barrier 2), #8 (safety and efficiency: technical barrier 3), #9 (inappropriate subsidy allocation and lack of appropriate tariff policy: economic and finance barrier 1), #10 (inefficient financing and donor dependent policy: economic and finance barrier 2), #14 (limited cooperation and transactional complexity: geopolitical barrier), are autonomous barriers that have limited interaction with other barriers and are in the middle of the ISM hierarchy. The results from the cross-impact matrix multiplication applied to classification analysis, the distribution of barriers by various typology, for energy access barriers are shown in figure 3.

Figure 2. Interpretive structure modelling framework for modern energy access barriers

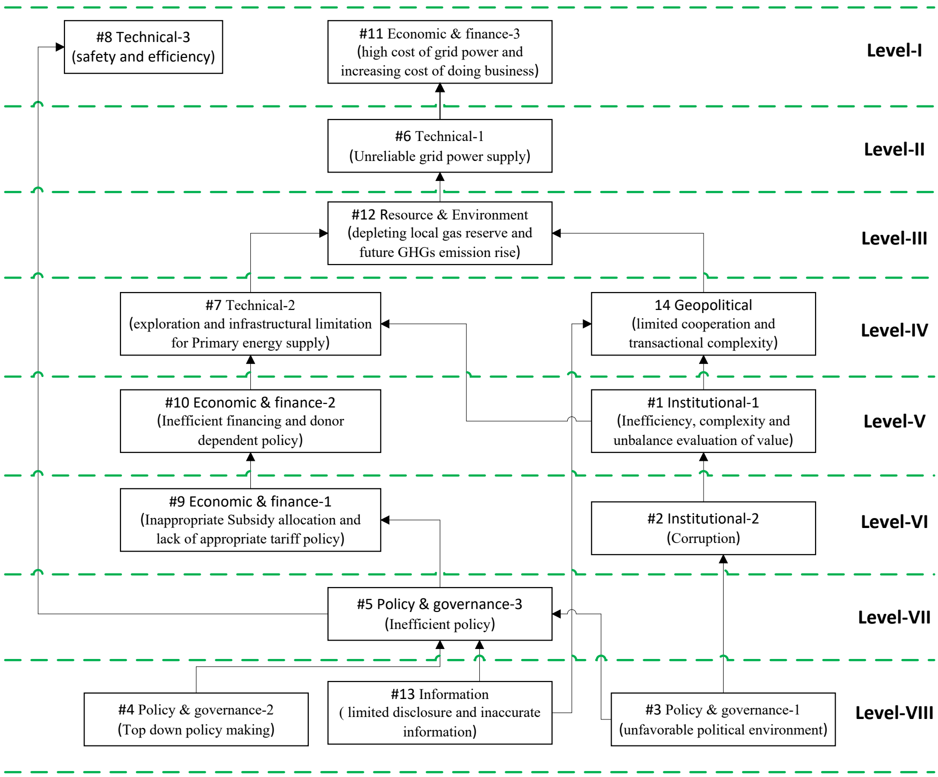
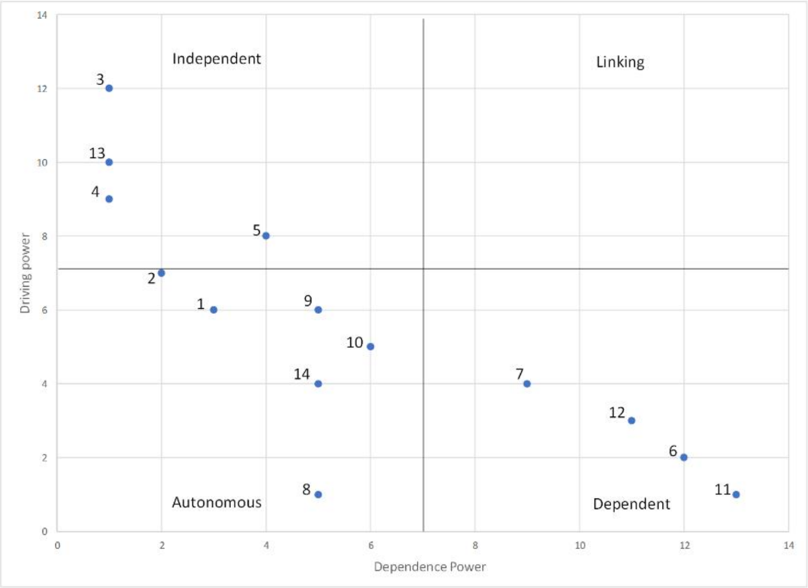


Figure 3. Barriers with varying driving and dependence power from cross-impact matrix multiplication applied to classification analysis



3.2 Interpretive structural modeling analysis for energy efficiency improvement barriers

The analysis and the findings for energy efficiency barriers are illustrated in sections 3.2.1 to

3.2.1 Structural self-interaction matrix.

SSIM for energy efficiency barrier are shown in table 13, in which four symbols V, A, O and X ,are used to represent the pairwise conceptual relationship between the barriers.

Table 13. Structural self-interaction matrix for renewable energy penetration barriers

Barriers	9	8	7	6	5	4	3	2
1	O	V	O	O	O	V	V	V
2	O	A	O	O	V	O	A	
3	O	A	V	V	V	O		

Table 13. *(continued)*

Barriers	9	8	7	6	5	4	3	2
4	O	O	V	O	V			
5	A	A	A	A				
6	O	O	V					
7	A	A						
8	V							

3.2.2 Reachability matrix.

Y replacing the symbols V, A, X and O with 0 and 1, SSIM in table 13 is converted into an initial reachability matrix shown, as shown in table 14.

The indirect linkages are incorporated in the final reachability matrix through transitivity tests using the transitivity criterion, as described in step 3 of the ISM approach in section 2. After completing first- and second-order transitivity tests, five indirect connections among energy efficiency barriers are discovered, which are incorporated into the final reachability matrix, shown in table 15. As an example of an indirect link, barrier 8 affects barrier 3, and barrier 3 influences barrier 6, therefore, barrier 8 indirectly influences barrier 6. As a result, cell (8, 6) which is represented by 0 in the initial reachability matrix (table 14) is substituted by 1 in the final reachability matrix (table 15). From the final reachability matrix, the driving power of a barrier is determined by counting and adding 1 in the corresponding rows, whereas dependency is measured by tallying and adding 1 in the column of the barrier (table 15).

Table 14. Initial reachability matrix for energy efficiency improvement barriers

Barriers	1	2	3	4	5	6	7	8	9
1	1	1	1	1	0	0	0	1	0
2	0	1	0	0	1	0	0	0	0
3	0	1	1	0	1	1	1	0	0
4	0	0	0	1	1	0	1	0	0
5	0	0	0	0	1	0	0	0	0
6	0	0	0	0	1	1	1	0	0
7	0	0	0	0	1	0	1	0	0
8	0	1	1	0	1	0	1	1	1
9	0	0	0	0	1	0	1	0	1

Table 15. Final reachability matrix for energy efficiency improvement barriers

Barriers	1	2	3	4	5	6	7	8	9	Driving power
1	1	1	1	1	1	1	1	1	1	9
2	0	1	0	0	1	0	0	0	0	2
3	0	1	1	0	1	1	1	0	0	5
4	0	0	0	1	1	0	1	0	0	3
5	0	0	0	0	1	0	0	0	0	1
6	0	0	0	0	1	1	1	0	0	3
7	0	0	0	0	1	0	1	0	0	2
8	0	1	1	0	1	1	1	1	1	7
9	0	0	0	0	1	0	1	0	1	3
Dependence power	1	4	3	2	9	4	7	2	3	

3.2.3 Level partitioning gives the relative importance of the barriers. In this analysis, barrier 5 is assessed as level I barriers from the first stage iteration (table 16) and is omitted in the subsequent iterations. In this approach six hierarchy levels of barriers are identified; the findings are presented in tables 17 to 19.

Table 16. Level partitioning of energy efficiency improvement barriers: stage 1

Elements	Reachability	Antecedent	Intersection	Level
1	1,2,3,4,5,6,7,8,9	1	1	
2	2,5	1,2,3,8	2	
3	2,3,5,6,7	1,3,8	3	
4	4,5,7	1,4	4	
5	5	1,2,3,4,5,6,7,8,9	5	I
6	5,6,7	1,3,6,8	6	
7	5,7	1,3,4,6,7,8,9	7	
8	2,3,5,6,7,8,9	1,8	8	
9	5,7,9	1,8,9	9	

Table 17. Level partitioning of energy efficiency improvement barriers: stage 2

Elements	Reachability	Antecedent	Intersection	Level
1	1,2,3,4,6,7,8,9	1	1	
2	2	1,2,3,8	2	II
3	2,3,6,7	1,3,8	3	
4	4,7	1,4	4	
6	6,7	1,3,6,8	6	
7	7	1,3,4,6,7,8,9	7	II
8	2,3,6,7,8,9	1,8	8	
9	7,9	1,8,9	9	

Table 18. Level partitioning of energy efficiency improvement barriers: stage 3

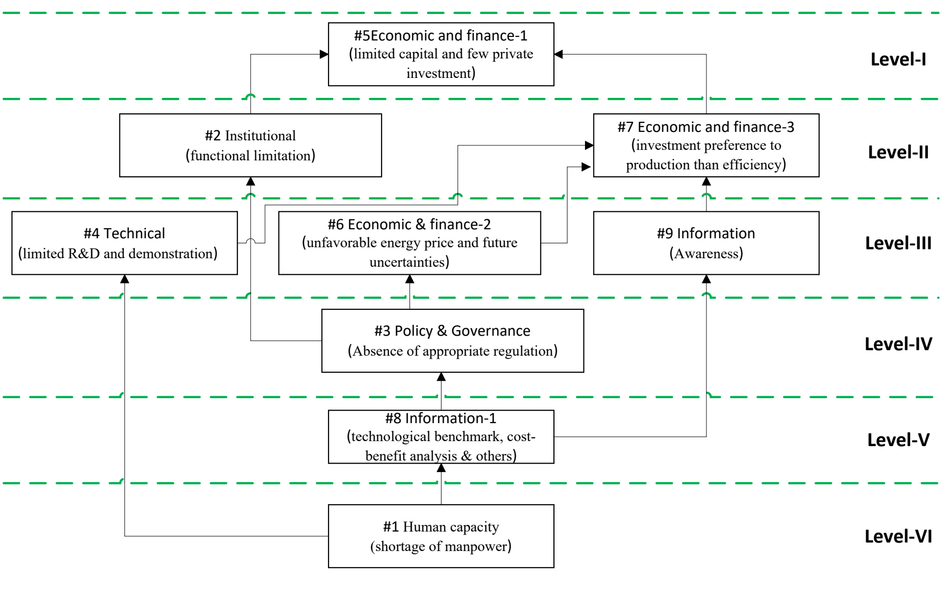
Elements	Reachability	Antecedent	Intersection	Level
1	1,3,4,6,8,9	1	1	
3	3,6	1,3,8	3	
4	4	1,4	4	III
6	6	1,3,6,8	6	III
8	3,6,8,9	1,8	8	
9	9	1,8,9	9	III

Table 19. Level partitioning of Energy Efficiency Improvement Barriers: stage 4

Elements	Reachability	Antecedent	Intersection	Level
1	1,3,8	1	1	VI
3	3	1,3,8	3	IV
8	3,8	1,8	8	V

3.2.4 Barrier hierarchy: The barriers are positioned in the hierarchy diagram according to their hierarchy level estimated in section 3.2.3. The arrows show the direction of interaction between two barriers. Figure 4 depicts the established ISM model for energy efficiency improvement barriers in Bangladesh; #5 (limited capital and few private investments; economic and financial barrier 1) is at the top level (level 1) and #1 (shortage of manpower: human capacity barrier) is at the bottom level (level VI). Between the top and lowest levels, are the technical, policy and governance, informational, institutional, and resource and environment barriers.

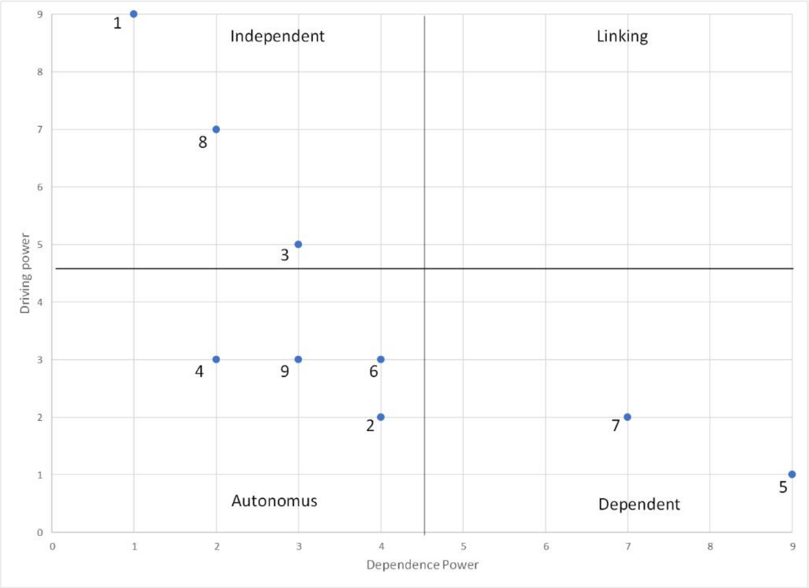
Figure 4. Interpretive structural modelling model framework for energy efficiency barriers



3.2.5 Cross-impact matrix multiplication applied to classification analysis: three independent, four autonomous and two dependent barriers are identified. Barriers #1 (shortage of manpower: human capacity barrier), #3 (absence of appropriate regulation: policy and governance barrier), and #8 (limited technological benchmark, cost-benefit analysis, and others: information 1) are independent barriers set in the lower portion of the ISM hierarchy. These are the most important barriers and have a significant impact on the dependent barriers: #5 (limited capital and few private investments: economic and finance barrier 1) and #7 (investment preference for production over efficiency: economic and finance barrier 3), which are at the upper part of the ISM hierarchy. Barriers #2 (functional limitation: institutional barrier),

#4 (limited research and development and demonstration: technical barrier 2), #6 (unfavourable energy price and future uncertainties: economic and finance barrier 2), and #9 (lack of awareness: information barrier 2), on the other hand, are autonomous barriers that have limited interaction with other barriers and are at the between the top and bottom levels of the ISM hierarchy. Figure 5 depicts the MICMAC results with their corresponding classifications.

Figure 5. Barriers with varying driving and dependence power indicated by the cross-impact matrix multiplication applied to classification analysis



Based on the ISM study on modern energy access barriers (figure 2), the most significant barriers for enhancing modern energy access are top-down policy formulation (#4), adverse political conditions (#3), and limited disclosure and inaccurate information (#13). As a result, the policy may become inefficient and ineffective (# 5). In the MICMAC study, they were identified as driving barriers (figure 3), which shows how the combined influence of these four barriers influence the other barriers, such as inappropriate tariff policy and subsidy allocation (#9), institutional inefficiency (#1), limited financing (#10), and exploration and infrastructure limitations in primary energy supply (#7). The end result is inconsistent grid power supply (#6) and high grid power costs (#11), which limit access to modern energy in Bangladesh.

Based on an ISM analysis, the major impediment to improving energy efficiency in Bangladesh is lack of skilled labour (figure 4). Aside from human capacity limitations (#1), based on the MICMAC analysis (figure 5), two other driving barriers were lack of suitable regulations (#3) and technical benchmark, cost-benefit analysis, and other relevant information limitations (#8). The collective impact of these three driving barriers exacerbates additional barriers, such as insufficient research and development (#4), institutional functional complexity (#2), unfavourable pricing (#6) and limited awareness (#9). The final barrier is lack of financial capital and low private investments (#5) and a bias towards investment in energy supply enhancement reflecting the preference for investing in gross output increase rather than in efficiency enhancement in the production process (#7), which limits efforts to improve overall energy efficiency in Bangladesh.

IV. CONCLUSION

This study makes an important contribution by presenting a comprehensive list of factors that act as barriers to accelerating improvements in energy efficiency and access to modern energy in Bangladesh. An analysis is conducted using an ISM framework and the cross-impact matrix multiplication applied to classification approach to find out how the barriers can be overcome by addressing them independently and/or in clusters/packages. While human capacity-building can be prioritized independently to enhance energy efficiency, to address energy access, lack of information, political interference, top down policy practices need to be considered together to overcome the barriers]. For this study, published literature is used to identify fourteen distinct barriers to modern energy access, and nine distinct barriers for improvement in energy efficiency in the context of Bangladesh. However, the systematic analysis helps in concluding that all fourteen barriers to modern energy access, and nine barriers for improvement in energy efficiency can be considered as interlinked systems in which no single barrier can be ignored. To remove barriers, a big push needs to come from strategic actions through regulations, more implementation of comprehensive energy policies that reflects the government's commitment to address multiple barriers and an incentive design for private sector investment. A whole policy portfolio with a strategic mix and sequencing of interlinked policies are necessary without losing sight of any one of the barriers.

Policy to advance progress in energy efficiency in Bangladesh cannot ignore factors, such as , the shortage of manpower and the need for research and development and energy auditing and energy management,. If long-term policies were to be put in place to regulate energy efficiency standards in various sectors, financing and energy management practices and energy audits would follow, but institutional arrangements could emerge through policy and regulations, as has been experienced in many other countries. Unfavourable conditions, such as additional taxes and duties on energy-saving technologies and equipment and limited information about cost-benefits analysis for energy efficiency improvement programmes and projects, and the development of a technological benchmark for energy efficiency improvement must be addressed immediately. Actions to address these factors would contribute towards tackling other barriers, such as the preference of investors for energy production projects over energy efficiency projects, limited capital and few private investments. Under a systems approach, to address the identified barriers, their interconnections and the nature of mutual interdependence must be considered. Barrier analysis suggests that limited research and development activities and limited technological demonstration of energy efficiency also need appropriate attention from line ministries, such as those responsible for industry, buildings, transport and relevant departments and not only the power and energy ministries. Simultaneously, focus should be placed on low electricity prices, which reduces motivation for change from end users, limited financial incentives and unpredictable energy prices, as they make it more difficult to implement energy efficiency measures. Institutional arrangements need to be in place to generate information and create awareness among end users, financiers and industrialists about the benefits of energy-efficient technologies. Institutional inefficiency, such as complexity of collaboration, poor association with energy service companies and lack of influence in energy management practices also need to be addressed by the government.

To achieve 24/7 access to modern energy services, the most important actions are to develop an accurate database for providing reliable demand estimates and encourage disclosures; create a political atmosphere with minimized intervention and long-term policy certainty; reform the highly centralized non-transparent bureaucratic system of policymaking under which constructive stakeholder's participation is absent; scrap inefficient policies, such as the continuation of power generation from an ad hoc policy favouring high-cost and inefficient quick rental power plants or captive power generation; and communicate a clear policy message to reconcile power sector development and climate change mitigation targets. Sequentially, such actions would help to overcome such barriers, such as limited exploration and infrastructure related to primary energy, inability to offer affordable and reliable grid power due to costlier petroleum and LNG imports, increased use of costly liquid fuel-based generation, and more emission intensive oil-based power generation. Six autonomous barriers also deserve equal attention: (1) institutional inefficiency,. such as delayed policy implementation, lack of coordination between generation, transmission and distribution; (2) the complex administrative environment and institutional corruption, such as illegal supply connection of gas and electricity, and bribes to tamper meters in urban areas; (3) inappropriate tariff policies, such as irrational energy subsidies and inefficient pricing structure and the absence of long-term energy tariff plans and market-based tariffs; (4) donor-dependent financing and policy formulation for the energy sector, which results in investment preferencing power generation over transmission and distribution; (5) the lingering problem caused by the low technical efficiency of the grid connected power plants; and (6) inadequate regional cooperation, such as the preference for bilateral policy rather than regional policy, the absence of open market concepts, geopolitical issues and few successes in cross-border electricity trade.

In summary, the analysis shows that the barriers can be overcome through various targeted policy and regulatory mechanisms. By making room for new institutional arrangements and the strategic role of local experts, stakeholders, such as manufacturers, businesses and users can create a sociopolitical environment that makes it possible to break the current interlinked chain of barriers. Simultaneous supplementary efforts, such as provision of capacity-building, creation of a database for both the demand and supply sides and improvement in coordination across institutions, could also be highly beneficial.

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Thematic Section: Green Transition and National Efforts towards Net-Zero Target

IDENTIFICATION AND PRIORITIZATION OF BARRIERS TO ACCESS INTERNATIONAL CLIMATE FINANCE FOR NEPAL

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This study covers perceived and prioritized barriers to access climate funds, using Nepal as a case for least developed countries. A comprehensive picture of the climate finance flow in Nepal is presented and barriers to access international climate finance are identified. These barriers are prioritized based on their importance and potentials to be removed. Out of the 63 identified barriers, most prominent ones are inadequate ministerial coordination, limited evidence-based research and limited understanding of public–private partnerships. Despite some successes in accessing climate finance, key challenges remain. Among them are low disbursement, inadequate information-base and limited choice of financial instruments.

Keywords: least developed countries, climate change, climate funds

JEL classification: G28, Q01, Q54

I. INTRODUCTION

The Annex I and Annex II Parties to the United Nations Framework Convention on Climate Change (UNFCCC) are obligated by Article 4(3) of the Convention to provide new and additional financial and technical resources to the non-Annex I Parties to support the incremental costs of mitigation and adaptation measures (United Nations, 1992). The pledged amount was $100 billion per year by 2020 (UNFCCC, 2010; United Nations, 2015). Between 2015 and 2030, the capital required for climate mitigation and adaptation projects is estimated to be approximately $16.8 trillion (Plunkett and Sabhlok, 2016) or $630 billion per year (Fankhauser, 2013). IPCC (2018) also suggests that investment in the energy system alone could cost up to $2.4 trillion per year until 2035, clearly indicating a finance gap.

Recent studies have found that these previously published figures are highly underestimated, further increasing the presence of the already significant finance gap (DeFries and others, 2019). UNEP (2016) reported that the cost of climate adaptation alone could reach $280 billion-500 billion per year by 2050, which is four to five times more than previous estimates. Delayed mitigation action is expected to add to these costs, and adaptation costs are also expected to increase with time.

Clearly, available financial sources are not enough and developing countries are struggling to access the available international climate finance (Tipmann, 2013; Nepal, National Planning Commission and others, 2011; Doshi and Garschagen, 2020; Robinson and Dornan, 2016; Huhtala, Bird and Herweijer, 2013; Samuwai, 2018). According to data provided by Aid Atlas, between 2009 and 2018, the top five recipients of development finance targeting climate change as the principal objective in Asia were India ($21.9 billion), Indonesia ($7.21 billion), Turkey ($6.49 billion), Bangladesh ($5.51 billion), and China ($5.12 billion). During the same period, funders committed $1.2 billion to Nepal.

Nepal faces a funding gap (Nepal, Ministry of Finance, 2017; Nepal, National Planning Commission and others, 2011; Mahat and others, 2019). The country's economy is largely climate dependent and vulnerable to climate change. Based on 2013 prices and historical extreme weather events, the direct economic cost (such as, damage to property and infrastructure, excluding welfare and other impacts) for the country was 1.5–2 per cent of gross domestic product (GDP) per year, reaching 5 per cent in extreme climate impact years (IDS-Nepal, Practical Action Consulting and Global Climate Adaption Partnership, 2014). Nepal requires a total funding of $350 million to adapt to climate change alone (Nepal, Ministry of Finance, 2010). By 2030, it will require $2.4 billion to increase its resilience and adapt to climate change (Nepal, Ministry of Population and Environment, 2016). A large chunk of the finance required to meet this need is expected to come from international climate finance.

An assessment made by the Public Financial Management has found that investment needs are projected to increase for hydropower from $390 million per year to 1.1 billion/year by 2030, for irrigation from $1.4 billion per year to $3.8 billion per year by 2030, and for water-induced-disaster activities, from $29 million per year to $ 60 million per year by 2030 (IDS-Nepal, Practical Action Consulting and Global Climate Adaption Partnership, 2014). Between 2014 and 2030, adaptation costs associated with agricultural development and irrigation plans are estimated at $1.7 billion, and the water disaster sector at $209 million.

A host of literature has specifically mentioned the need for research on climate finance or that the lack of studies has impeded decision-making, negotiations, planning, analysis, improvement of instruments, and implementation processes (Nepal, National Planning Commission, and others, 2011; Nepal, 2011; Nepal, Ministry of Environment, 2010; Nepal, Ministry of Population and Environment, 2016; Fankhauser, 2015). IDS-Nepal, Practical Action Consulting and Global Climate Adaption Partnership (2014) suggested that studies on the barriers to climate finance could contribute significantly to the present scenario of the country. Increased knowledge about climate finance could contribute to the implementation of transparent and harmonized approaches in tracking and reporting on climate finance.

In this context, several questions are key for least developed countries, such as Nepal, What is the current state of international climate financing sources, flow, modalities, sectors and projects procured?; What are the barriers for accessing international climate finance and how do they differ across mechanisms?; and Which barriers should be prioritized first for to be removal? This study is intended to answer these questions. First an analysis was conducted to review the structure of international climate finance in Nepal; second, various barriers influencing access to international climate finance were identified and third, identified barriers were prioritized for removal based on their relevance.

II. METHODOLOGY

Various national documents (climate change policy, nationally determined contributions, national action programmes of action, local adaptation plans of action, climate change financing framework, the Climate Public Expenditure and Institutional Review: Nepal, and Climate Change Budget Tag), academic papers, development reports and the Aid Atlas online interactive database were reviewed to assess the climate finance scenario in Nepal over the period 2009–2020. The academic papers and development reports that focused on identifying barriers present in other recipient countries were also systematically reviewed. Stakeholder identification was carried out through extensive research. Open-ended questions were developed and tailored for each stakeholder interviewee based on their experience and expertise. Officials and representatives from different sectors, who met the following list of criteria were interviewed:

- Governmental and non-governmental institutions involved in accessing climate finance
- Institutions that had applied for the nomination of an accredited entity or executing entity
- Developed national reports and planning
- Developed academic or development reports
- Involved in the process of project development
- Involved in project implementation.

Identifying and analysing the structure of international climate finance

The projects listed in the public database, the Aid Management Information System for Nepal (AMIS), provided by the Ministry of Finance (as of October 2020), was reviewed to identify climate change-relevant projects and to retrieve such details as their volume, source, funding modalities, sector funded, mitigation vs. adaptation ratio and disbursement ratio. Projects that met any of the following criteria were considered:

- The name of the project contains the phrase, "climate change"
- In project was tagged in the AMIS database as being "highly relevant", "relevant" or "neutral" under the Climate Change Relevance section.
- The project is in line with the climate change policy under the "national plan section".
- The official project website contains any one of the key words.

The project details on the AMIS website were meticulously inspected, and when information was limited, the official project website was referred to. Projects that were either funded by well-known climate funds and/or had "climate change" specifically mentioned in the project title were then listed and further subdivided based on their source – UNFCCC, non-UNFCCC, bilateral, and other. The project details were then subject to the following analysis:

1. Total finance based on type of fund: The sum of the committed finance for all projects for each subgroup was taken.

2. Sectors funded: The total number of projects for each subgroup and the total number of the different types of sectors were counted. The percentage of the number of projects for a particular sector from the total number of projects was taken.
3. Financial Instrument: The total number of projects and the total number of the different types of financial instruments for each subgroup was counted. The percentage of the number of projects using a particular financial instrument from the total number of projects was calculated.
4. Source of finance: The total finance sourced from each fund/country was taken under each funding mechanism. The total finance sourced from the entire funding mechanism was added. The percentage of the total finance sourced from each/fund country against the total finance sourced from the entire funding mechanism was taken.

Identifying the barriers impeding access to international climate finance

To identify the barriers impeding access to international climate finance, two rounds of primary interviews were conducted. The first round included a questionnaire aimed at retrieving a list of barriers. Part A of the questionnaire was semi-structured. The pre-identified barriers from the comprehensive literature review guided the interviewee in identifying the barriers, and its semi-structured nature made it possible to identify barriers that had not been identified previously. Part B of the questionnaire was structured and the relevant criteria to be used to evaluate the barriers were identified. Stakeholders were asked to respond to in-depth open questions based on their experience with international climate finance to gain deeper insight into the barriers and the overall international climate finance scenario of the country.

Prioritizing the identified barriers based on their relevance

The barriers and criteria obtained in the first round of interviews were grouped, streamlined, and tallied. The scored questionnaire was structured according to the needs of the Analytical Hierarchical Process (AHP) framework. First, all criteria were subjected to a pairwise comparison to calculate their relative importance. Thereafter, the barriers or alternatives were compared pairwise based on each criterion. The data obtained were then subjected to AHP, which is a powerful technique that can be applied to solve complicated and unstructured problems through the organization of the important aspects of a problem into a hierarchical structure. AHP breaks the issue in consideration into three layers: goals; criteria; and alternatives, which makes it possible to quantify the alternatives in relation to the goal to convert qualitative data into quantitative data. Stakeholders make judgements through pairwise comparisons of criteria to eventually create an overall structure consisting of alternatives that are ranked based on their priorities. The pairwise comparisons require a scale of numbers (1 to 9) to indicate the importance of one element over the other with respect to the criterion with which the alternative is being compared with. Each alternative is judged against each criterion. The judgements and their consistency are taken into consideration based on the results are presented. The next steps involved are as follows:

1. Identification of the goal or problem to be solved: The goal is to access international climate finance in Nepal and the problem to be solved is to remove the barriers identified through the study.

2. Identification of criteria and alternatives: The criteria and alternatives were identified in the first round of interviews. Examples of criteria could include "ease of removal" and an alternative could include "lack of institutional capacity".

3. Relative importance of decision criteria: The criteria was prioritized in the second round of interviews. When a criterion is given a higher preference, it was given a higher value. Eventually, the criteria were listed based on their priority, giving them weighted importance.

4. Relative value of the alternatives against the criteria: Each alternative was then weighed against each criterion to give their relative importance a numerical value. The ranking can be represented through a matrix of weights in which element aij is the designated relative weight. The element aji is then designated the reciprocal value, that is (1/aij). The values associated with aij when i=j is 1, is shown in equation 1. Here, the weight ratios of individual factors have been specified in the rows where the values of aij > 0 .

$$A = (aij) = \begin{pmatrix} 1 & w1/w2 & & w1/wn \\ w2/w1 & 1 & w2/wn & \dots \\ : & : & : & : \\ wn/w1 & wn/w2 & \dots & 1 \end{pmatrix}$$

Multiplying matrix A and matrix M, where matrix M is the transpose of the vector of weights,

$$AM = N.M = \lambda max\ M$$

Here,

N = number of rows and columns, W = (W1, W2, …, WN) and λmax is the largest Eigen Factor. If the matrix is consistent, then λmax = N. If inconsistent, $\lambda max \neq N$. To check consistency, equations (3) and (4) must be applied:

$$CI = (\lambda max - N) / (N-1)$$

$$CR = CI/CR$$

Here, CI = Consistency Index, RI = Random Index and CR = Consistency Ratio.

5. Judgements were aggregated and inconsistencies were checked.
6. Result synthesis and final ranking of alternatives.
7. Calculations for the consistency ratio were performed and the geometric mean of the normalized values of all multistakeholder input judgements were taken to obtain the prioritization of barriers. Figure 1. Annual funding for neglected disease product development, 2007–2020

III. RESULTS AND DISCUSSION

3.1 Structure of climate finance for Nepal

As of October 2020, a total of 229 out of 1,029 international aid projects listed in the AMIS database were found to contain at least one keyword relevant to climate change. Out of this, 107 projects were tagged climate change relevant by the database. 75 projects were identified to have a strong climate change aspect. 30 projects were funded by well-known climate finance funds and/or had “climate change” specifically mentioned in the project title were selected for further analysis.

Bilateral finance mechanism

Eight out of the thirty climate projects were sourced from bilateral finance; a majority of the eight projects were sourced by the United States of America. Germany and the United Kingdom of Great Britain and the Northern Ireland, respectively, based on the amount of finance committed (table 1). The total finance amounted to $86,465,928, making bilateral finance the second largest source of finance related to climate change in Nepal.[1]

[1] There is still a lack of certainty whether these bilateral finance arrangement are considered overseas development assistance (ODA)0 or climate finance. The finance indicated does not specify the new and additional amount but it includes the entire finance committed for the projects.

The main funding instruments employed by the United Kingdom and the United States were grant aid and technical assistance. The only form of financial instrument used by Germany was technical assistance to Nepal.

Bilateral donors directed 37.5 per cent of the total finance to the forest sector, followed by 25 per cent equally to alternate energy and environment, science and technology sector in terms of the number of projects. The rest, 12 per cent of the finance was directed to the energy sector. The United States tended to finance forests and the energy and environment, science and technology sectors. Finance extended by Germany was more focused on energy, alternate energy and forests, finance from the United Kingdome was dedicated to alternate energy and the energy and environment, science and technology sectors.

The United Kingdom and the United States financed projects faces no issues of disbursement of finance. However, two of the three completed Germany-funded projects indicated difficulties in disbursing finance, with close to only 50 per cent of the committed amount being disbursed by the end of the project (which was also later confirmed by related stakeholders). On another note, the finance indicated in the AMIS database for the Hariyo Ban I project was $37.6 million (table 3), however, the official United States Agency for International Development (USAID) fact sheet (USAID, 2022) of the project indicated the project amount to be $39 million. This could imply various issues:

1. Faulty data- sharing or uploading to the AMIS database or differences in exchange rates

2. Additional amount was provided for the project than what was indicated initially in which case the database was not updated accordingly.

3. There could also have been overreporting from the donor side. Mahat and others (2019) mentions that overreporting of climate-specific assistance, the value of loans, and climate relevance of fundings, has been an issue and should be resolved.

According to the database, the NEEP III project’s proposed date was December 2017, but other indications were that the project began only in January 2018 (GIZ Agency, 2019). Only 50 per cent of the committed finance was disbursed – an indication of the extensive processes involved in obtaining consent and paperwork from the Government of Nepal.

The total committed finance for the Climate-Smart Development Programme was not reported on the AMIS database. This suggests that the database requires a detailed revision and update.

Table 1. Bilateral-funded climate relevant projects (as of October 2020)

Programme/Projects		Year	Total finance committed (USD)	Total finance disbursed (USD)	Disbursed percentage
United States	Hariyo Ban	2011–2016	37 595 245	37 595 245	100%
	Hariyo Ban II	2016–2021	18 000,000	17 387 165	97%
	International Council of Chemical Associations (CCA)	2012–2017	2 000 000	2 000 000	100%
Germany	Real Estate (Regulation and Development) Act, 2016	2016–2019	5 949 540	4 901 065	82%
	Northeast Energy Efficiency Partnerships	2017–2020	5 686 250	2 759167	49%
	REDD++	2013–2020	4 983 388	2 477 792	50%
United Kingdom	Nepal Climate Change Support Program		4 212 110	4 152090	99%
	Common Security and Defense Policy	2016–2024	8 039 395	8 039 395	32.10% [a]

Source: [a] The figure was sourced from Development tracker (https://devtracker.fcdo.gov.uk/projects/GB-1-204984/summary)

Non-United Nations Framework Convention on Climate Change financial mechanisms in Nepal

With six projects under non-UNFCCC mechanisms, the total committed finance was $130,412,110. Most projects were in the form of pure grant aid, and the rest were either in the form of technical assistance or a combination of grant aid with concessional loan and/or technical assistance. Three projects were financed solely by the trust funds of the World Bank and three projects were financed by the Asian Development Bank (ADB) in cooperation with the Nordic Development Fund, Climate Investment Fund and the World Bank. The top donors for non-UNFCCC mechanisms are difficult to accurately assess as many of the projects were n jointly financed, and despite indicating the specific amounts on the project websites it is still difficult to trace and comprehend the source. The main sector funded by the non-UNFCCC mechanism funds was the energy, science and technology sector, followed by the forests sector and then the alternate energy" sector.

As details regarding the project duration of the listed non-UNFCCC mechanisms were mostly unclear, it was difficult to determine progress regarding the disbursement of finance. One project jointly funded by ADB, the World Bank and the Climate Investment Funds indicated that only 27 per cent of the finance was successfully disbursed, however, there are indications that disbursement could be an issue mainly due to the recipient side.

Table 2. Non-United Nations Framework Convention on Climate Change-funded projects

Programme/Projects		Year	Total finance committed (USD)	Total finance disbursed (USD)	Disbursed percentage
World Bank Trust Funds	Paid Pilot Program f or Climate Resilience	2011	31 000 ,000	23 670 099	76%
	Nepal REDD+ Readiness	-	5 200 000	2 079 382	40%
	Scaling up Renewable Energy Program	2015	7 900 000	1 876 847	24%
ADB + Climate Investment Funds + World Bank	Strategic Performance for Climate Resilience + Paid Pilot Program f or Climate Resilience	2013–2019	31 000 000	8 374 742	27%

Table 2. *(continued)*

Programme/Projects		Year	Total finance committed (USD)	Total finance disbursed (USD)	Disbursed percentage
ADB + Climate Investment Funds	Strategic Performance for Climate Resilience	2015	23 000 000	628 741	3%
ADB + Nordic Development Fund	Building Climate Resilience of Watersheds in Mountain Eco-Regions	Ongoing	28 100 000	2 047 498	7%

United Nations Framework Convention on Climate Change financial mechanisms in Nepal

Ten projects were sourced from funds from UNFCCC mechanisms. Two types of financial instruments were used – technical assistance and grants; 75 per cent used technical assistance as the main mode of financial instrument. The largest donor for multilateral finance was the Green Climate Fund, which provided 85 per cent of the total being financed through two projects, followed by the Global Environment Facility (GEF), which provided 10 per cent of the total multilateral finance through two projects and also co-financed a third project with the Green Climate Fund (GCF) and the United Nations Development Programme (UNDP), which made up 2 per cent of the total. Other funders were the World Food Programme (WFP), the Food and Agriculture Organization of the United Nations (FAO), the United Nations Environment Programme (UNEP) and the United Nations Human Settlements Programme (UNHSP). An equal number of programmes were directed to the agriculture and environment, science and technology sectors by multilateral sources[2], which made up almost 89 per cent of projects. For their projects, GEF and UNDP recorded a high disbursement ratio, while, UNHSP, FAO, and UNEP recorded low disbursement amounts.

[2] This data do not include the GCFF-funded project “Improving Climate Resilience of Vulnerable Communities and Ecosystems in the Gandaki River Basin, Nepal”

Table 3. Projects funded by the United Nations Framework Convention on Climate Change

Programme/Projects		Year	Total finance committed (USD)	Total finance disbursed (USD)	Disbursed percentage
GCF	Building a Resilient Churia Region in Nepal	2020–2027	39 300 000	N/A	N/A
	Improving Climate Resilience of Vulnerable Communities and Ecosystems in the Gandaki River Basin, Nepal	2021– 2028	27 404 139	N/A	N/A
GEF	Small Grants Programme	Completed	5 113 149	5 188 096	101%
	Reducing Vulnerability and Increasing Adaptive Capacity to Respond to Impacts of Climate Change and Variability for Sustainable Livelihoods in Agriculture Sector in Nepal	2013– 2019	31 000 000	8 374 742	27%
UNDP	Integrating Agriculture in National Adaptation Plans (NAP-Ag) programme	-	420 000	354 740	84%
WFP	Nepal Country Strategic Plan 2019–2023 CCA	2019–2023	-	1 223 664	-

Table 3. *(continued)*

Programme/Projects		Year	Total finance committed (USD)	Total finance disbursed (USD)	Disbursed percentage
GEF + GCF + UNDP	GCF Readiness	2015–2016	1 580 929	1 487 762	94%
UNEP	Promoting transformative and climate resilient agriculture(for GCF)	2017–2018	230 907	155 327	67%
FAO	Strengthening agro-ecosystems resilience for climate change adaptation to improve food and nutrition security in Nepal	2019–2020	350 000	208 399	59.54%
UNHSP	Cities and Climate Change	2009–2012	26 000	9 441	36%

Other projects

The total committed finance for projects other than the above-mentioned mechanisms has been $2,458,069. Only one out of six projects have used technical assistance as the financing instrument whereas the rest were in the form of grant aid. The highest funded sector was agriculture. Other sectors, such as energy, forest, environment, science and technology, were funded nearly equally based on the number of projects.

3.2 Comparing the funding mechanisms

More detailed analysis of past climate finance-related projects was hindered by the lack of agreed definitions. Furthermore, the vagueness in the phrase "new and additional" and how climate finance differs from overseas development assistance (ODA) further complicates attempts to analyse projects relevant to climate change. Accordingly, it is crucial to formalize a collective definition to systematically determine the climate finance architecture and ensure effective and efficient tracking and monitoring of projects.

The highest amount of finance was sourced from non-UNFCCC mechanisms, followed by the bilateral mechanisms and then UNFCCC mechanisms. The total amount of finance sourced for 30 projects totalled $295 million.[3] Overall, pure grant aid was the dominant financing instrument used by non-UNFCCC mechanisms, while technical assistance was the predominant financing instrument for bilateral and UNFCCC mechanisms. Stadelmann and Falconer and Stadelmann (2015) explain how technical assistance as a climate finance instrument directly and indirectly mobilizes investments through capacity-building and the creation of a conducive environment. However, on the contrary, this could also indicate that much of the finance in the form of technical assistance is being circulated within the implementing organizations, which are often the development partners or organizations linked with the donors themselves. In such scenarios, the finance does not directly stimulate or contribute to the gross national product (GNP) of the country as often a large chunk of the budget gets spent on administrative costs, such as staff salary, transportation and logistics, and only nominal amounts reach the targeted areas.

Furthermore, disbursement of finance appears to be an issue for a significant number of projects. As this track record can influence donor decisions for future finance, it is important to investigate the challenges presented in Nepal that hinder aid disbursement. Finally, some finance amounts indicated by the AMIS database and the official project factsheets did not match; crucial details, such as the finance amount, were missing, indicating a need for a detailed revision of the database.

3.3 Barriers to access climate finance

There were several barriers to access international climate finance for Nepal. This research has listed 40 relevant barriers through the literature review. The stakeholders, through primary interviews, were asked to validate these barriers for Nepal, and also give additional barriers. Twenty-three new barriers were identified. The consolidated list of 63 barriers is presented in annex I, categorized as behavioural, technical, institutional, policy-related, and governance-related. 12 barriers received an above 70 per cent score (70% of the respondents agreed that they were barriers) and 17 barriers received a score that exceeded 65 per cent.

3.3.1 Taxonomy of top ten barriers

The top ten barriers, based on the frequency of stakeholders' selection, are presented below along with additional insights obtained from the stakeholders.

[3] It should be noted that this amount is not indicative of the climate finance accessed by Nepal, but it was sourced primarily for activities related to climate change.

1) Frequent transfer of government officials hindering the effectiveness of capacity-building and the project formulation process

   Capacity-building is a key process in ensuring efficient access to international climate finance. The Climate Change Financing Framework (CCFF) also stresses the need for training to appraise officials of the complexes involved in climate financing (Nepal, Ministry of Finance, 2017). As the concept of climate change and climate finance is new and dynamic, Government officials often lack adequate knowledge on climate finance and how to access it, raising the need for capacity-building programmes.. However, the high turnover rate of government officials hinders such efforts. By the time the officials are properly equipped to access international climate finance, they are transferred. Despite having many different fund-specific documents to aid the process, the practical knowledge often declines and needs to be built up again when government officials get transferred. Low institutional memory and lack of practice of handing over notes to the new officials also persists.

   Frequent transfers could also affect willingness to initiate activities. Even if a programme is initiated, those who develop it are often not present during its implementation and the new officials are often unclear about the implementation processes.

2) High dependency on international consultants

   Project bankability is not only limited to monetary return on investment for positive net present value, but also it includes socioeconomic metrics, such as community resilience to climate change, gender equality and co-benefits. Skills and capacity to write strong proposals with proper access to quality data are key, which are limited in Nepal. Multilateral funding agencies often have high standards and requirements; consequently, similar to many other countries, Nepal extensively relies on international consultants, particularly in taking projects forward with a presentable business model. The cost of hiring an international consultant is high and as a result, competing for a multilateral fund becomes more challenging and expensive. In parallel, ensuring local relevance in the projects also is an issue as the international experts involved often have a limited understanding of the local context and rely on secondary information, which is again challenging due to the limited availability of quality and relevant data. The Nepal project portfolio of GCF shows that out of eight submitted concept notes only two were approved, both of which were accessed by international accredited entities, as of April 2021.

3) Challenge of translating policies into action

Nepal is considered as a donor driven country. Careful considerations are not made on whether international policies and obligations are fully relevant or can be fully implemented in the country. The tendency to endorse international agreements in haste with less understanding about the implementation process persist. Practices of developing policies in haste without enough evidence as well as replicating other countries' documents make policies even less relevant for the country. As a result, the policies of Nepal for climate action are viewed as being commendable on paper but there is a struggle to execute them

4)Limited types of projects pursued

Out of the GCF four result areas for mitigation – forest and land use, energy generation and access, transport, and building cities, industries and appliances – awareness and project development in Nepal are limited to forest and land use, and to a certain extent energy. To date, Nepal has made very few attempts to access climate finance for transport and infrastructure-related projects, drainage systems to deal with rainfall and flooding, and add the mitigation aspect to development projects. As a result, different windows made available by various funds are not accessed.

As an example, Nepal imports oil for vehicles in the country, in 2018/19, the country imported petroleum products worth 214.48 billion Nepali rupee (NPR) from India, which accounted for 15.2 per cent of the country's total import bill (Khanal, 2019). So, if a project could decrease the country's reliance on petroleum products even if just by 5 per cent through the promotion of electric vehicles or the introduction of electric public buses, Nepal could save NPR 10.72 billion. This saving could then be directed towards other development activities. Such a project would have monetary value, result in lower air pollution, and decrease expenses related to public health. The tourism industry could also co-benefit from it. Some bilateral funds have dedicated funds and are willing to provide finance. However, Nepal has not been able to move further than projects limited to technical assistance, studies, seminars, travel, and capacity-building. Climate discussions are also limited to vulnerable communities, forests, and adaptation.

Blended finance has also not been accessed to make, for example, climate resilient roads. Well designed, constructed, and managed infrastructure is crucial for the economic growth of a country. According to a CNI study, Nepal requires $29.72 billion of finance to maintain an annual GDP growth rate of 5 per cent, $36.93 billion for 7 per cent, and $45.25 billion for 10 per cent between 2019 and 2030 (CNI and IID, 2019). Despite this, line ministries are reluctant in taking initiatives to access additional finance to climate-proof their projects.

5) Limited Coordination among ministries

Climate change and climate finance are cross-cutting issues and an integrated approach is needed to deal with them. However, weak institutional capacity combined with the absence of interagency relationships strain such efforts (Nepal, Ministry of Finance, 2017). In Nepal, limited communication among line ministries is prevalent, and the level of coordination is even more constrained among the subordinate agencies and the departments under the ministries.

One example of this situation: the Ministry of Finance made a call for proposals, a certain accredited entity provided a concept to take forward with a non-technical ministry. The process was already challenging as officials attempted to grasp the concept of adaptation. Despite that, the concept note was developed and submitted, and only at that stage, the Ministry was informed that similar project administered by another agency was being implemented in the targeted region/area. Since the projects would overlap, the Ministry of Finance then directed that project be carried out in other provinces, and the accredited entity had to rework the entire concept note.

As a more diverse set of stakeholders engage in the development processes, the need to place an effective coordination system is even more important. The Climate Change Financing Framework also acknowledges that fragmentation remains a challenge that can be reduced with better coordination among government entities. It, therefore, aims to strengthen information-sharing and coordination through increased government-led dialogue (Nepal, Ministry of Finance, 2017).

6) Silo culture

Ministries, once involved with a project, prefer not to get involved with other line ministries and are often seen to be making independent decisions first and then sharing the information. As indicated by various stakeholders, the Ministry of Finance and the Ministry of Forest and Environment often do not coordinate efforts with other government entities. Similarly, in another instance, stakeholders noted that assistance extended by the Ministry of Agriculture and Livestock Development to the Ministry of Finance would have made processes simpler during the formulation of a project, yet no assistance was provided from the sectoral ministry. It should be noted that this situation is not unique to Nepal; it is prevalent in other countries. The cross-cutting nature of adaptation projects make this barrier even more stark, as it is difficult to bring together different ministries. As shared by a few government officials, certain aspects of the National Adaptation Programme of Action and the climate change budget coding are the responsibility by other ministries and programmes being developed need to be aligned with the Programme of Action. However, during the alignment process the ministries have not reviewed the climate change documents.

7) Level of national ownership

The Global Climate Fund gives substantial importance to country ownership. Activities related to it, both during project formulation and implementation, is expected to be government-driven (GCF, 2016). However, national government ownership is said to be limited in Nepal, the extent of which is often largely influenced by the focal point of a project. While individuals have different paces and approaches, at times, there is a clear lack of ownership in taking things forward. Although not entirely non-existent, a sense of ownership is said to arise only after the successful access of funds. Prior to that, especially during the application process when major efforts are made mainly by the accredited entities to ensure the successful procurement of the funds, the government is reported to be not active. Many stakeholders became more starkly aware about this deficit when they noticed how other governments lobbied internationally for their country's projects. Stakeholders pinned this dearth of ownership to the perception that the government views projects – not as their own, but that of the accredited entities: and also the possibility that as the national designated authority is a non-technical ministry (such as the Ministry of Finance for GCF), and as climate change funding volume is very small compared to other development finance, other sectoral priorities overshadow climate finance.

8) Lack of evidence-based research to inform governments in formulating strategies and action plans

Studies and data on emission accounting, potential mitigation actions, predictions on climate, climate-related damages in monetary value, local impact studies and how climate change will affect the various economic sectors, could provide very worthwhile information to project developers to use to justify to the donors on the need for funding climate-proof activities.

Nepali academia produces many papers and research, but very little research of good quality covering topics that are relevant to project developers has been conducted. Report recycling, lack of evidence-based in-depth research, and lack of accumulated knowledge and centres of excellences are problems. Government officials also need to take note of research and advice from experts. Stakeholders involved in the processes noted that policies in Nepal were often developed based on what the involved officials believe is right rather than on evidence. The Climate Change Financing Framework, however, aims to promote increased use of data for evidence-based decision-making (Nepal, Ministry of Finance, 2017), which indicates that efforts are increasingly being placed on developing of evidence-based policy.

9) Lack of understanding of the potential public-private partnership initiatives

Through a public-private partnership (PPP), the Government can save resources and mobilize the private sector's competencies in a synergistic manner. However, awareness that PPPs can create a collaborative synergy is not recognized in Nepal. GCF uses various instruments to enable the public and private sector to blend varying sources of finance to mobilize climate-friendly investments, It has also successfully directed 33 per cent of its total committed finance to the private sector, as of March 2021 (GCF, 2021). This indicates that receiving finance for private sector development is an option. The issue remains, however, that the role of the private sector investment in climate change has not been recognized and efforts have not been placed to enable such a partnership to flourish. The Federation of Nepalese Chambers of Commerce & Industry (FNCCI) is involved a number of activities related to, for example, cottage industries and sustainable agriculture practices, from which climate benefits could be reaped. A small technological shift can reduce great amounts of emissions. If the private sector were to agree to pursue the low-carbon pathway, this would significantly complement government initiatives, such nationally determined commitments to UNFCCC.

10) The national designated authority as an institution: balancing responsibilities, support and involvement

The GCF guidelines specifies that the national designated authority should spearhead the project formulation and implementation, ensure effective coordination mechanisms are bringing together national actors and stakeholders, and ensure that it has access to flexible support that maintains capacities, which allows it to exercise leadership (GCF, 2021).

In simpler words, GCF demands a country-driven process and expects accredited entities to approach them through the national designated authority. The Ministry of Finance is the national designated authority of Nepal for GCF. However, the Ministry is also the key institution through which all national activities pass through, and is reported to be overloaded with multiple responsibilities. Stakeholders shared experiences in which government officials were said to have requested them to write summaries. The reasoning behind this was that the government officials had claimed they did not have the time to read the lengthy technical proposals. In addition, the national development authority is a non-technical ministry and cannot be expected to have expertise on all areas of covered by the projects. The line ministries are said to be reluctant to provide needed technical assistance to the Ministry of Finance. During 2018/2019, the national development authority was commended for pushing accredited entities, communicating with them, and keeping updated with the developments of the project. However, the same effort no longer occurring; instead, accredited entities are said to be reminding them of the project developments. The standard of support is said to largely fluctuate depending on the entities functioning as the focal point.

Nepal already has a number of international accrediting entities that are working relentlessly to access the funds and, as a result, the country also had several domestic accredited entities and several entities in the process of accreditation. Accordingly, if the climate finance section within the government entity, the International Economic Cooperation Coordination Division, were to be made more productive, more efficient access to international climate finance could be ensured.

3.3.2 Ranking the top ten barriers based on their importance to be removed

The top ten barriers mentioned above were subjected to the AHP analysis to identify the barriers that are most important to bring effective access to international climate finance from the viewpoint of the stakeholders. Through it, seven criteria from the literature were identified, namely administrative feasibility, barrier lifespan, effectiveness, ease of removal, risks associated with the barrier, importance/relevance and cost associated with the removal of the barrier. The top three criteria voted by the stakeholders were (a) administrative feasibility,[4] (b) effectiveness,[5] and (c) cost

[4] Administrative feasibility evaluates whether it is possible to remove a barrier while often also considering how intricately it might be associated with something else of importance that could might hinder the possibility of its removal.

[5] Effectiveness refers to the increased level of accessibility to international climate finance if a particular barrier is removed.

associated with the removal of barriers.[6] These criteria were used to rank the ten barriers mentioned above for being the most relevant to Nepal with the ability to spur effective access to international climate finance should it be removed.

It is important to ensure that the judgements in AHP analysis are consistent. This is presented by the consistency ratio (CR). According to Saaty (1987), a CR < 0.1 indicates that the judgements are consistent. Higher values of a consistency ratio suggest that results are not trustworthy. The results obtained through AHP in this study are consistent as CR is < 0.1. The consistency ratios for each criterion is presented in table 4.

Table 4. Consistency ratio

Criteria	λmax	CI	CR
Administrative feasibility	11.3858	0.1541	0.1020
Cost associated with the barrier	11.0739	0.1199	0.0794
Effectiveness	11.2665	0.1408	0.0933

The results of the AHP, with their normalized scores, are presented in table 5.

Table 5. Ranking of top 10 barriers in Nepal that must be addressed to improve access to international climate finance

Rank	Barriers	Normalized Score
1	Limited coordination	0.151375
2	Inadequate evidence-based research to guide government officials	0.109160
3	Limited understanding of potential PPP initiatives	0.107442
4	Sparse level of national ownership	0.106693
5	Silo culture	0.099297
6	Frequent transfer of government officials	0.085286
7	Challenging to translate policies into action	0.071438
8	National development authority: burdened with varying responsibilities; limited technical assistance provided by line ministries	0.052119

6 The expense included to remove a barrier.

Table 5. *(continued)*

Rank	Barriers	Normalized Score
9	Limited types of projects	0.048603
10	High dependency on international consultants	0.047007

IV. CONCLUSION

Nepal faces a funding gap and various challenges are embedded in the system that do not allow for effective access to international climate finance. Between 2010 and August 2020, Nepal successfully procured finance from various financing mechanisms; 44 per cent of the total finance was sourced from non-UNFCCC financing mechanisms, 29 per cent from bilateral funding mechanisms and 27 per cent from UNFCCC mechanisms. Overall, Nepal was most effective in acquiring finance from non-UNFCCC mechanisms. The United States was the top donor for bilateral finance. GCF, and the World Bank and ADB were the main sources of funding for UNFCCC and non-UNFCCC finance mechanisms, respectively. Furthermore, climate change-related projects indicated facing disbursement issues for a significant number of projects.

While not an issue per se, technical assistance was the dominant financing instrument for bilateral and UNFCCC funding mechanisms. This type of funding is often limited to capacity-building programmes and/or developing a conducive environment for future access; it does not stimulate the economy or make a substantial contribution to it. Despite the capacity-building activities, Nepal is still highly dependent on international consultants to access international climate finance, owing to the issue of the frequent transfer of government officials. For the country’s project portfolio to digress from capacity-building activities, more infrastructure focused projects and efforts to stimulate the economy are needed.

Barriers, such as the absence of policies, strategies and frameworks and lack of basic infrastructure, that were relevant to the context of African nations were not relevant to Nepal. Among the barriers noted to be unique to Nepal are transition to a federal government structure, high dependency on international consultants to develop project proposals, limited interest and coordination from sectoral ministries, limited national ownership and balancing the national development authority’s sectoral responsibilities.. As the country transitions towards a federal structure, government bodies are struggling to gain clarity on their roles and responsibilities. While local and provincial level bodies are still being established, central level bodies with limited dedicated staff are overburdened with responsibilities. The Ministry of Finance also faces challenges with other sectoral responsibilities, such as inadequate coordination, a silo culture and limited national ownership, which makes it difficult to balance responsibilities.

Multilateral donors often have high standards of requirements that developing countries often find difficult to meet. This, in combination with their limited knowledge on climate finance and its various elements, results in high dependency on international consultants. Consequently, the process of developing projects becomes expensive and ensuring local relevance in them becomes a challenge. Furthermore, limited access to quality data and the hassles associated with bureaucracy complicate the efforts related to project development even more. Limited engagement with the private sector and development of only a few types of projects also restricts Nepal from accessing the different climate finance windows.

The most prominent barrier in Nepal to be tackled is inadequate coordination among government ministries. The limited coordination is not only restricted to the absence of the identification and pursuance of potential interactions, but it is also associated with a silo culture wherein a common national agenda is overlooked and institutional agendas are prioritized. Furthermore, inadequate evidence-based research to guide government officials and limited understanding of potential PPP initiatives were also determined as prominent barriers. When policies are formulated without evidence or proper research, they tend to lack context and relevance to the country, eventually making it challenging to translate it into action. As a result, there are many policies and frameworks in place but no resultant effective action.

In summary, the identified barriers indicate that challenges are intricately present within the system. Addressing the top identified barriers could ensure efficient access while also holding the potential of producing co-benefits for sectors outside climate finance through an improved public finance management system, proper formulation of policies and increased and more effective coordination.

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ANNEX

Identified barriers

Institutional barriers	Policy-related barriers
• National development authority: Balancing responsibilities • Sectoral ministries: limitation • Limited dedicated staff • Ministry of Finance vs. Ministry of Forest and Environment: Accreditation Challenges • Nepal Rastra Bank: opening a dollar account • Inadequate institutional and legal frameworks • Lack of transparency during decision-making processes	• Challenging to translate policies into action • Unclear national climate change policies and strategies • International conferences as travel incentives • GCF: frequent change of policies and processes • Implementing agencies do not follow national development strategies and procedures • Lack of academic research to guide governments to build climate change strategies and action plans • Difficulty in planning climate change agendas

Annex. *(continued)*

Technical barriers	Governance-related barriers
• Capacity constraint • High dependency on international consultants • Conceptual understanding and perception on climate change • Challenges associated with developing project proposals • Limited type of projects • Complex procedures involved in disbursing finance • Lack of expertise to bring research to application and implementation • Limited engagement with the private sector • Complexity in assessing the additional cost of adaptation • Lack of capacity to conduct vulnerability assessments • Limited availability of data resulting in difficulty in analysing how to better access funds • Lack of robust fiduciary capacities and self-investigative powers • Lack of tools and techniques for efficient absorption capacity of Climate Finance • Inability to develop bankable projects	• Transition to a federal structure • Frequent transfer of government officials • Level of national ownership • GCF: handling fiduciary risks and acquiring government approval • Bureaucratic system • GCF: challenges in including the gender aspect • Political Instability, Governance Issues, and diplomatic relations • Limited/inadequate coordination between ministries and involved agencies • Inability to develop a conducive environment for climate compatible investment • Lack of strong local finance delivery mechanism • Unclear administration and management of funding at national and sub-national levels • Lack of proper designated roles that lead to institutional coordination challenges

Behavioural barriers	Miscellaneous
• GCF: competition among project developers • International donor regulation vs. national government rules and policies • Silo culture among ministries • Lack of cooperation among involved actors	• Donor interest mismatch • Lengthy decision-making procedures especially during the procurement of goods and services

Annex. *(continued)*

Knowledge and understanding related barriers
• Lack of understanding of potential PPP initiatives • Limited knowledge on the requirements of the funding source • Limited understanding about international climate finance, its associated elements and opportunities • Limited knowledge on structures and mechanisms capable of incentivizing the private sector • Limited knowledge on the applicability of the sources in different contexts and the inability to match finance modality with institutional function and spending objective • Limited knowledge on the effectiveness of policy interventions • Limited knowledge on how to ensure project relevancy at the local level • Inadequate recognition of the important role of private sector • Uncertain about optimal fund management and accountability in terms of local relevance, international harmonization, effectiveness of climate financing

POLICY PAPER

Policy paper

ALIGNING CRITICAL MINERAL DEVELOPMENT IN THE ASIA-PACIFIC REGION WITH THE SUSTAINABLE DEVELOPMENT GOALS

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The low-carbon energy transition will create significant demand for critical minerals. The extraction and processing of these minerals creates challenges for sustainable development, particularly in Asia and the Pacific, a major supplier and consumer of these inputs. Diverse supply chains in the world trade of critical raw materials mean fragmented and sometime insufficient approaches to align the extraction of critical raw materials with the Sustainable Development Goals, and accordingly, international cooperation must increase. This presents opportunities for the United Nations to do more to align the development of critical raw materials with the 2030 Agenda for Sustainable Development.

Keywords: energy transition; critical mineral; Sustainable Development Goals; Asia and the Pacific; United Nations

JEL classification: Q38; Q32; O19; O53

I. INTRODUCTION

Replacing fossil fuels with clean and renewable energy sources by extension increases dependence on mineral resources. The energy sector is transitioning from a fossil-intensive to a more mineral-intensive sector as the process of energy decarbonization deepens (Gielen, 2021). As clean and renewable energy technologies generally require considerably more minerals than their fossil fuel counterparts, minerals have emerged as a key topic in the energy transition (IEA, 2021). Some minerals (especially metallic minerals) are required in large quantities to produce clean energy technologies, in particular, electric vehicles, solar panels, and wind turbines, and battery storage. These minerals are often considered critical (Gielen, 2021). On average, the level of mineral intensity of new power generation has increased by 50 per cent since 2010 on the back of the greater share of renewables (IEA, 2021). The material intensity is expected to continue to increase with further decarbonization (World Bank, 2020). The International Energy Agency (IEA) has estimated that, compared to today, total mineral demand from clean and renewable energy technologies will double by 2040 under the Stated Policies Scenario (STEPS), which assumes the implementation of current and planned policies, and quadruple under the Sustainable Development Scenario (SDS), which assumes that countries meet the Paris Agreement goals [climate stabilization at "well below 2°C global temperature rise"]). To achieve net-zero emissions by 2050, IEA projects that the mineral demand will increase by six times (IEA, 2021). World Bank (2020) and Gielen (2021) present outlooks that reach similar conclusions.

The development of CRMs does not always contribute to sustainable development, as commonly defined by SDGs. In terms of activities, mining for critical minerals has many of the same potential economic, social and environmental consequences as has been seen in fossil fuel extraction and other extractive industries[1]. In terms of revenue, the potential for high and increasing revenue from critical mineral development poses challenges to countries with weak governance and revenue management capabilities. There are many examples in which resource revenue has not always been translated into positive impacts on development and social well-being (Badeeb and others, 2017).

Accordingly, the energy transition is accompanied by challenges with the sustainable development of the critical minerals sectors. While developing CRMs creates significant economic opportunities, their extraction, as with other extractive industry products, may result in significant environmental, social and governance

[1] Extractive industries, in the context of this report, are referred to as the process of extracting raw materials from the earth, including fossil fuels (in particular, coal, gas and oil), minerals (including rare earth minerals, bauxite and gold) and aggregates (such as sand, gravel and clay).

challenges and unintended economic consequences. The development of the critical minerals touches on issues well beyond the extractive industries, including, among them, regional economic development, industrial restructuring and the need to reskill workers. These problems could also put the survival of many species at risk, and pose significant risks to public health, especially in communities in proximity to extractive activities. Addressing these and other challenges is critical if CRM development is aligned with SDGs.

II. CRITICAL MINERAL DEVELOPMENT FROM THE PERSPECTIVE OF ASIA AND THE PACIFIC

The challenges in critical mineral development during the energy transition are significant for the Asia-Pacific region and require urgent action. The countries of this region will play an important role in the future supply of critical minerals, due not only to their resource abundance compared to countries in other regions but also because of the growing demand for CRMs within the region.

The Asia-Pacific region has large reserves of critical mineral resources. Member States of the Economic and Social Commission for Asia and the Pacific (ESCAP) account for approximately one fourth of the world's total reserves of mineral resources. two thirds of the world's iron ore reserves (United States Geological Survey, 2021), 41 per cent of the world's bauxite reserves (The Aluminium Association, 2020), and more than 60 per cent of the world's total reserves of rare earth metals (BP, 2021). Countries in Asia and the Pacific control approximately 30 per cent of the world's reserve of cobalt, copper and lithium, 53 per cent of graphite, 59 per cent of nickel, 75 per cent of the rare earth elements (REEs) and 80 per cent of lead (United States Geological Survey, 2021).

The relative position of ESCAP member States in critical mineral production is even more prominent. As of 2019, the region's share of the world's bauxite production was 63 per cent, lithium production, 66 per cent, graphite production, 70 per cent, nickel and lead production, 74 per cent, and REEs production, 96 per cent (United States Geological Survey, 2021). Several countries in the region are among the top producers of more than one key critical mineral. Taken as a whole, the Asia-Pacific region is the world's largest supplier of cobalt, copper, lithium and bauxite. Many resource-rich Asia-Pacific countries export critical minerals to other countries for processing and, as a result, play an essential role in the world's critical mineral trade and security of supply.

Given the significant development potential, the Asia-Pacific countries will face many of the same challenges in managing the impacts of mining activities and revenue as other resource-rich countries have. These challenges include, but are not necessarily limited to, expanding production, enhancing supply diversity, mitigating social changes and environmental risks, ensuring a just and equitable transition, addressing gender impacts, and developing secure and affordable supply chains. They extend throughout the value chain, from unmitigated emissions during extraction to insufficient use of recycling and circular economy practices. Many countries in the region that have well-developed extractive industries will benefit. Still, some countries will develop a significant extractive industry for the first time, and much more work needs to be done. Understanding the implications, and the impact of the energy transition are prerequisites for the Asia-Pacific region to align the development of its CRM resources with sustainable development.

III. STRATEGIC PRIORITIES FOR ALIGNING CRITICAL MINERAL DEVELOPMENT IN ASIA AND THE PACIFIC WITH THE SUSTAINABLE DEVELOPMENT GOALS

Critical mineral development to meet the increasing demand needs to keep pace with broader system-wide transitions, including increased alignment of finance with economic, environmental, social and governance (E2SG) requirements in the industry, circularity, and digital transformation (Shi and others, 2023). Three main principles should guide future work by the Asia-Pacific countries. First, countries must be sufficiently prepared for the economic impacts of the energy transition on the extractive industries and align the development of critical minerals with SDGs. Second, it is critical that producing countries improve the ESG sustainability of the extractive industries, so that increased demand does not lead to increased environmental degradation and inequality. Third, the future direction for both producing and consuming countries must be towards circularity to ensure long-term environmental and economic sustainability.

To meet the increasing demand for critical minerals in a just, equitable, and sustainable manner in the Asia-Pacific region, four strategic priorities have been identified:

1. Supply security and circular economy.

Providing sufficient amounts of mineral resources at affordable prices is critical to facilitate the energy transition. To ensure that producing countries can sustainably and securely meet rising demand, attention should be devoted to addressing issues, such as commodity market price volatility, supply chain bottlenecks and diversification, mining safety and efficiency, and the potential for increased social and geopolitical tensions.

The only two effective ways to meet rising demand are increased extraction through mining and recycling. Efficient recycling of extractive wastes (metals, ores, coal, oil and gas) is highly desirable (Kalisz and others, 2022). Breaking down the material and reforming it for alternative use (recycling) can reduce the need for extraction.

Reducing overall consumption by avoiding or minimizing use and other circular economy approaches is equally important. Design innovation can eliminate the need for permanent magnets in wind turbines and electric vehicles, for example, and can substantially reduce demand for cobalt in batteries (Gielen, 2021).

Reuse is another important strategy. Many low-carbon technologies, such as batteries, should be reused for other purposes without changing their original components. For example, lithium-ion batteries that are retired from use in electric vehicles could potentially be used in other types of energy storage applications, thus extending their life (World Bank, 2020). Recycling, reusing, reducing and better resource efficiency extend the lifetimes of products, stretch out mineral reserves and thus contribute to the sustainable development of minerals.

2. Better management of resource revenues.

Building the capacity of resource-rich developing countries in resource management and other governance areas will help those countries and the global community as a whole to achieve the energy transition and SDGs.

Accordingly, better resource revenue management is critical for resource-rich Asia-Pacific countries to capitalize on their deposits of critical minerals and for translating economic benefits from the extractive industries, including those for critical minerals, into broader positive socioeconomic and environmental outcomes (Addison and Roe, 2018). In many countries with large critical mineral deposits, mining sector governance is potentially vulnerable to corruption, and policies related to the extractive sector are limited or absent. Good governance has a broad scope, including benefits sharing, effective regulation, anti-corruption, and international cooperation. Governments are responsible for establishing conducive environments that incentivize the private sector and other stakeholders to align future critical mineral extraction and trade with SDGs.

Effective regulatory and governance environments are urgently needed to transform these resources into a source of prosperity for all. Ensuring that mining revenue is an enabler of inclusive economic growth and sustainable development requires efficient and transparent management of it. This includes ensuring that the benefits from the extractions of transition minerals are fairly distributed across stakeholders, in particular among disadvantaged groups and across generations. Revenue should be invested in long-term savings, infrastructure development and economic development efforts that can stabilize and diversify the economy in the communities and regions (Haggerty and others, 2018). Natural resource management policies that include multi-stakeholder and democratic governance can improve resource efficiency and sustainably manage scarce resources (Cartegna, 2021).

3. People-centred sustainable mineral production.

Aligning mineral development with SDGs is some kind of complex system cannot be accomplished by any single actor, such as the government. There are many stakeholders in the nexus of mineral development and SDGs. A shared vision is needed to spur the critical mineral sector's development and realize the sector’s transformative potential in the developing country context. The development of this vision needs to be people-centred and sustainable, and include the involvement of all relevant stakeholders, especially the most vulnerable ones. Stakeholder engagement and participatory approaches are particularly critical for developing long-term strategies and plans, considering the need for transformational change across all sectors (IPCC, 2018; Schaeffer and others, 2019).

Promoting sustainable economic development for mining projects requires diversifying mining communities and economies, meeting the investment requirements and fair sharing of mining revenue with broader stakeholders and future generations. Adding value to critical minerals is crucial for industrializing the economy and achieving economic diversification. Successful case studies (Lebdioui, 2020a; 2020b) highlight that economic reorientation works better when new projects are related to the extractive industries in resource-abundant regions, rather than creating new industries. However, the potential for indirect job creation depends largely on local conditions, such as the existence of a well-trained, diversified workforce and local suppliers of the relevant goods and services to the mining industry (International Resource Panel, 2020).

4. Maintaining environmental integrity

Managing the environmental impacts of mineral development often includes adoption of a life-cycle management approach that covers planning and design, production and consumption. Full life cycle integrated mining planning is necessary if the critical minerals supply chain is to be included as a growth anchor for the sector (Manley, Heller and Davis, 2022). This means going beyond the core element of critical minerals development – the extractive industries – to also consider the sustainable development of regions and communities, including investment in rail, roads, and port infrastructure to deliver products to market, support for worker retraining to stimulate labor mobility and the establishment of an education system that can support economic diversification (Syahrir Wall and Diallo, 2020).

Reducing the extractive industries' carbon footprint requires a well-designed and enforced regulatory framework covering the entire life cycle of mining sites. Some key aspects of such a framework are conducting an environmental impact assessment in the planning phase of a mining site; enforcing minimum performance standards during its operational phase; and restoring the environment and natural landscapes affected by mining activities in its decommissioning phase (United Nations, 2021).

Other relevant efforts, such as the Climate-Smart Mining Initiative of the World Bank, could be adopted to support the responsible extraction and processing of minerals and metals for a clean energy transition and sustainable development. This new initiative of the World Bank aims to minimize the life-cycle social, environmental, and climate footprint of those materials in resource-rich developing countries (World Bank, 2020).

IV. INTERNATIONAL COORDINATION IS REQUIRED

Promoting the sustainable development of critical minerals requires coordination among countries. On the one hand, as supply chains become more global and diverse, policy changes in one country affects other countries and regions. Due to the resource concentration in a few countries, planning regionally and working closely with neighbours become necessary and desirable for CRM development (Manley, Heller and others, 2022). On the other hand, due to increased geopolitical tensions among major countries, there may be decoupling among country groups, which could break the global value chains and create uncertainty within critical mineral markets. While large countries may have options to deal with this, small countries are more likely to be affected, as alternative options for them are limited.

While national governments are the key players, the international community should promote sustainable investments by rewarding supplies from countries and companies that follow sound environmental practices, such as through carbon footprint labelling and other standards and labels (Shi, 2013), formulating regional guidelines for investment and operations, and implementing recycling practices that fully consider environmental and safety costs (World Bank, 2020). To facilitate cross-border supply chains and develop partnerships with a wide range of consumer economies, governments should share geological and other relevant data, and develop business and customs regulations through coordination with neighboring countries (Manley, Heller and Davis, 2022).

The international community should work together to create norms and other arrangements to promote free markets for critical minerals. Free global markets can ensure a sustainable and secure critical mineral supply, and governments should, therefore, support and enable the development of free markets for CRMs. An international agreement to mitigate the impact of supply disruptions and promote sustainable use of scarce mineral resources should be explored (Henckens and others, 2016).

A number of international initiatives have emerged in recent years to promote the development of secure, sustainable and responsible supply chains, including, among them, the Africa Mining Vision, the United Nations Guiding Principles on Business and Human Rights, the Extractive Industry Transparency Initiative, the Dodd-Frank Act, the Global Reporting Initiative, the Model Mining Development Agreement, the Initiative for Responsible Mining Assurance, and the Natural Resource Charter (International Resource Panel, 2020). Many international initiatives, such as the Extractive Industries Transparency Initiative (Marques, 2020), have tried to play a role in safeguarding the sustainable development of the extractive industry. Multilateral efforts also have been explored to ensure a safe and secure supply of critical materials. For example, Geoscience Australia, the Geological Survey of Canada and the United States Geological Survey have created a shared foundation of mineral information by coordinating their critical mineral mapping and research efforts (United State Geological Survey, 2020).

However, many gaps remain. A series of United Nations Environment Programme (UNEP) consultations have identified the following priority areas for global consideration: the material intensity of recovery from the COVID-19 pandemic; cooperation and development of capacity-building platforms; tailings management; harmonization and alignment of governance initiatives; artisanal and small-scale mining; mine waste recycling, reuse and circularity; and national-level governance reform (Franks, Keenan, and Hailu, 2022). Currently, however, no globally agreed upon sustainability framework suitable for the sustainable development of CRMs in the context of the energy transition exists.

From the perspective of international cooperation there is no overarching international governance framework for critical minerals or coordinated policy action, leaving room for enhanced alignment and coordination (IEA, 2021). Lack of coordination across sectors and stakeholders is particularly disadvantageous to communities affected by the extraction of CRMs, which are often not sufficiently represented in the development or management of extractives industry projects, and therefore, do not benefit fully from local development. Lack of coordination may also hinder the process of economic diversification (United Nations, 2021).

V. CONCLUSION AND RECOMMENDATION

Mitigating climate change requires countries to transition away from fossil fuel-dominant energy systems to low-carbon and renewable energy systems. This energy transition will create significant demand for critical minerals including critical raw materials (CRMs) because the technologies that underpin low-carbon energy systems, such as wind, solar photovoltaic and batteries, are more mineral intensive than fossil-fuel-based technologies. These challenges are prominent in the Asia-Pacific region due to their resource advantages. Given the globalized supply chains of CRMs, more international coordination is needed in Asia and the Pacific.

The United Nations is well positioned to support and enable coordination among countries at the global, regional, and even subregional levels. Member States have an appetite for greater international cooperation on mineral governance (Ali and others, 2017). In March 2019 in Nairobi, the fourth session of the United Nations Environment Assembly (UNEA) – the principal global decision-making body on the environment – adopted a resolution on mineral resource governance, the implementation of which involved the organization of subregional, regional and global consultations in obtaining feedback on the governance of extractive industries to understand the political landscape and regional needs (UNEP, 2022).

As the guardian of SDGs, the United Nations is the key global coordinator to achieving SDGs and the Paris Agreement. The United Nations also actively promotes the sustainable development of critical minerals. For example, in May 2021 a high-level global round table was organized from which messages from round tables organized by the five United Nations regional Commission – including ESCAP – were highlighted (United Nations, 2021).

A regional committee with membership comprising all Asia-Pacific countries could become an important policy coordination body for the region. Such a committee could act as a focal point for articulating interests and cross-cutting issues regarding mineral resource sectors, help reconcile differing interests, and facilitate regional policy coordination.

Supportive entities, such as ESCAP, could help promote sustainable critical mineral development by creating and sharing knowledge, assisting in building national strategies and capacity, examining national case studies and coordinating regional efforts, with the overarching goal of promoting the sustainable development of critical minerals in Asia and the Pacific.

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SUBMITTED PAPERS

Submitted papers

HOW SUCCESSFUL WERE THE LEAST DEVELOPED COUNTRIES IN ATTAINING THE MILLENNIUM DEVELOPMENT GOALS? AN ASSESSMENT BASED ON A SYNTHETIC APPROACH

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The present paper used a synthetic approach to create a composite of two indices to measure countries' progress toward attaining global development goals. The technique assesses the performance of least developed countries (LDCs) in achieving the Millennium Development Goals (MDGs). The results indicate that by the end of 2015, progress was uneven across indicators, with Asian countries performing better. The LDCs that performed better based on the assessment, progressed closer towards graduating from the LDC group. The synthetic, analytical approach proposed for this paper can be applied to measure countries' comparative progress towards realizing the Sustainable Development Goals (SDGs).

Keywords: Millennium Development Goals, least developed countries, development; progress assessment

JEL classification: O10/LDCs, O57/Comparative Country Studies, 020/Development Policy, I15/Poverty, I25/Human Development

I. INTRODUCTION

There has been a conscious effort to reflect on lessons learned from the experience to implement the initiative to achieve the Millennium Development Goals (MDGs), the predecessor to the 2030 Agenda for Sustainable Development framework, which included the Sustainable Development Goals (SDGs). The report of the Secretary-General to the General Assembly on the implementation progress stated the following:

> Together, we need to focus on those Goals that are most off-track and on countries that face particular development challenges, including the least developed countries (LDCs), land-locked developing countries (LLDCs), small island developing States (SIDS) and countries affected by or recovering from conflicts or disasters (United Nations, 2013).

The principle of "leaving no one behind" is often conceptualized in individual terms, but it can be equally applied in country or group terms (Gertz and Kharas, 2018). In this spirit, UNCTAD (2018) termed the least developed countries (LDCs), one of the most structurally disadvantaged groups, as the "battleground" for achieving SDGs. Indeed, LDCs, which include several landlocked developing countries (LLDCs), small island developing States (SIDS) and conflict-affected and post-conflict countries and countries vulnerable to climate change and associated shocks, are recognized as being among the most vulnerable country groups (Bhattacharya and Khan, 2017). Accordingly, progress of LDCs should set the benchmark metrics for progress against the commitment to leave no one behind.

For LDCs, the success of the SDG delivery will be informed by efforts intended to realize the MDGs. Scrutiny of the implementation status of the MDGs in LDCs should provide important insights into how and why successor goals and targets were articulated and how they will be realized. This is very important, as the succeeding international development framework, the 2030 Agenda is "universal". It is, therefore, pertinent to understand, based on experience, how the development challenges of countries with special needs, particularly LDCs, will be accommodated within a framework for all.

The obvective of this paper is to fill the gap in contemporary understandings of the experiences of LDC in implementing the MDGs by estimating degrees of success and the pace at which they were achieved. In recent years, several studies (Klasen and Lange, 2012; Boussichas, Coudert and Gillot, 2013) reviewed MDG delivery in LDCs. Furthermore, the progress of LDCs towards achieving the MDGs was reported as a part of global reviews conducted by international organizations.[1] However, no

[1] An earlier review was by the United Nations Department of Economic and Social Affairs, which

previous studies have dealt with how the introduction of the MDGs affected the rate of progress of LDCs in different indicators. This paper, an extension and update of Bhattacharya and others (2013), is, therefore, a novel attempt at a detailed analytical look at MDG implementation status in LDCs. In it, a new method of tracking a country's (or region's) progress on MDG attainment is introduced. This method can also be applied towards tracking progress on achieving SDGs. Similar to McArthur and Rasmussen (2017), one of the critical issues investigated in this paper is whether launching the MDGs accelerated the attainment of 14 selected indicators in LDCs. The proposed synthetic, analytical approach provides a comparative assessment among countries, which has helped to investigate whether countries graduating from the LDC group performed better in attaining the MDGs.

An assessment of MDG progress by LDCs is fraught with a dearth of required data, and hence, for this exercise. Out of a total of 60 MDG indicators, 14 indicators[2] relevant to LDCs are selected for the empirical application of the proposed methodology. These indicators inform the nature of the vulnerability of LDCs. For assessing countries' progress in attaining the MDGs and estimating their distance from the respective target, the MDG-related data set maintained by the United Nations was inadequate.[3] Due to comparability problems, national reports on the MDGs could not be used in most cases. Coordinated by the United Nations Statistics Division, the Inter-agency and Expert Group on MDG Indicators has tried to aggregate country data meaningfully to override comparability problems.[4]

Following this introduction, relevant policy and academic literature is reviewed in the second section to highlight various methodological approaches used to track progress towards attaining the MDGs. The core contribution of this paper is in the third section in which a new synthetic approach to conduct this study is outlined, the results of which are in the penultimate section. The final section provides a summary of conclusions drawn from the foregoing analysis.

Progress towards the Millennium Development Goals, 1990-2003 in 2004 (United Nations Department of Economic and Social Affairs, 2005). A more comprehensive report, "Measuring progress in least developed countries: a statistical profile", which covered progress of LDCs beyond MDG indicators, was jointly prepared in 2006 by the United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States and the World Bank (UN-OHRLLS and World Bank, 2006). Also, UNCTAD (2014), in chapter 2 of *The Least Developed Countries Report 2014*, reported progress of LDCs' towards achieving the MDGs.

2 See figure 1 for the indicators.

3 For details, see United Nations (n.d.). Data was updated as of 6 July 2016.

4 It may be true that some reported data for some countries may be modelled. However, for comparability, this paper uses official data reported by the United Nations.

II. Tracking progress towards achieving the Millennium Development Goals: a methodological review

Several methods have been used to track progress towards attaining the MDGs in developing countries in general (Leo and Thuotte, 2011; Vandamoortele and Delamonica, 2010; Go and Quijada, 2011; De Muro, Mazziotta and Pareto, 2011; Hailu and Tsukuda, 2011; Fukuda-Parr and Greenstein, 2010), but none were sufficient to capture the complexity of implementation experiences. This section contains a review of a set of eight studies that demonstrate the diversity of methods to measure MDG progress.

Drawing on official reports, the annual *Millennium Development Goals Report* of the United Nations provides a summary of MDG progress to date. In the 2014 report, 21 targets and 60 official indicators were considered to measure progress toward achieving the eight MDGs (United Nations, 2015). Using 1990 as the baseline year, country data were aggregated at the regional and subregional levels to show overall progress over time. Weighted averages of country data were used to generate figures, and United Nations classifications were used to define LDC subgroups according to geography, export specialization, vulnerability and conflict status. National governments provided official statistics to United Nations agencies, which published relevant data on MDG progress. A few indicators' data were derived exclusively from information collected through surveys to fill the data gaps.

In addition to the United Nations, scholars and researchers have been analyzing country-level progress towards achieving the MDGs in various ways. Leo and Thuotte (2011) compared countries' performance with required achievement trajectories, which were estimated for each MDG indicator based on linear annualized rates of improvement. If a country's actual rate of improvement during the observation period was above the obligatory trajectory, then the country received a score of one. Countries that realized at least half of the obligatory trajectory was assigned a score of 0.50. Then, by combining performance across the eight MDG targets for which data were available, the country's MDG index score was achieved.

The *Millennium Development Goals Report* Card, which was published by The Overseas Development Institute (ODI) in 2010, ranked countries on absolute progress, ignoring their initial conditions, with top performers achieving the most significant positive changes in the indicators. Relative measures to examine progress at the country level were also used for the report. Using the methodology developed by Vandemoortele and Delamonica (2010) to analyse progress across wealth quintiles on reducing under-five mortality, the performances of poorer wealth quintiles were weighted more heavily than those of wealthier quintiles in the report. For unadjusted progress measures, all wealth quintiles were weighted uniformly. Constructing the equity adjusted indicator, whether wealthier or poorer primarily benefited from the progress realized. A relative difference measure was also used for the report to examine the equity of indicators. Moreover, countries were ranked according to their progress and categorized as the lowest, the middle and the highest. In measuring progress across gender categories and rural-urban locations, female-male and rural-urban ratios were used to rank countries according to the distance to parity. In line with guidelines provided by the United Nations Educational, Scientific and Cultural Organization (UNESCO), female-male ratios between 0.97 and 1.03 were used in the report to represent gender equality, ratios between 0.97 and 0.94 or 1.03 and 1.06 to be middle range and ratios below 0.94 and above 1.06 to represent high disparity (ODI, 2010).

Using a linear annualized rate of improvement calculation, Go and Quijada (2011) distinguished countries that were on target to attain the MDGs from those that were off target. To examine a country's progress, lagging countries close to becoming on target were differentiated from those that were far from being on target. The performance of a country was measured by the deviation of its latest data from the trajectory required to attain an MDG. Mean gaps were used as cut-off points to divide lagging countries into two subgroups: (a) off target and above average and (b) off target and below average.

To considerate the desirable properties that a composite index should have, De Muro, Mazziotta, and Pareto (2011) proposed the Mazziotta-Pareto Index of development and poverty, which introduced penalties for countries or regions with "unbalanced" values of indicators starting from linear aggregation. Selecting the human development index (HDI)[5] and human poverty index, they compared respective results with the Mazziotta-Pareto Index.

Several studies evaluated the progress made by countries before and after the launch of the MDGs. For instance, Hailu and Tsukada (2011) evaluated whether a country is "on track" or "off track" by measuring rates of progress. In measuring the rate of progress, they assessed the commitment of a policymaker that might have been misapprehended with flaws in prior measurements. They recognized that the rates of progress in MDG indicators might not be linear over time, and that attaining MDG targets might be harder when a country's baseline indicators' value is approached to its target value, demanding escalated efforts. They, therefore, adopted the Unbiased Rate of Progress Method to solve two measurement biases arising from non-linearity and effort escalation.

[5] HDI measures the average achievements of a country or region along three basic dimensions: well-being; knowledge; and standard of living.

Fukuda-Parr and Greenstein (2010) proposed a methodology to compare rates of progress in the periods before and after the launch of the MDGs. They used data covering three different years for each country and each indicator: the baseline year of 1990, the middle year of 2003 – since new policies associated with adopting the MDGs had implementation lags, 2003 was considered the preferable middle year –and the most recent year available. Several indicators were excluded for many countries due to data insufficiency. The comparison of the two periods showed whether there had been an acceleration of improvement.

Boussichas and Nossek (2016) argued that progress in an indicator often takes a non-linear path. The progress is slow at the start, accelerates in the middle and slows again when it reaches the maximum level. Hence, they argued for a logit function.

The eight methodologies discussed above vary widely. While each method has its own benefits and drawbacks, it is clear that differences in the choice of assessment objectives can significantly influence estimation outcomes. In some studies, a country’s performance progress towards attainment of the MDGs was measured against the baseline year of 1990. In others, progress was measured in terms of a country’s achievement after the launch of the MDGs in 2000. Some studies measured progress on a linear scale, whereas others used non-linear scales. In this paper, most of these variations to develop a new synthetic approach as a more comprehensive analytical technique to measure countries' progress towards attaining development goals, with which progress of LDCs on MDG attainment were estimated.

III. Methodology of the synthetic approach

This paper’s core contribution is a new synthetic approach that uses the MDG Attainment Index, which is based on the Linear Progress Method, to project country progress and the Unbiased Rate of Progress Method Index, which compares the rate of progress before and after the adoption of the MDGs (Hailu and Tsukada, 2011) to build a composite to rank countries that benefited from the adoption of the MDGs. Empirical results were obtained by applying this methodology to LDCs considering 14 selected MDG indicators, using 1990 as the baseline year. To assess the progress of LDCs as a group and as different subgroups, weighted averages of country data were aggregated. A group or subgroup was considered to meet its target in an indicator if the progress was 100 per cent.

This paper attempts to estimate a country-level indicator-specific MDG Attainment Index.[6] An MDG Attainment Index is derived through the following steps. First, a country's performance is compared against the "required progress rate[7]" for each of the selected MDG indicators.[8] Second, a country's actual rate of improvement or deterioration during the observation period is calculated, and a country's projected value –either equal to, above or below the target of an MDG indicator – is determined. Actual values instead of projected values are used in cases in which data for 2015 is available for an indicator.

Considering the progress status, an MDG indicator can be either positive or negative. Positive indicators are those in which progress refers to an increase in the value of an indicator (for example, the net enrolment ratio in primary education has increased). In contrast, negative indicators are those in which progress refers to a decrease in the value of an indicator (for example, tuberculosis cases per 100,000 people have decreased). For positive indicators, if the projected or actual value of an indicator for any country is equal to or more than the target value of that indicator, the country is "on track" towards attaining the respective indicator target. Suppose the projected or actual value of an indicator is less than the target value of that indicator but more than the baseline value. In that case, the indicator is tagged as "slow progress". Finally, if an indicator's projected or actual value is equal to or less than the baseline value, the indicator is labelled as "off track". For negative indicators, if an indicator's projected or actual value is equal to or less than the target value of that indicator, the indicator is considered "on track". If the projected or actual value of an indicator is more than the target value of that indicator but less than the baseline value, the indicator is tagged as "slow progress". Moreover, if an indicator's projected or actual value is equal to or more than the baseline value, the indicator is labelled as "off track".

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6 One can argue that the MDGs were set as collective targets for the world. However, this progress has also been reviewed and analysed at the country level. It may be true that imposing global targets for all countries may be unfair without taking country-specific realities into cognisance. Indeed, taking a cue from this, the post-MDG development targets (SDGs) upheld the spirit of "leave no one behind". The SDG framework has also allowed countries to set their development targets. In reality, it has been seen that most countries have opted for global targets, and some have included additional targets for their country.

7 The "required progress rate" is the annual growth rate required for MDG indicators to attain their respective target values within given target years. It is calculated based on linear annualised rates of improvement.

8 One can argue that the shape of possible trajectories may also be non-linear, including exponential, logarithmic and S-shaped. Also, in the real world, the shape of the progress may vary from indicator to indicator and country to country. For simplicity, annualized linear rates of improvement are considered.

A country's progress status – "on track", "slow progress", and "off track" – is then used to obtain an MDG Attainment Index value. The calculation begins by assigning a score of '+1' for a country that is "on track" to attain an MDG target, whereas a score of '-1' is assigned when a country is "off track". A country is assigned a score of '0' when it has made "slow progress". A country's MDG Attainment Index is then derived by adding its scores for all indicators and dividing it by the number of indicators for which data are available. The MDG Attainment Index value of a country can be in the range of -1 to +1. The ranking of countries is prepared according to MDG Attainment Index values; the higher MDG Attainment Index values represent countries making greater progress on MDG attainment.

This approach seeks to gauge progress inn implementing the MDGs, but it needs to be revised due to several framework issues. The approach is incomplete mainly because it does not account for political commitment[9] to the implementation of the MDGs. An important issue is whether there is a political commitment that results in accelerated progress. A comparison of progress on MDG indicators before and after the adoption of the MDGs should, therefore, be built into the approach. For example, if the countries have made true efforts to achieve the MDGs, there would be accelerated progress relative to the previous decade. The Unbiased Rate of Progress Method is added to the approach to assess political commitment to implementing the MDGs.[10]

The progress on MDGs attainment for each country is based on the Unbiased Rate of Progress Method, as follows:

First, a country's average annual progress is measured for each indicator using the equation below:

$$P(x_1,x_2,U,L) = \frac{f(x_2, U, L) - f(x_1, U, L)}{t_2 - t_1}$$

[9] Other exogenous factors may have played a role, such as natural disasters, conflict in neighbouring countries causing an influx of refugees, epidemic outbreaks and adverse weather conditions.

[10] The Unbiased Rate of Progress Method is applied by following the methodology proposed by Hailu and Tsukada (2011). The equations used in this paper are also adopted from their paper.

Where,

$$f(x, U, L) = \frac{\ln(U\text{-}L) - \ln(U\text{-}x)}{\ln(U\text{-}L)}$$

Second, P, which denotes the rates of progress for the periods 1990s and post-2000 (after the adoption of the MDGs in September 2000), are measured using two equations:

$$P_{90s} = \frac{f(x_m, U, L) - f(x_s, U, L)}{t_m - t_s}$$

$$P_{MDGs} = \frac{f(x_f, U, L) - f(x_m, U, L)}{t_f - t_m}$$

Here,

x = value of the MDG indicator

U = upper possible value of the MDG indicator

L = lower possible value of the MDG indicator

t = time period

s = starting year

m = mid-point year (to represent the adoption of the MDGs)

f = latest year that data are available for a country

In the analysis of progress of LDCs, 1990 is selected as as the starting year and the earliest year after 2000 (2001, if available, otherwise the closest year) is the mid-point year. The latest year that data are available differs among the countries. However, for four indicators (1.9, 5.1, 7.8 and 7.9), 2015 (MDG target year) data are available for almost all LDCs.

Third, the rate of progress after the adoption of the MDGs as compared to the rate of progress during the 1990s. Following Hailu and Tsukada (2011), a 5 per cent margin of statistical error is taken into account, which was chosen arbitrarily (indeed, the margin of statistical error can be set higher, which would provide more conservative results). Accordingly, a country is achieving an “accelerated” rate of progress for an MDG indicator if:

$$\text{PMDGs} >= 1.05\ \text{P90s} = \text{P90s}\ (1 + 0.05)$$

A country is achieving a “slow” rate of progress for an MDG indicator if:

$$\text{PMDGs} <= 0.95\ \text{P90s or PMDGs} < 0$$

A country is achieving a “maintained” rate of progress for an MDG indicator if:

$$0.95\ \text{P90s} < 0.95\ \text{PMDGs} < 1.05\ \text{P90s}$$

The ranking of LDCs is based on countries’ performances on the 14 MDG indicators selected for this paper.[11]

Finally, country rankings emerging from the MDG Attainment Index and the Unbiased Rate of Progress Method are combined to derive comprehensive results. A new method to combine these two approaches into a single platform on a scatter diagramme is introduced in which the vertical axis shows the country ranking based on the MDG Attainment Index, and the horizontal axis shows the country ranking based on the Unbiased Rate of Progress Method. On the vertical axis, the closer a country is to the origin, the more it is “on track” to attain MDG targets. On the horizontal axis, the closer a country is to the origin, the more it is considered able to achieve an “accelerated” rate of progress after adopting the MDGs. On the scatter diagramme, the best performance that a country can have is to be on the (1, 1) point. The closer a country is to the (1, 1) point, the more it is making progress on attaining an a MDG after the adoption of the MDGs. The next step is to rank countries according to their distance from the (1, 1) point on the scatter diagramme, with the top-performing country closest to that point. The Pythagorean Theorem is used to measure the distance from the (1, 1) point on the scatter diagramme. The equation used is as follows:

$$d = \sqrt{(x-1)^2 + (y-1)^2}$$

[11] For this paper, MDG indicator 3.1, the ratio of girls to boys in primary education could not be considered for the Unbiased Rate of Progress Method analysis because it lacked an upper value.

Here, x stands for the rank of a country based on the Unbiased Rate of Progress Method. y stands for the rank of a country based on the MDG Attainment Index. Based on the value of d, which represents the distance from the (1, 1) point, countries are ranked to measure the composite progress on MDG attainment. Countries with lower values of d hold higher-ranking positions.

Although United Nations agencies collaborated with partners to produce adequate and consistent estimates for all MDGs indicators, sufficient and reliable data for all indicators and all countries were unavailable. For example, the data availability for indicator 1.1, the proportion of the population with purchasing power parity (PPP) below US$1.25 per day, could have been much higher. For this paper, data from national country reports tracking MDG progress were compiled and supplemented when necessary, risking comparability issues. Due to a lack of data availability, the focus was on analyzing 14 of the 60 MDG indicators.[12] These 14 indicators were chosen to capture the seven broad aspects of MDG performance, though data availability partly defined the choice of indicators. Progress on MDG 8 was not analyzed as most of the indicators are concerned with the performance of advanced industrialized countries.

IV. ASSESSING THE PROGRESS OF LEAST DEVELOPED COUNTRIES ON THE ATTAINAMENT OF THE MILLENNIUM DEVELOPMENT GOALS

4.1 Progress of least developed countries as a group

Leaset developed countries as a group failed to achieve any of the targets of the selected MDG indicators. However, LDCs were no exception as none of the other country groups collectively met the MDG targets. The projection based on the Linear Progress Method suggests that among 13 indicators,[13] more than 95 per cent of the progress made was against the targets of six indicators (figure 1). These indicators are dietary energy consumption, the gender ratio in primary education, under-five mortality rate, infant mortality rate, maternal mortality ratio and HIV prevalence among the population aged 15–24.[14] This was possible due to a high political commitment to

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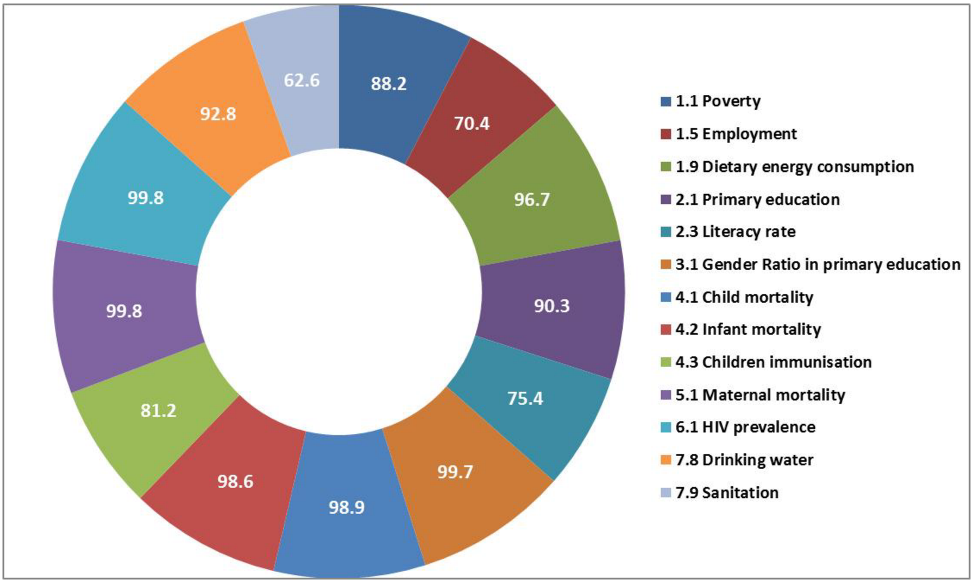
[12] Is also should be noted that the proposed methodology, to some extent, depends on data availability. Indeed, data availability has influenced the country's performance analysis and choice of indicators under the analysis.

[13] The indicator relating to the proportion of land area covered by forest has been dropped from the projection as there is no corresponding empirical target.

[14] The target of HIV prevalence is to bring it down to the 1990 level. Although it is close to the 1990 level, higher prevalence means that LDCs as a group are "off track" regarding progress on this indicator.

tackling hunger and undernutrition. According to the Hunger and Nutrition Commitment Index of Lintelo and Lakshman (2015), LDCs account for four out of seven countries with a high level of political commitment to tackling hunger and undernutrition. For two indicators – employment-to-population ratio (1.5) and HIV prevalence among the population aged 15–24 – the group was "off track", meaning that, on average, these countries have all deteriorated since 1990. In contrast, in increasing the proportion of the population with access to improved sanitation, the group's progress was slow overall due to slow progress in African and among small island LDCs.

Figure 1. Pogress by least develoed country as a group across Millennium Development Goal indicators



Source: Estimated by the authors based on the MDG database of the United Nations Statistics Division.

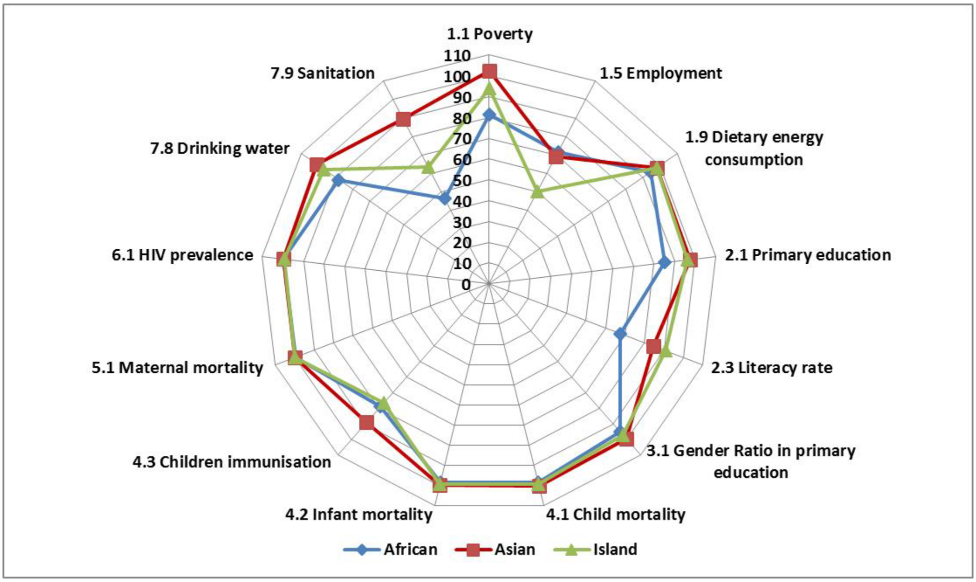
Note: Progress is measured in percentages. A group is considered to meet its target in an indicator if its progress is 100 per cent.

The heterogeneity among LDCs can be further demonstrated using their various characterizations that arise from their geographical location, export specialization, vulnerability status and conflict situation (UNCTAD, 2015; UN-OHRLLS, 2009).

4.2 Progress by geographical/structural classification

At the regional level, Asian LDCs performed better than African and island LDCs. African LDCs met none of the targets, while island LDCs met one target. For at least three indicators, the proportion of the population below US$1.25 per day PPP, the under-five mortality rate and the proportion of the population using improved sanitation facilities, Asian LDCs, as a group, could meet targets. Indeed, the general failure of non-Asian LDCs to achieve the MDGs reflects their inability to translate historically rapid economic growth since the mid-1990s into corresponding increases in employment (UNCTAD, 2014). Progress of Asian LDCs was very close to the targets – more than 97 per cent – for six other indicators, as presented in figure2. These are HIV prevalence among the population aged 15–24 years, maternal mortality ratio, infant mortality rate, the gender ratio in primary education, minimum dietary energy consumption and net enrolment in primary education. However, Asian LDCs were "off track" on the employment-to-population ratio.

Figure 2. Progress of least developed countries by geographical/structural classification across Millennium Development Goal indicators

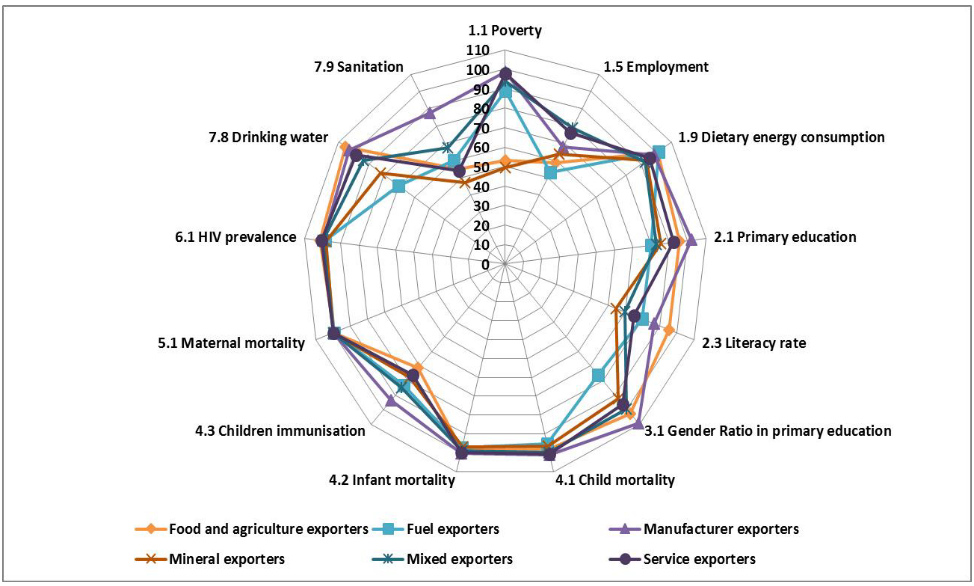


Source: Estimated by the authors based on the MDG database of the United Nations Statistics Division.

4.3 Progress by export specialization

Based on export specialization,[15] the LDC subgroup that made the most progress in the selected MDG indicators had traditionally been the manufacturer exporters (most of which are in Asia) — at least targets of six indicators were met by them (figure 3). However, other strong performances were recorded by food and agriculture exporters and service exporters – at least the targets of four indicators and two indicators were met by them, respectively. By contrast, the exporter groups in which progress was slower were fuel, minerals, and mixed exporters — as no target was met by mineral exporters (Democratic Republic of the Congo, Eritrea and Zambia, in particular) and mixed exporters (especially, Benin, Central African Republic, Sierra Leone and Togo). A sharp fall in oil prices in the second half of 2014 adversely affected fuel exporters (Angola, Chad, Equatorial Guinea, Sudan and Yemen) (UNCTAD, 2015).

Figure 3. Progress of least developed countries with export specialization across Millennium Development Goals indicators



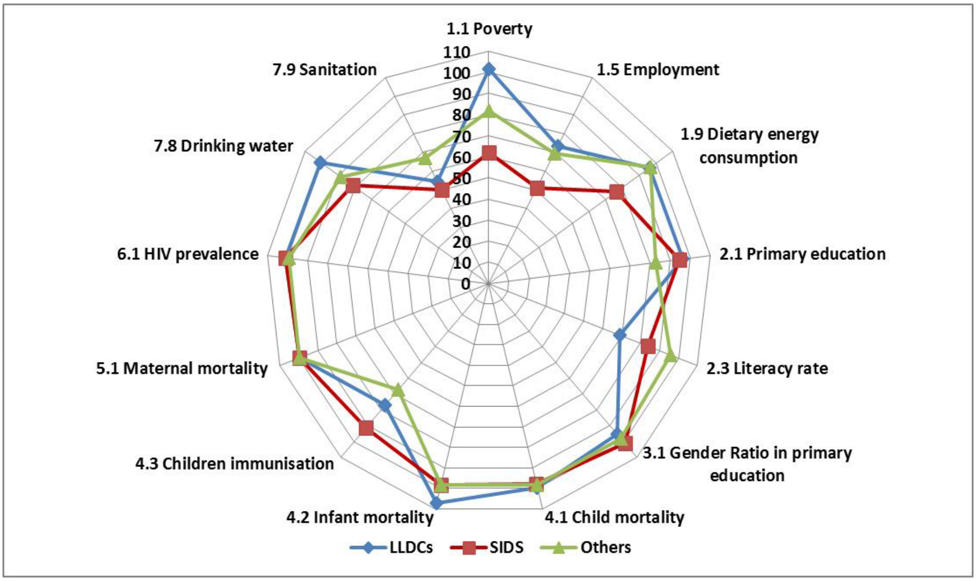
Source: Estimated by authors based on the MDG database of the United Nations Statistics Division.

[15] UNCTAD (2015) has classified LDCs under six export specialization categories: food and agricultural; fuel, manufacturer; mineral; mixed;a nd service exporters. The categories are based on the type of export that accounted for at least 45 per cent of total exports of goods and services in the period 2010–2012.

4.4 Progress of least developed countries by vulnerability status across Millennium Development Goals indicators

The progress of LDCs according to vulnerability status suggests that LLDCs succeeded in attaining targets of at least four MDG indicators (proportion of population below the poverty line, infant mortality, improved drinking water sources and HIV prevalence) and made very slow progress towards meeting the proportion of people with improved sanitation facilities target. SIDS were able to meet the targets of at least two indicators (HIV prevalence and gender ratio in primary education), while for the literacy rates of 15–24 years old indicator, the group was "off track" (figure 4). In 2002, the international community created the Global Fund to Fight AIDS, Tuberculosis and Malaria to combat infectious diseases, which might have helped these LLDCs and SIDs decrease their HIV prevalence (Boussichas, Coudert and Gillot, 2013). Regarding improved sanitation and poverty reduction, this group made very little progress. All the three subgroups (LLDCs, SIDS and others) in this category were "off track" with regard to meeting the employment-population ratio target.

Figure 4. Progress of least developed countries by vulnerability status across Millennium Development Goals indicators

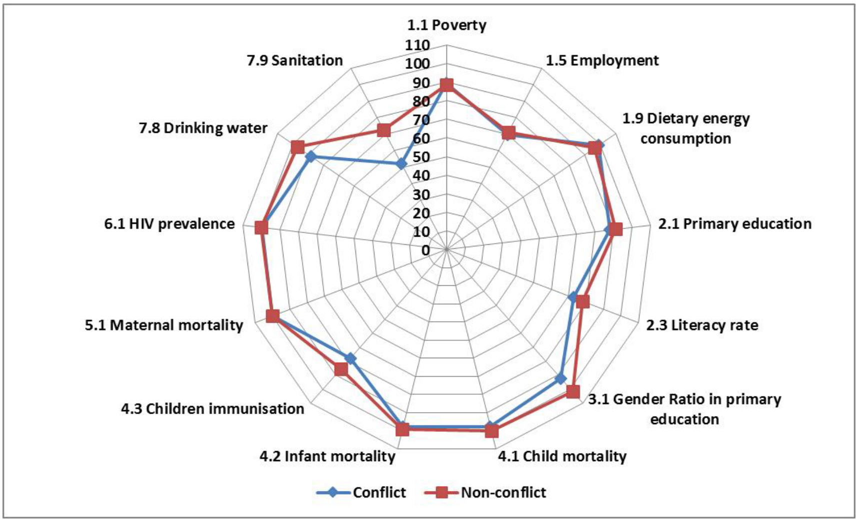


Source: Estimates of authors based on the MDG database of the United Nations Statistics Division.

4.5 Progress of least developed counties by conflict status across Millennium Development Goals indicators

In the present analysis, attempts were made to assess the progress of LDCs in terms of their conflict situation. In that regard, it was found that LDCs in non-conflict areas made greater progress than the LDCs that were experiencing violent domestic conflict or were in a post-conflict stage, mainly Chad, Liberia, Somalia, Central African Republic and Sudan. LDCs in conflict failed to meet any of the targets, while LDCs that were not in conflict attained targets of at least three indicators – gender ratio in primary education, child mortality and HIV prevalence (figure 5). Interestingly, LDCs in conflict made marginally more progress with regard to poverty reduction and dietary energy consumption than LDCs in non-conflict areas. There can be two plausible explanations for this phenomenon. Conflict-affected countries have been among developing countries' top economic performers during the 2001-2015 period. For example, Chad and Liberia recorded double-digit GDP growth during the 2001-2010 period, primarily due to their natural resources, though Liberia achieved this during the post-conflict stage (Burt, Hughes and Milante 2014). Agricultural productivity gains for countries, such as Angola, Mozambique and Sierra Leone, related to post-conflict reconstruction, may have contributed to a more rapid reduction of their undernourishment situation compared to non-conflict LDCs (UNCTAD, 2015). However, LDCs in conflict made very slow progress with regard to improved sanitation targets.

Figure 5. Progress of least developed countries by conflict status across Millennium Development Goals indicators



Source: Estimates of authors based on the MDG database of the United Nations Statistics Division.

4.6 Country rankings based on the MDG Attainment Index

Estimates from the MDG Attainment Index indicate that Bhutan was in the top position with an index score of 0.50 in the country ranking. This country attained seven of the 14 selected indicators and achieved significant progress on four others. Six out of 10 top-ranked LDCs based on the MDG Attainment Index were Asian LDCs. Among other Asian LDCs, Cambodia secured the second position, Nepal paced third, Bangladesh and Lao People's Democratic Republic were jointly sixth, and Myanmar was ninth.

At the bottom of the list, all eight countries were African LDCs. Equatorial Guinea, a fuel-exporting LDC, was in the last position, despite having a middle-income country's per capita GDP ($11,121) and, at the time, likely to be soon graduating from LDC status. The country was "off track" on six indicators out of 11 indicators for which data were available. Data for Sudan, a fuel-exporting country in conflict, were available for ten indicators. The country was "off track" on four indicators and failed to achieve any of the targets.

At the country level, 40 out of 48[16] LDCs could have attained at least one target among the 14 selected indicators. The seven countries that failed to meet any of the targets are Afghanistan, Chad, Comoros, Equilateral Guinea, Somalia, Sudan (former) and Yemen.

4.7 Progress across indicators

Table 1 presents the ranking of indicators based on estimates of the MDG Attainment Index. The top three indicators are proportion of population below the minimum level of dietary energy consumption, under-five mortality rate, and proportion of the population with sustainable access to an improved drinking water source.

Table 1. Millennium Development Goals indicator ranking based on MDG Attainment Index[17]

Indicator		Normalized score
1.9	Proportion of population below minimum level of dietary energy consumption	0.32

[16] Samoa graduated from the LDC group in 2014, Equatorial Guinea in 2017 and Vanuatu in 2020. In this analysis, the countries that were on the LDC list in 2013 and throughout the time frame for the implementation of the MDGs (2000 – 2015) were considered.

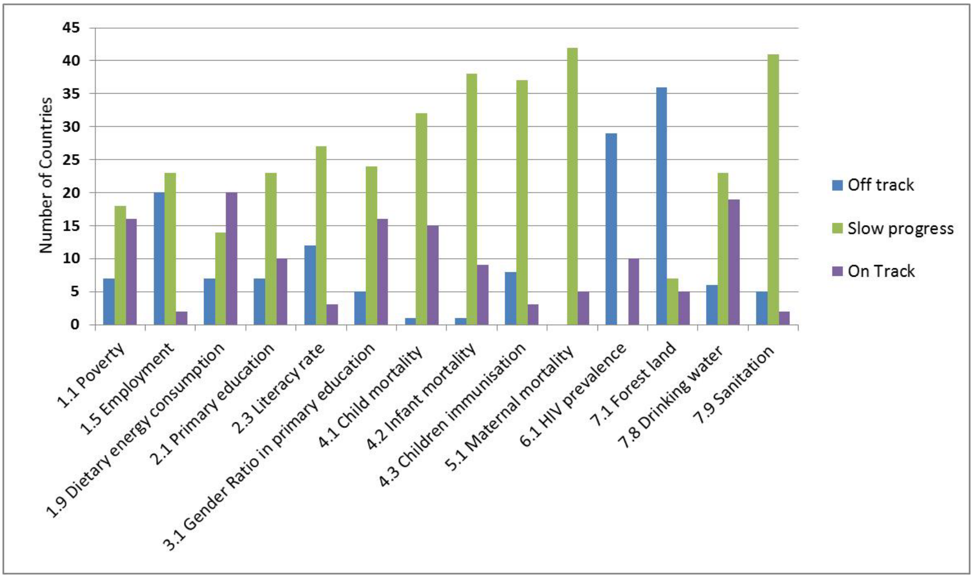
[17] Progress on the 14 selected indicators is likely to be interdependent, but to capture that, econometric analyses are required.

Indicator		Normalized score
4.1	Under-five mortality rate	0.29
7.8	Proportion of population using an improved drinking water source	0.27
3.1	Ratios of girls to boys in primary education	0.24
1.1	Proportion of population below Poverty line	0.22
4.2	Infant mortality rate	0.17
5.1	Maternal mortality ratio	0.11
2.1	Net enrolment ratio in primary education	0.08
7.9	Proportion of population using an improved sanitation facility	-0.06
4.3	Proportion of 1 year-old children immunized against measles	-0.10
2.3	Literacy rate of 15-24 year-olds, women and men	-0.26
1.5	Employment-to-population ratio	-0.47
6.1	HIV prevalence among population aged 15–24 years	-0.54
7.1	Proportion of land area covered by forest	-0.65

Source: Estimates of authors based on the MDG database of the United Nations Statistics Division.

If the number of countries that successfully attained a target is considered, then the minimum dietary energy consumption tops the list of indicators, as shown in figure 6. Regarding this indicator, 20 out of 41 LDCs (49 per cent) could attain the target. 19 out of 48 LDCs (40 per cent) were “on track” to attain the target of the proportion of the population using improved drinking water sources. 16 out of 41 LDCs (39 per cent) were “on track” to attain the target of the proportion of the population below US$1.25 (PPP) per day. However, as 7 LDCs (17 per cent) were “off track”, the indicator remained in the middle of the ranking order. Targets for employment-to-population ratio, HIV prevalence among the population aged 15–24 years and proportion of land area covered by forest remained at the top in terms of being “off track”. UNCTAD (2013) showed that LDCs with more rapid economic growth relative created less employment. Accordingly, the report called for a departure from the “business as usual” policies and practices of the current growth model. It also suggested a new set of priorities and policies based on inclusive growth and sustainable development to create better and more employment.

Figure 6. Millennium DevelopmentEoals indicators by progress status



Source: Estimates of authors based on the MDG database of the United Nations Statistics Division (UNSD).

4.8 Acceleration towards Millennium Development Goals attainment

Progress towards attaining MDG targets does not necessarily imply that countries have accelerated their progress since the launch of the MDGs. To identify the countries that accelerated progress on selected indicators after 2000, which implies acceleration due to the adoption of the MDGs, the Unbiased Rate of Progress Method was applied to the data set to generate the results shown in table 2.

Most notably, more than half of countries accelerated their progress for five indicators – the infant mortality ratio, proportion of population using improved sanitation, proportion of population using an improved drinking water source, the maternal mortality ratio and HIV prevalence among population aged 15–24 years.

These findings do not always correspond with earlier findings regarding progress towards the attainment of the MDG targets. This largely concerns the benchmark situation (1990) and its development until 2000, as many countries made good progress until 2000 but could not maintain the rate of progress after adopting the MDGs. Some LDCs could attain MDG targets because they had a head start, supported by national achievements in the 1990s. Rahman, Khan and Sadique (2014) found that the development plans of low-income countries, such as Bangladesh and Uganda, that were formulated during a pre-MDG period had already identified and incorporated several MDG-relevant areas that had been accorded high policy priority. Other literature also indicated that greater public expenditures (Milller and Watts, 2013), as well as disbursement of official development assistance (Fukuda-Parr, 2008), were channelled towards MDG-related sectors to a greater degree during the post-MDG period.

Table 2. Improvement in the rate of progress by indicator

MDG	Indicator	Accelerated progress		Maintained progress		Slow progress	
		Countries	(%)	Countries	(%)	Countries	(%)
1	1.1	6	31.58	2	10.53	11	57.89
	1.5	7	16.67	1	2.38	34	80.95
	1.9	16	40.00	0	0.00	24	60.00
2	2.1	12	35.29	0	0.00	22	64.71
	2.3	8	40.00	1	5.00	11	55.00
4	4.1	2	4.17	0	0.00	46	95.83
	4.2	41	85.42	3	6.25	4	8.33
	4.3	20	42.55	0	0.00	27	57.45
5	5.1	29	61.70	4	8.51	14	29.79
6	6.1	20	51.28	0	0.00	19	48.72
7	7.1	2	4.17	9	18.75	37	77.08
	7.8	31	67.39	2	4.35	13	28.26
	7.9	33	68.75	4	8.33	11	22.92

Source: Estimates of authors based on the MDG database of the United Nations Statistics Division.

Niger topped the ranking of countries making accelerated progress, followed by Mauritania, Timor-Leste, Bangladesh and Nepal. The weakest performers were Lesotho, at the bottom, followed by Zambia, Gambia, Equilateral Guinea, and Yemen, in ascending order.

4.9 Combining the results from the MDG Attainment Index and the Unbiased Rate of Progress Method

Combining the MDG Attainment Index and the Unbiased Rate of Progress Method rankings resulted in 14 LDCs (29 per cent) being placed in the category where countries ranked high in terms of the MDG Attainment Index (that is, made significant progress towards achieving MDG targets) and the Unbiased Rate of Progress Method (accelerated their progress towards achieving the MDGs after 2000) (Figure 7).[18] Only five countries attained positions within the top 25 per cent of both rankings. Nepal ranks third in the MDG Attainment Index and fourth in the Unbiased Rate of Progress Method ranking. Similarly, Bangladesh ranked sixth in the MDG Attainment Index and fourth in the Unbiased Rate of Progress Method ranking. The other three countries were the the Lao People's Democratic Republic, Myanmar, and Togo.

The composite country ranking compiled by combining the MDG Attainment Index and the Unbiased Rate of Progress Method rankings showed that six Asian LDCs, Nepal, Bangladesh, Myanmar, Timor-Leste, the Lao People's Democratic Republic and Bhutan, held the first, second, third, fourth, sixth, and eighth positions, respectively.[19] All five of the lowest-ranked LDCs in the composite ranking were from Africa. Equatorial Guinea performed the worst among the bottom-ranked countries, followed by Lesotho, Zambia, the Central African Republic,and Chad,. in ascending order.

Notably, although Mali, Benin, the Democratic Republic of the Congo and Sudan were among the top 10 LDCs using the Unbiased Rate of Progress Method ranking, they were not among the top-ranked LDCs in the composite ranking. The same is the case for Cambodia, Rwanda, Gambia and Solomon Islands, which were among the top 10 countries in the MDG Attainment Index ranking, but not in the composite ranking.

4.10 Are the graduating least developed counries performing better in achieving the Millennium Development Goals?

To address the second issue of investigation, given the similarity between indicators under two out of three LDC graduation criteria and the MDGs, it is assumed that countries that are graduating from the LDC list are essentially graduating because of their performance regarding the MDGs. CDP (2018), in the 2018 triennial review, found that Kiribati was eligible for graduation for the third consecutive time while Bhutan, São

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[18] South Sudan is omitted from this analysis as it is a relatively new country, having gained independence in 2011.

[19] The composite country ranking and other rankings are presented in table 1 of the annex.

Tomé and Príncipe, and Solomon Islands were eligible for graduation for the second consecutive time and recommended them for graduation from the LDC list. Meanwhile, Nepal and Timor-Leste were found to be eligible for the second consecutive time but were not recommended for graduation. The committee for Development Policy (CDP) also found Bangladesh, the Lao People's Democratic Republic and Myanmar to be eligible for graduation for the first time. Two other countries which were graduating and were reviewed by CDP are Angola and Vanuatu. Out of the 11 countries that are graduating or have been recommended for graduation, six countries (all from Asia) are among the top eight countries in the composite country ranking made by combining the MDG Attainment Index and the Unbiased Rate of Progress Method results. In addition, Solomon Islands is among the top 10 countries regarding the MDG Attainment Index ranking, while Kiribati and Vanuatu jointly share the twenty-first position in the ranking, meeting the income and human assets index criteria. Angola, an oil export-dependent country, failed to achieve noteworthy progress in the MDGs. However, it is graduating based on its very high per capita income.

Similarly, Samoa, which graduated from the LDC group in 2014, secured the fifteenth position in the MDG Attainment Index ranking while remaining vulnerable to economic and environmental shocks. Meanwhile, despite being at the bottom of the composite ranking, Equatorial Guinea graduated from the LDC list based only on the per capita income criterion keeping a large imbalance between per capita income and the level of the human asset index. Thus, apart from one or two outliers, such as Angola or Equatorial Guinea – the countries graduating based on the "income only" criterion. This assessment suggests a clear association between countries' MDG progress and their chance of graduating from the LDC list.[20]

V. CONCLUSION

Using a synthetic approach, a novel assessment of how successful LDCs – a disadvantaged group of countries whose progress towards achieving the MDGs hads not yet been comprehensively assessed – were in attaining the MDGs is made in this paper. Five overarching conclusions can be drawn from this paper.

First, although LDCs as a group failed to achieve any of the targets of the 14 selected indicators, they generally made discernible progress on most indicators, particularly dietary energy consumption, gender ratio in primary education, under-five mortality rate, infant mortality rate, maternal mortality ratio and HIV prevalence among population aged 15–24 years. It is critical to provide special attention in the areas

[20] Indeed, some of the indicators considered for the LDC graduation criteria are similar to the MDG indicators. Hence, this trend may be expected.

where progress has not been very satisfactory in the LDCs during the implementation of the 2030 Agenda, including the use of improved sanitation facilities, children immunization against measles, literacy rate, employment-to-population ratio, HIV prevalence and land area to be covered by forest.

Second, progress towards attaining the MDGs by the end of 2015 remained uneven across indicators within the group of countries. The heterogeneity among LDCs based on their geographical location, export specialization, vulnerability status, and conflict situation can largely explain this variation. For example, Asian LDCs – most of which are manufacturing exporters – performed better than African and island LDCs. In addition, LDCs in non-conflict areas (most Asian LDCs) made greater progress than those in conflict or post-conflict stages. Indeed, African LDCs require more attention during the implementation period of the 2030 Agenda.

Third, LDCs that were able to attain greater progress in the MDG indicators moved closer to graduating from the LDC group. The Asian and island LDC groups primarily dominate these LDCs. The African LDCs also, in this context, remained left behind. However, from a policy perspective, it should be noted that the graduating LDCs did not fully implement targets set by the MDGs, and the development targets of SDGs remain more challenging.

Fourth, some countries, such as Bangladesh and Uganda, that started to work on key MDG issues before adopting the related agenda have achieved the relevant targets more successfully. Hence, policy preparedness at the national level is also critical for the attainment of SDGs in LDCs.

Finally, regularly assessing countries' comparative progress during the implementation of the 2030 Agenda can contribute to policy adjustments as necessary. The methodology proposed in this paper can be adapted to specific country circumstances as an operational framework for assessing progress towards attaining the SDGs.

However, following the lessons learned from the MDGs experience, there is a greater consensus among the stakeholders that the availability of better quality data in larger quantities are central to measuring SDG progress. More efforts, at country and global levels, are required to make data available for a strengthened assessment of progress in SDG delivery and to adjust the policies accordingly.

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ANNEX TABLE

Composite ranking of least developed countries

Country	Unbiased Rate of Progress Method ranking	MDG Attainment lindex ranking	Index value (d)	Composite ranking
Nepal	4	3	3.61	1
Bangladesh	4	6	5.83	2
Myanmar	8	9	10.63	3
Timor-Leste	3	12	11.18	4
Ethiopia	12	3	11.18	4
Lao People's Republic	12	6	12.08	6
Togo	11	9	12.81	7
Bhutan	15	1	14.00	8
Mauritania	2	15	14.04	9
Niger	1	18	17.00	10
Cambodia	20	2	19.03	11
Mali	4	21	20.22	12
Senegal	15	18	22.02	13
Rwanda	25	3	24.08	14
Djibouti	15	21	24.41	15
United Republic of Tanzania	25	12	26.40	16
Mozambique	12	26	27.31	17
Benin	7	29	28.64	18
Burkina Faso	25	18	29.41	19
Sierra Leone	15	27	29.53	20
Malawi	32	12	32.89	21
Vanuatu	28	21	33.60	22

Annex table. *(continued)*

Country	Unbiased Rate of Progress Method ranking	MDG Attainment Iindex ranking	Index value (d)	Composite ranking
Burundi	32	15	34.01	23
Eritrea	22	28	34.21	24
Democratic Republic of the Congo	8	35	34.71	25
Uganda	15	37	38.63	26
Guinea-Bissau	28	29	38.90	27
Samoa	38	15	39.56	28
Solomon Islands	40	9	39.81	29
Sao Tome and Principe	31	29	41.04	30
Guinea	37	21	41.18	31
Tuvalu	32	29	41.77	32
Angola	21	38	42.06	33
Haiti	28	35	43.42	34
Comoros	22	39	43.42	34
Kiribati	40	21	43.83	36
Gambia	46	6	45.28	37
Afghanistan	38	29	46.40	38
Sudan	8	47	46.53	39
Somalia	22	44	47.85	40
Liberia	32	40	49.82	41
Yemen	40	34	51.09	42
Madagascar	32	45	53.82	43
Chad	40	40	55.15	44
Central African Republic	40	45	58.80	45
Zambia	47	40	60.31	46

Annex table. *(continued)*

Country	Unbiased Rate of Progress Method ranking	MDG Attainment lindex ranking	Index value (d)	Composite ranking
Lesotho	48	40	61.07	47
Equatorial Guinea	45	48	64.38	48

Source: Authors' calculations.

Submitted papers

GROWTH, YIELD AND ENVIRONMENTAL SUSTAINABILITY OF COTTON PRODUCTION IN INDIA: PERFORMANCE AND POLICY MEASURES

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This paper reviews the growth performance, potential and environmental sustainability of cotton production in India. Using a decomposition analysis, it provides a comprehensive picture of growth in the production of cotton from 1947 to 2021 and during various development phases. It also discusses the environmental sustainability of Bt cotton and the potential of organic cotton farming in addressing the challenges faced by cotton growers. The results from this study can be used to inform policymakers in framing policies to exploit the potential of this sector, to generate additional employment and preserve the sustainability in cotton production.

Keywords: cotton, area, production, yield, variability, sustainability, decomposition analysis

JEL classification: Q16, Q18

I. INTRODUCTION

Cotton is an important cash crop and plays a crucial role in achieving sustainable agricultural and industrial growth of India. In 2020–21, it was cultivated on approximately 32.9 million ha around the world and on approximately 2.35 million ha in India, where the crop is a source of livelihood for a substantial share of farm households. Approximately 37 per cent of the area devoted to growing cotton is in India; the country accounted for 24 per cent of global cotton production in 2020–21(Cotton corporation of India (2022).India exports 5.5 million bales a year, making it the third largest exporter of the crop after the United States of America (16.25 million bales) and Brazil (10.7 million bales) (Sood, 2022).

Approximately 50 million to 60 million people across India depend on cotton cultivation, processing, marketing and exports for their livelihood (Patel, 2021). The textile industry is a major exchange earner for the country, accounting for approximately 4 per cent of the country's national income. Cotton is also widely used as a principal raw material. As a result, cotton production and cotton based products from the textile industry play a prominent role in the overall welfare and development of Indian economy (Textile World, 2021).

Since independence, India has experienced tremendous quantitative growth in cotton production. Until the 1970s, India used to be a major importer of cotton, however, in the mid-1970s, production of the crop gained momentum, spurred by an increase in the cultivation area and sowing of new hybrid varieties following the launch of various government schemes, such as a cotton production programme implemented through five-year plans. Thereafter, India became self-sufficient in cotton production except for during a few years in the late 1990s and early 2000s when imports of cotton increased due to losses resulting from the occurrence of American bollworm and increased demand for cotton from the domestic textile industry.

Following the introduction of "the Technology Mission on Cotton" in 2000, high yielding varieties and hybrids improved agronomic practices and appropriate transfers of technology were adopted, which helped to enable substantial progress in increasing the yield and production of cotton. In addition, in 2002, a genetically modified seeds (Bt cotton) was introduced in India by Mahyco-Monsanto Biotech. This led to greater pest control, which, in turn, positively affected the yield of cotton and significantly increased cotton production, as well as the area for cultivation (Bajaj and Kumria, 2021). The yield per ha had been stagnant, at approximately 300 kg, for many years prior to the launch introduction of the Bt cotton phase (before 2002). It increased to 472 kg in 2005–06 and was projected to reach 510 kg in 2021–22 (Cotton Corporation of India (2022).

But despite this, there is still a substantial difference in the yield[1] levels of cotton in India vis a vis the global average, indicating that there is low productivity per unit of land. As per a report of the United States Department of Agriculture (USDA), global cotton farming decreased by 6.5 per cent in 2020-21 from the previous year as the COVID-19 Pandemic peaked. The declining production affected the Indian cotton market as well. Cotton farmers in India must deal with several challenges, including, among them, adverse weather conditions, excessive use of chemical fertilizers, threat of pink worm and whitefly, poor credit facilities, falling prices, rising labour costs and little knowledge about new technology. During the initial years of the production of Bt cotton (2002–2014), the production area and yield increased significantly, but, since 2015, the production of cotton and productivity has declined dramatically (Kranthi and Stone, 2020).

In the light of the above discussion, the objective of this paper is to review the growth performance and challenges faced by the cotton sector in India since the country achieved independence. Using the Cuddy Dalle Valle Index, an analysis of the growth rates and instability/variability indices in production, area and yield of cotton in India from 1947–48 to 2021–222 is conducted. In addition, an analysis of various components of total growth in output of cotton, such as the contribution of the area and yield, are important issues that require research and understanding. The overall growth rates (1947–48 to 2021–22) are also reviewed along, with the growth rates during the different phases of development, namely the pre Bt cotton phase (1980–-81 to 2002–03) and post Bt cotton phase (2003–04 to 2021–22). Using data from various published sources and applying the decomposition analysis, the contribution of various factors, such as area and yield, towards total cotton output change during the two phases are reviewed.

The paper also contains a discussion on the several factors constraining cotton production in India and an attempt is made to explore the reasons for slow growth in cotton production and productivity in the post Bt cotton phase (2015 onwards). The environmental sustainability of Bt cotton is reviewed, as well as the potential of organic farming in enhancing income and engendering additional employment in India. The paper concludes with various policy suggestions that could enhance cotton productivity to levels comparable to the world average. The results from this study can be used to inform policymakers in attaining a holistic view regarding the performance of cotton for framing sound policies to exploit the crop's potential. Most of the studies that have used the Cuddy Dalle Valle Index to measure the growth performance and variability in production of cotton are outdated. This study presents

[1] Crop yield is a measurement of the amount of agricultural production harvested per unit of land area. In this paper, the terms yield and productivity are used synonymously and is measured in kilogrammes per hectare.

a comprehensive picture of the cotton growth performance for the period 1947 to 2021, using the latest available data obtained from published sources. Moreover, the decomposition analysis is used to compare the growth performance in the pre and post Bt cotton phases. All in all, the sustainability of cotton production, in particular environmental sustainability, is reviewed and policy measures to enhance sustainable production in cotton are suggested. Such a study has not been done for India, to the best of the authors' knowledge.

II. DATA AND METHODOLOGY

The present study has used secondary data published from various authentic public sources and records. Area, production and productivity data were taken from the Cotton Corporation of India and from Agricultural Statistics at a Glance of the Ministry of Agriculture and Farmers Welfare. Scanned reports of the Cotton Corporation of India were used to access data on area, production and yield parameters. Data on organic cotton production were taken from the 150th Parliamentary Report on Organic Cotton in India, the Agricultural and Processed Food Products Export Development Authority and the USDA Cotton and Products Annual Report, March 2022.

For the study, the compound annual growth rate[2] of the area under cultivation, production and cotton yield from 1947–48 to 2021–22 is calculated. The Cuddy Dalle Valle Index (1978) is used to study the instability/variability in the cotton area, production and yield. This index is a refinement/modification of the coefficient of variation, as it accommodates the trend of the time series data. Recent literature has used this approach to understand the extent of instability and risk in agricultural production (Simhar, 2014; Dudhat, Pushpa and Venujayakanth, 2017; Chand and Raju, 2009; Tewari, Singh, and Tripathi,. 2017; Kakali and Basu, 2006).

The decomposition analysis, which was introduced by Minhas and Vaidyanathan (1965), is widely used to understand agricultural performance. They used the additive method to estimate the change in the value of agricultural output and the 4-component segregation of total output to understand area, yield, cropping patterns and the interactions between them. Later Parikh (1966) conducted a study using a multiplicative model for the analysis of decomposition effect. The main difference between these two models is that the additive model estimates are based on absolute growth rate as against the multiplicative model, which uses relative growth rate. Moreover, the

[2] Growth is measured in terms of compound annual growth rate (CAGR), which depicts the cumulative performance of a particular crop over a given period of time. As against this, growth of a plant refers to a permanent change that increases the size of the plant. Plants grown on a large scale are known as crops. In this paper, the performance of the cotton crop is measured in terms of growth rate of the area under cotton crop, and production as well as productivity.

residual impact is included as an interaction term in the additive model, which is not the case with the multiplicative method (Pattnaik and Shah, 2015).

A seven factor additive model with the main components comprised of area, yield and cropping pattern and the interaction between them is used by Dashora, Dhaka, and Agarwal (2000) and Sankar and Chakraborty (2002). Majumdar and Basu (2005) used a three component additive model to understand the impact of area, productivity and the cropping patterns on absolute growth of agricultural output from 1970–71 to 1999–2000 (Shende. Thakare and Roundhal, 2011). Singh and others (2018) redesigned the model to study the performance of crops in various states in India.

Recent literature suggests that although the additive and multiplicative models for decomposition of growth in agricultural output have been used by researchers, the suitability and superiority of one method over another is not known. The additive method is preferred in the literature over the multiplicative method, as the interpretation of the results is very straight forward in the former one (Pattnaik and Shah, 2015). For this study, an additive model is used for the decomposition analysis.

The following sections provide descriptions of the methodology used to calculate the compound annual growth rates, instability/variability indices and decomposition of various components of growth. The analysis was carried out for the period 1947–48 to 2021–22 for pre-Bt cotton period (1980–81 to 200-03) and the post-Bt cotton (2003–04 to 2021–22) introduction period.

Measurement of growth rate: The annual growth rates in production, area and yield of cotton are estimated using time series data from 194748 to 202122. Following Nethrayani (2013), an exponential model is used to estimate the growth rates , as described below:

$$Y_t = P\, Q^t V_t .... (1)$$

Where Y_t is the production, area and yield in year t

P= Intercept indicating Y in the base period t=0

t = time period

Q= 1+r

V_t = random disturbance term

Converting equation (1) into logarithmic form to make it in a linear form:

$\ln Y_t = \ln P + t * \ln Q + \ln V_t$

This is of the following form:

$$M_t = p + qt + U_t \ldots\ldots\ldots\ldots\ldots (2)$$

Where $M_t = \ln Y_t$

$p = \ln P$

$q = \ln Q$

$U_t = \ln V_t$

Equation (2) is estimated using OLS estimation technique and the estimates of p and q are obtained. Finally, by taking antilogarithms of 'p' and 'q' values, the original P and Q parameters are obtained:

P = antilog p

Q = antilog q

r = (Q-1) *100, which gives the average annual compound growth rate(CAGR).

Instability Index (Cuddy Della Valle Index): The Cuddy Della Valle Index is an instability index model used to examine the extent of risk and variability in area, production and yield. Ramadas, Poswal and Sharma (2012) used this index for an analysis of the performance of wheat production in India. The production of any crop is considered sustainable if its high growth rate is accompanied with a low level of instability (Tripathi and Prasad, 2009). The simple coefficient of variation (CV) is a traditional instrument that overestimates the level of instability in time series data, as it often contains a trend component. To overcome this problem, this study uses a more advanced instability index used by Cuddy and Della (1978), which corrects the coefficient of variation as follows:

Cuddy Della Valle Instability Index (%) $I = CV * \sqrt{1 - R^2}$

Where, I is the instability index

CV is the coefficient of variation in percent, $CV = \frac{S.d}{mean} * 100$

R^2 = Coefficient of determination from a time trend regression adjusted to its degrees of freedom.

Following Rakesh and Sihmar (2014), the ranges of Cuddy Della Valle Index can be described as follows:

A Cuddy Della Valle Index between 0 and 15 = low level of instability

(> 15 and < 30) = medium instability

(> 30) = high instability

Decomposition of growth components

To understand the relative contribution of area and yield towards total output change in the cotton crop, a decomposition analysis is used in this study. To assess the impact of structural change, namely a comparison of the pre-Bt and the post-Bt scenarios, and also to examine the impact of different factors towards output growth over time, the study period for the decomposition analysis is classified into three periods: one overall period (1947–48 to 2021–22), the second pre Bt cotton period (1980–81 to 2002–03) and the other post Bt cotton period (2003–04 to 202122).

$$\Delta P = A_0 \Delta Y + Y_0 \Delta A + \Delta Y \Delta A$$

Total change in production = yield effect (area in base period* change in yield) + effect (yield in base period*change in area) + interaction effect (change in yield * change in area)

Accordingly, the total change in production of cotton can be decomposed into three effects viz yield, area and interaction effects.

III. RESULTS AND DISCUSSION

The production, area, and yield of cotton in India from 194748 to 202122 are depicted in figure 1, which shows that there has been a tremendous increase in area cultivated, production and yield. Also visible in the figure is that among the three parameters, production has a significant increase with a compound annual growth rate (CAGR) of 8.3 per cent followed by area (5.5%) and yield (2.6%). In addition, the figure shows there is significant vast variation in product, which has a CV of 110.8 per cent followed by area, at 78.5 per cent, and yield, at 58.9 per cent. However, both production and area have a high level of instability, the extent of risk and instability is more (greater than 30) using the Cuddy Dalle Valle Index of 35.0 and 35.1, respectively (table1).

Table 1. Compound annual growth rates and Cuddy Dalle Valle Index for the overall period, 1947–48 to 2021–22, pre Bt cotton (198081 to 200203) and post-Bt cotton (2003–04 to 202122) period

	Overall			Pre-Bt cotton			Post- Bt cotton		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
Compound annual growth rate	5.5	8.3	2.6	0.81	2.27	1.45	2.7	4.3	1.6
Adjusted R2	0.8	0.9	0.91	0.29	0.41	0.25	0.78	0.64	0.3
CV	78.5	110.8	58.9	9.6	22.3	17.8	15.8	25.2	14.4
Cuddy Dalle Valle Index	35.1	35.0	17.7	8.1	17.0	15.4	7.4	15.1	12.0

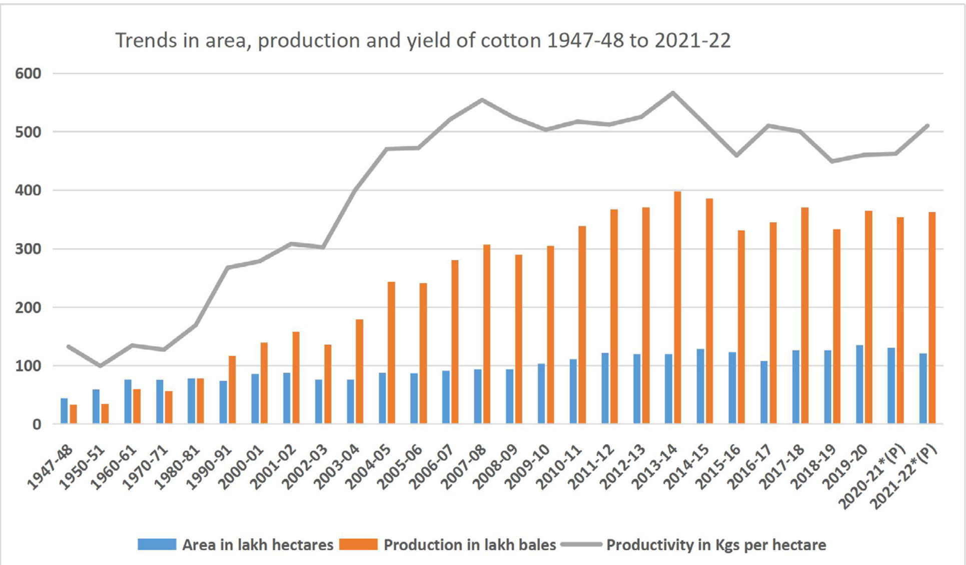
Source: Calculations using data from the Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare

*Area is measured in lakh hectares, production in lakh bales and Yield in Kgs per hectare

In addition to an overall analysis of the study period, a comparative analysis was carried out separately for pre- and post- Bt introduction periods. In 2002–03, Bt cotton was introduced in India. It has significantly affected the productivity of cotton. Growth of three parameters, area, production and productivity, improved during the post-Bt cotton introduction period with CAGRs of 2.7, 4.3 and 1.6, respectively, as compared to the pre-Bt cotton scenario (table 1). In addition, for area and production, there was a wide variation with CVs of 15.8 per cent and 25.2 per cent, respectively, in the post-Bt cotton period as compared to the pre-Bt- cotton with CVs in area and production of 9.6 per cent and 22.3 per cent, respectively. However, CV is low in the case of yield (14.4%) in the post-Bt phase as compared to the pre-Bt cotton introduction phase (17.8%) (table 1).

It should be noted that the Cuddy Dalle Valle Index scores for area (7.4), production (15.1) and yield (12.0) of cotton are low in the post Bt cotton introduction phase, as compared to the pre-Bt cotton phase, with corresponding values of 8.1 per cent, 17.4 per cent, and 15.0 per cent, respectively. This indicates that volatility declined with the introduction of Bt cotton under all three parameters as yields stabilized with the introduction of Bt-cotton seeds. To summarize, the introduction of Bt cotton has led to an increase in the growth rate of production, area and yield, complemented by a lower level of variability. This period of introduction of Bt cotton was marked by a higher and more stable yield rate as compared to the traditional varieties. This could be because Bt cotton was not affected by the American bollworm and therefore, a considerably higher increase in yield was possible. This forced cotton growers to allocate more area towards adopting Bt cotton from 2003–04 until 2014–15 (figure 1).

Figure 1. Trends in production, area and yield of cotton in India



Source: Author's computation using data from the Cotton Corporation of India

Table 2 presents the results of the decomposition analysis, namely the relative contribution of area and yield and their interaction to changes in cotton output in India for the overall period as well as for the two subperiods. It can be observed that the interaction of both area and yield is the main contributor towards the growth in output during the study period. However, when comparing the pre-Bt and post-Bt cotton scenarios, it was seen that the increase in production of cotton in the pre- Bt introduction phase came from area (18942.8) whereas the contribution of yield (-1416.15) and the interaction effect (-363.35) was negative during the pre-Bt cotton introduction period. However, during the post-Bt cotton introduction period, a positive contribution of yield is notable along with the interaction effect towards the total production of cotton in India. This observation is justifiable as the introduction of the Bt gene in cotton, which was effective in controlling American bollworm, led to reduced pesticide usage, which, in turn, resulted in increased yields and higher profitability for farmers (Sadashivappa and Qaim, 2009). The contribution of area is highest (6,859.9) followed by yield (6,101.8) and then the interaction (4,034.7) towards the total cotton production in the post Bt cotton introduction period.

Table 2. Decomposition effect and its components for cotton crop in India

Decomposition effect	Overall (1947–21)	Pre Bt cotton(1981–2002))	Post Bt cotton(2003–-2021)
Area effect	690.87	18 942.8	6 859.9
Yield effect	2 813.25	-14 16.15	6101.8
Interaction effect	13 490.9	-363.35	4 034.7

Source: Computed using data from India, Ministry of Agriculture and Farmers Welfare (2020).

It is evident from the trends in figure1 that the initial years of the introduction of Bt cotton (2002–2014) was marked by a considerable increase in production, area, and yield. However, in 2015, there was a significant decline in cotton production and productivity followed by greater variability. This could be because the northern area of India was hit by an outbreak of whitefly during this period, which, adversely affected the production (The Economic Times, 2016)). This creates the desire to further investigate the factors causing a reversal of trends.

IV. PROBLEMS AND CHALLENGES FACED BY COTTON GROWERS IN INDIA

India accounts for 24 per cent of the global cotton production, which provides livelihoods for approximately 5.8 million farmers and 40 million to 50 million people engaged in related activities, such as cotton processing and trade. Although cotton production and productivity has trended significantly higher over the past 10 years (except for during 2015–16, 2016–17 and 2018–19), many adjustments need to be made to improve the cotton yield to a level that is close to the global average and meets the requirements for it to be used as a raw material by the textile industry. Specifically for cotton growers, some of the challenges they face are related to water quantity and quality issues, and excessive use of pesticides and fertilizers and the inappropriate application of them (Dewan, 2019). In addition, the rising cost of the production of seeds and low income of small farmers significantly constrain cotton production. More than 60 per cent of the global production is carried out by small cotton farmers, who grow the crop on small landholdings (<2 ha). Of the 100 million small farmers, approximately 90 per cent reside in developing countries (Rapsomanikis, 2015). Many small cotton farmers struggle to fulfil their basic subsistence requirements, live below the poverty line and fail to earn enough income to meet their requirements. Compounding this, farmers in the cotton-producing zones in India, the northern, central and southern parts of the country, are also affected by insect and disease infestations, including bollworms, white fly, jassids, and leaf curl virus. (Naveed and others, 2020). In addition, fluctuating market prices for cotton and the average quality of the cotton produced is making it difficult to develop a globally competitive cotton industry. All these factors can be tied to the low yields in cotton vis a vis the global average.

4.1 Environmental sustainability of cotton production in India

Over the period 2001–2010, the production of cotton, the area used to cultivate cotton and cotton yields increased significantly: The area used to cultivate cotton increased from 7.9 Mha in 2002 to 12 Mha in 2011, and production increased from 13.6 million bales (170kg per bale) in 2002 to 49 million bales in 2014 (Cotton Corporation of India, 2022). India emerged as the world's largest cotton-growing country and as a major exporter of the crop. Recent literature indicates that the adoption of Bt cotton has led to a significant increase in the gross profit margin of cotton and farm income at the national level (Sadashivapa and Qaim, 2009; Krishna and Qaim, 2007; Subramanian and Qaim, 2008). Several research studies have showed that Bt crops have helped in efforts to reduce chemical pesticide use and increase effective yield (Qaim and de Janvry, 2003; Wossink and Denaux, 2006 and Carpenter, 2010).

It is acknowledged through the literature that although Bt cotton cultivation reduced the volume of insecticide used to control bollworm from 864g per ha in 2003 to 10 per ha in 2013, the per hectare active ingredients of insecticide used for sucking pest control more than doubled from 381g in 2003 to 950g in 2013 (Gujar and Peshin, 2022). During early 2010s, cotton growers started to record much lower yields in cotton, as compared to the initial years of adoption of Bt cotton. As the area under Bt cotton started to increase, it provided a more favourable agroecological condition for the pest complex to multiply. In addition to bollworm, other major pests harmful to Bt cotton are whitefly, leafhopper (jassid), thrip, aphid and mirid bug. In 2015, the northern state of Punjab was hit by an outbreak of whitefly, which severely affected more than 65 per cent of the cotton production (Gujar and Peshin, 2022). According to Gujar and Peshin (2022), there has been a steep decline in insecticide applications to control bollworms, the targeted pest affecting Bt cotton, by 97 per cent, however, this has been offset by an increase in insecticide applications by 154 per cent to control sucking pests. In addition, the ineffectiveness of Bt cotton being immune to pink bollworms had raised concerns regarding its sustainability.

Roy (2006) found in an assessment of the social and environmental impact of Bt cotton in India that the continuous and prolonged application of insecticides builds resistance in pests, which further intensifies the usage of higher doses of chemicals. This, in turn, not only damages the ecosystem but has inevitably raised the cost of cotton cultivation, making organic cotton cultivation the second-best alternative (Roy, 2006). Moreover, Bt cotton growing farmers are forced to buy new expensive hybrid seeds each year, erasing the previous savings from the need to purchase less cotton seeds. .

According to the World Health Organization (WHO), to cultivate 5 per cent of land used to cultivate cotton, more than 10 times, 54 per cent of total pesticides, are used in the agriculture in India. This is adversely affecting the environment and ecology, leading to human hazards, such as poor quality of soil health and agroecology, environmental pollution and low profitability in cotton farming. Other factors, such as poor extension services and seed quality, erratic rainfall and lack of credit at reasonable rates, aggravate and worsen the situation for farmers who are unable to cover the increasing costs of production. All these factors are pushing cotton farmers to despair, and at times, death. Transition to sustainable and climate resilient agroecology based on sound science is the solution to the agrarian crisis and farmers' distress. This has raised the demand for eco-friendly organically cultivated or "green" cotton.(Fashion Revolution and Fair Trade India, 2021)

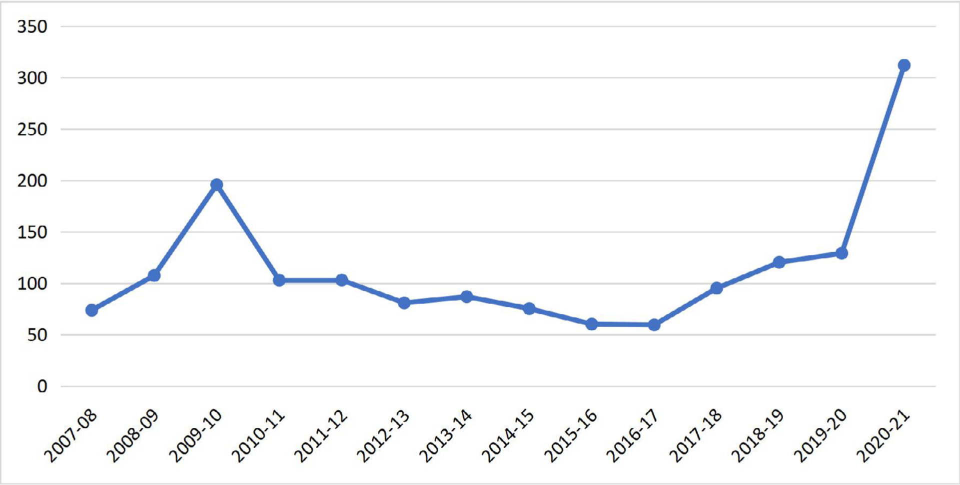
4.2 Potential of organic cotton farming in India

Organic cotton farming is an emerging method, which ensures optimum utilization of natural resources and has the potential to bring environmentally sustainable practices into cotton farming. It is an eco-friendly method that relies on non-chemical inputs and thus decreases pollution hazards. The use of bio-rational products and biocontrol agents for pest management in organic farming does not result in pesticide residues in fibres, which are harmful to users (Rajendran, Venugopan and Tarhalkar 2000). Organic farming is cost effective, results in additional rural employment and does not lead to the multiplication of secondary pests in cotton. In addition, recent studies have pointed out that cultivating organic cotton reduces greenhouse gas emissions, as it produces approximately 46 per cent less carbon dioxide (CO_2) and uses 62 per cent less energy (Bahadur, 2020). All these factors are paving the way to prompt Indian cotton growers to shift from conventional/genetic modification farming to organic cotton farming.

India is the leading producer of organic cotton, accounting for approximately 51 per cent of the global production. According to industry experts, the area under organic cotton cultivation in India is approximately 2 per cent of the total cotton cultivation globally. According to Bahadur (2020),. cotton is the single largest organic crop, covering approximately 45 per cent of the total area under organic cultivation.

Figure 2 presents the production of organic cotton in terms of cotton lint in thousand metric tonnes (MT) from 2007–08 to 2020–21. It shows that the production of organic cotton rose from 2007–08 to 2011–12. According to the Ministry of Textile, global production of organic cotton grew rapidly from 141.5 thousand metric tonnes in 2007-08 to 241.70 thousand metric tonnes (MT) in 2009-10 and then declined rapidly to 117.11 thousand MT in 2016-17 (Parliament of India, 2019). The decline can be attributed to a decrease in the contribution of India from 196 000 MT in 2009–10 to 60,000 MT in 2016–17. Farmers in India used to consider organic cotton farming as a low-volume business because demand for it was limited due to higher prices. A shift in production to other organic crops and the adoption of other sustainable cultivation practices, such as under the Better Cotton Initiative and Fair-Trade Cotton, resulted in the decline ifron organic cotton production in India between 2012–13 and 2016–17 (Bahadur, 2020). However, organic cotton production increased over the period 2017–2020. The increase in production was supported by greater demand stemming from leading brands increasing their use the use of the fibre in their product lines in response to concerns over the textile industry's impact on environment and rising consumer demand for sustainable choices. The overall CAGR for organic cotton was 2.69 per cent from 2007–08 to 2020–21. In 2020–21, India and Türkiye were the major producers of organic cotton, which increased by 48 per cent from the previous year. Rising demand for organic cotton is a major factor driving this growth, which is resulting in higher prices and making it an attractive option for farmers to dedicate a larger share of their certified organic land to growing cotton versus other crops.

Figure 2. Production of cotton lint in India (2007-08 to 2020-21) (thousand metric tonnes)



	Production of Organic Cotton (2007–21) in thousand metric tonnes	Production of Bt cotton 2007–-21 in thousand metric tonnes
CAGR	2.69	1.94
Adjusted R2	0.10	0.23
C.V	61.77	14.91

Source: Parliament of India (2019) and Sood (2021).

Ministry of Textiles data indicate that the production of organic cotton in 2020–21 was 8,10,934 MT compared to 3,35,712 MT in 2019–20 and 3,12,876 tonnes in 2018–19. Organic cotton production is limited to a few states, owing to the high production cost and farmers using illegal genetically-modified seeds, which disincentivizes them to cultivate organic cotton. Over the period 2017–2021, organic cotton production rose sharply despite the proliferation of illegal herbicide-tolerant cotton seeds in Maharashtra, Andhra Pradesh, Telangana and other states. Organic cotton production is concentrated in the states of Madhya Pradesh, Maharashtra, Gujarat, Odisha, and Rajasthan. Together, these states account for 18,61,926 tonnes of organic cotton, which is 99 per cent of the total organic cotton production in India over the period 2017–2021.

Table 3. Compounded annual growth rate, Cuddy Dalle Valle Index for organic cotton and Bt cotton from 2007–08 to 2020–21

Cuddy Della Valle Index	58.55	13.08

When comparing the production of organic cotton vis a vis Bt cotton in 2007–08 with 2020–21 in India, the growth rate of organic cotton is higher, but it has high levels of instability (58.55) as measured by the Cuddy Dalle Valle Index (13.08). This indicates that the production of organic cotton increased at a rapid pace, as compared to Bt cotton, but that there is considerable volatility/instability in the production indices. The volatility/instability could be poor yields, unattractive price premium, or lack of organized market, among other factors.

Although the production of organic cotton in India accounts for approximately 51 percent of the world's organic cotton production, farmers in India do not find this sector as being very attractive due to uncertain and unattractive price premiums for their crop. Accordingly, continuous efforts on the part of the government, such as providing price premium for organic cotton production, easing the procurement process and setting up minimum support price for organic cotton farming in the country. Moreover, contract farming and agricultural startups could be initiated, which would lead to the development of an organized market for organic cotton farmers (Parliament of India, 2019).

Inaccessibility to good quality non-Bt cotton seeds because of inefficient supply chain management is a major challenge faced by organic cotton farmers in India. To overcome that, the Government could foster research and development of non-genetically modified cotton seeds, particularly in indigenous cultivars, and promote effective public-private partnerships. Although yields from organic farming are lower as compared to genetically modified seeds, it should be noted that the cost of chemical fertilizers and pesticides are nil in case of organic farming (Rajendran, Venugopan and Tarhalkar, 2000). The negligible input costs makes it profitable and attractive for cotton growers.

All these efforts could be beneficial for cotton farmers and help make cotton production globally competitive and sustainable, They also could help in raising farmers income and add additional employment in the country.

V. CONCLUSION AND POLICY SUGGESTIONS

Using secondary data from various published sources and applying various statistical tools, the growth performance of cotton in India since independence is reviewed in this paper. Based on results, cotton production has expanded the most in terms of area and yield, but both of them are characterized as having high levels of instability, as compared to yield in which stability is at a moderate level.

In addition to the overall growth analysis, a comparison of the growth performance of cotton is made between the pre Bt cotton introduction phase (1980–81 to 2002-03) and the post-Bt introduction phase (2003–04 to 2021–22). The results indicate that during the introduction of the Bt cotton phase, area, the growth rate was higher for production and yield, which was accompanied with a low level of instability as measured by Cuddy Dalle Valle Index.

In addition, a decomposition model indicated that area and yield, namely the interaction between the two of them, were the main factors behind the increase in total production of cotton since independence to 2021. The contribution of area towards the increase in total output during the pre-Bt cotton phase was positive and quite large, while during the post-Bt cotton phase, yield contributed largely towards higher production of cotton.

A deep analysis of the trends in area, production and yield reveals that the cultivation of Bt cotton helped to increase the production and productivity of the crop for a few years after it was introduced. However, in 2014–15, cotton production and productivity began to decline significantly. This could be due to sudden attacks of white fly, pink bollworm and other secondary pests in cotton, which have developed resistance towards Bt cotton (Gujar and Peshin (2022). A study by Roy (2006) pointed that out the cultivation of Bt cotton is a pesticide-intensive activity. Continuous application of insecticides has built resistance in the pests thereby increasing the requirement of higher doses of chemicals, which has not only adversely affected the ecosystem but has also raised the cost of cultivation. Accordingly, in this paper, concerns regarding the environmental sustainability of Bt cotton are raised and the potential of organic farming in India is explored.

Organic farming is an emerging cost-effective method, which makes optimum utilization of resources and has the potential to promote sustainable and environment friendly cotton farming. Trends in organic cotton cultivation in India are studied for this paper. The findings indicate that that the production of organic cotton increased from 2007–08 to 2011–12, boosted by the challenges faced by Bt cotton cultivation in India. However, from 2012–13 to 2016–17 production of organic cotton declined because of a shift in production to other organic crops and the adoption of other sustainable cultivation practices, such as those proposed by the Better Cotton Initiative and Fair-Trade Cotton. (Bahadur, 2020). However, over the four-year period 2017–2020, the production of organic cotton has again gained momentum, supported by rising demand among major brands using the fibre in their product lines and greater environmental consciousness among farmers and consumers. CAGR for organic cotton was higher as compared to Bt cotton from 2007–08 to 2020–21, but during this period, there was a high level of instability in the production of organic cotton vis a vis Bt cotton in India. Some of the factors behind this are ineffective price premiums for farmers, poor yields from organic cotton, inaccessibility of good quality non Bt cotton seeds and lack of an organized market.

Government schemes, such as Mission Organic Value Chain Development for Northeastern Region, the National Mission on Oilseeds and Oil Palm, and Paramparagat Krishi Vikas Yojana, were initiated to encourage the use of natural on-farm inputs for chemical free farming.

Despite these efforts, organic cotton production in India is limited to a few States, owing to the high production costs, uncertain and unattractive price premiums and farmers using illegal genetically modified seeds. To rectify this, certain actions should be considered by policymakers and the Government. Among them are to set up a minimum support price mechanism, promote price premiums for organic cotton production and ease the procurement process for organic cotton farming in the country. Moreover, contract farming and agricultural startups could be initiated to facilitate the establishment of an market for organic cotton farmers. Basically, organic cotton cultivation in India is more volatile and could be less profitable with relatively lower yields and high costs in comparison to Bt cotton. However, when taking into account that organic cotton it is environmentally sustainable, the social benefits could exceed the smaller amount of profits attained by farmers from cultivating it. Therefore, government and policymakers should consider offering output price incentives and input subsidies for organic farming.

Raw organic cotton (seed cotton) is mandated under the certification from the National Programme for Organic Production as specified under the Foreign Trade Act of Directorate General of Foreign Trade. The processing activities, such as ginning, spinning, knitting and weaving, are considered to be mandatory requirements for export by the National Programme for Organic Production Processed organic cotton is exported under a private certification system. To overcome these challenges, issues related to the supply chain for processed cotton, national agencies, such as the Agricultural and Processed Food Products Export Development Authority, are developing standards for organic textiles for the entire value chain in a phased manner and getting them accredited from certification agencies. An efficient certified system could raise farmers income and serve as a stamp of surety for buyers of organic products.

Other major challenges faced by farmers that impedes the adoption of organic cotton cultivation is the unavailability of non-Bt seeds and difficulty in accessing organic fertilizers and bio-pesticides. In this regard, the Government could offer incentives or subsidies to enable farmers to attain wider access to non-Bt seeds. It could promote research and development of non-genetically modified cotton seeds, particularly in indigenous cultivars. Additionally, the government could encourage farmers to use their own bio-fertilizers and pesticides for wider adoption of organic cotton cultivation in India.

Another action to consider is for the Government to raise awareness among farmers' producer organizations on organic cotton cultivation through sustainable farming practices such as soil fertility management and pest management. It could organize training programmes for organic cotton farming that involves chemical-free cultivation. Safe and environmentally friendly inputs, such as bio-fertilizers and bio-pesticides, along with certain practices, such as crop rotation, would make organic cotton farming a far more sustainable option for farmers, as well as for the ecosystem. These practices could reduce production costs substantially and prove to be more profitable for small and marginal cotton-growing farmers who rely on growing pesticide intensive Bt cotton seeds.

These suggested policy measures could enhance the production of organic cotton production, which, in turn, could raise incomes and lead to additional employment, while helping to make cotton production in India sustainable.

NOTE ON CONTRIBUTOR

Anchal Arora is an assistant professor of economics at Indian Institute of Foreign Trade, New Delhi India. Her broad area of research includes environment and agricultural economics. She is a recipient of various international fellowships and has published in reputed peer-reviewed journals.

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EARLY CAREER RESEARCHER

DEVELOPMENT OF ASIA-PACIFIC COUNTRIES: DOES BELT AND ROAD INITIATIVE MAKE ANY DIFFERENCE?

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Using annual data for the period 2000–2019, the paper reviews economic progress in Asia-Pacific countries and assesses whether the China-led Belt and Road Initiative (BRI) contributes to this trend. Based on selected development indicators and their trends before and after the announcement of the Initiative, the findings confirm significant trade expansion associated with growing connectivity achieved through infrastructure finance from China to BRI economies vis-à-vis their non-BRI counterparts. The rising trade ties are associated with output growth, contributing to the development trajectories of BRI countries and bringing some modest positive spillover effects to non-BRI members. Policy implications are proposed accordingly.

Keywords: China; Belt and Road Initiative; infrastructure; development assistance; Asia-Pacific region

JEL classification: 010, 053

I. INTRODUCTION

The Asia-Pacific region has become an increasingly important part of the global economic landscape over the past six decades.[1] The region's rapid transformation was sparked first by Japan, and then by the newly industrialized economies of the Republic of Korea; Taiwan Province of China; Hong Kong, China; and Singapore, and most recently by China, India and Bangladesh in a "flying-geese"-like formation.[2] In part, this improvement reflects export-led economic growth, more openness to foreign direct investment (FDI) and cooperation between countries, notably in the South.

The epicentre of this remarkable transformation has been inexorably moving towards China since the turn of this century due to positive growth spillovers from the country to other Asian-Pacific countries. In addition to trade linkages, China has emerged as an influential actor in global development finance among emerging donors, mainly because of the availability of project finance. Development finance from traditional sources has been inadequate in the face of growing needs and challenges, especially for green transformation. Moreover, development finance from conventional sources is becoming more constrained and unpredictable. Most of the wealthy countries that are members of the Organisation for Economic Co-operation and Development (OECD) have failed to meet promised annual aid disbursements of 0.7 per cent of their gross national income (GNI), made more than fifty years ago. Worse, actual disbursements have declined from 0.54 per cent in 1961 to 0.33 per cent in recent years.[3]

Formerly an aid recipient itself, China has emerged as a key official creditor, rivalling traditional Western donors by committing more than $843 billion in official finance to developing countries between 2000 and 2017 (Custer and others, 2021). Accordingly, China has cemented its position as one of the world's largest development financers partly because funding from OECD donors has declined (Hutchings, 2020). More recently, the country's Belt and Road Initiative,[4] a platform for its global investment,

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[1] See ESCAP (2014) for a comprehensive analysis of the transformation and resurgence of the Asia-Pacific region.

[2] The phrase "flying geese pattern of development" was coined by Japanese economist Kaname Akamatsu in articles in Japanese written in the 1930s, and became familiar in wider academia in the early 1960s (Kojima, 2000).

[3] See https://www.oecd.org/dac/financing-sustainable-development/development-finance-standards/official-development-assistance.htm (accessed on 9 June 2022).

[4] China proposes to build a transport network along the Silk Road Economic Belt – the "Belt" and the 21st Century Maritime Silk Road – the "Road", officially known as the "Belt and Road Initiative" (see figure A.1 in the appendix).

notably in all subregions of Asia and the Pacific, has given impetus to the increasing debate on the potentialities (and pitfalls) of the growing presence and engagement of China with other economies in the region. Whether this new dimension of Chinese investment in Asia and the Pacific and the dynamic transformation of the region are interrelated has yet to be determined or documented. This debate is critical, as it affects regional development and is central to the global social and economic outlook.

The Belt and Road Initiative is an enormous infrastructure project that can stimulate economic growth globally, including in developing Asia-Pacific countries. Years of tepid economic recovery in Europe and the United States from the 2008 global financial crisis and decades of secular stagnation in Japan has resulted in shrinking export markets for developing countries of the Asia-Pacific region. Accordingly, China has become an important trade partner for Asia-Pacific developing countries, especially by connecting them to the global value chains, as the country has emerged as the "factory of the world" (Das, 2014). Additionally, China has "demonstrated" comparative advantages in infrastructure, while many Asia-Pacific economies possess "latent" comparative advantages due to their "long-term orientation" and "patience" with investment. According to Lin and Wang (2017, p.149), "[o]nly if these comparative advantages are utilized can these economies cooperate to potentially achieve win-win [outcomes]".

China can also ensure its economic growth through cross-border trade and investment by enhancing connectivity between China and the Belt and Road Initiative economies and among Belt and Road Initiative economies (Huang, 2016; Wang and Tian, 2022). This outcome is highly desired by China, given that the enormous demand for Chinese products from its old trading partners, such as the United States of America, the European Union and Japan, is unlikely, at least in the short run. At the same time, infrastructure projects may facilitate Chinese exports of construction-related goods.

Consequently, the Belt and Road Initiative offers "win-win" prospects for China and recipient countries; as OECD notes, "Its [China's] investments, by building infrastructure, have positive impacts on countries involved. Mutual benefit is a feature of the BRI" (OECD, 2018, p.3). Among these Chinese recipients, the role of the Asia-Pacific region is critical, as it involves five out of six economic corridors under the Belt and Road Initiative.[5] Countries within these corridors are connected through a complex network of roads (including maritime silk routes), rails and pipelines. Accordingly, the Asia-Pacific region can benefit from the Chinese initiative

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[5] China–Indochina Peninsula Economic Corridor, the China–Pakistan Economic Corridor, the China–Central Asia–West Asia Economic Corridor and the Bangladesh–China–India–Myanmar Economic Corridor.

with substantial infrastructure investment in cross-border logistics facilities, which mitigates the disadvantages and improves the infrastructure distance of the host countries from China.

In the light of the above background, the objective of the present paper is to provide a qualitative assessment of the economic progress of Asia-Pacific countries (excluding China). More explicitly, an attempt is made to explore how the Belt and Road Initiative has contributed to their economic progress. This is done through a comparative analysis of some key indicators of development of the Asia-Pacific countries before and after the launch of the Belt and Road Initiative. Estimating the impact of the Initiative on the economic progress of the Asia-Pacific region qualitatively may provide a basis for in-depth quantifications of the Initiative's impacts.

The main contributions for this paper are: first, a number of countries in the Pacific subregion are included in the analysis that have been absent in previous studies. This may appear as an anomaly, as the subregion is not directly connected to the ports and cities of countries along the Belt and Road Initiative. Nevertheless, experts have argued that given the difficulties in participating in markets in Asia, the Belt and Road Initiative makes sense to the Pacific island countries, which have been restricted from trading with OECD countries and other Pacific states (Szadziewski, 2021). In addition, the Initiative's contributions to human development in the subregion have yet to be documented. Second, the work of Luo and others (2021) is followed, but previous research has been enhanced by investigating the impact of infrastructure finance before and after the implementation of the Initiative. In line with Luo and others (2021), close attention is paid to the Belt and Road Initiative economies of the Asia-Pacific region and their performance is compared with non-members of the region using a relatively long time series. Third, the heterogeneous impacts of the Belt and Road Initiative is studied further across the five Asia-Pacific subregions where Initiative and non-Initiative countries are located; five case examples, one from each subregion, are presented to assess the robustness of the qualitative analysis.

There are at least four caveats worth mentioning: first, the sample includes only a subset of countries in the Asia-Pacific, so the evidence is relevant to these countries only. Second, different socioeconomic parameters used in this article may not be perfect, as they do not always reflect contextual factors that apply to specific countries. Still, these indicators make it possible to draw a reasonably accurate picture of development progress. Third, the infrastructure finance estimates may differ from other estimates due to differences in how infrastructure is defined and the methodologies used; and fourth, the results should be interpreted as evidence of association rather than causation. Nevertheless, the result of the association between Chinese finance for infrastructure, economic growth and trade expansion is one with considerable policy significance.

The paper is organized as follows: section 2 includes a discussion on the data and methodology of the paper. Section 3 contains an outline of the economic progress of Belt and Road Initiative and non-Belt and Road Initiative economies of the Asia and the Pacific; in this section, some important patterns and trends of the subregions are highlighted to fully understand the current situation. Section 4 contains analyses to what extent the Belt and Road Initiative is linked to the development progress of Asia-Pacific countries. Section 5 includes case studies. Section 6 concludes the paper.

II. DATA AND METHODS

Macro data of 40 lower- and middle-income countries in the Asia-Pacific region over the period 2000–2019 are used. The role of China as an emerging development partner was more explicitly recognized in this period (Strange and others, 2017). Forty countries are divided into 34 Belt and Road Initiative[6] (and six non- Belt and Road Initiative) economies that have signed (not signed) cooperation agreements with China on the Initiative during the period 2013–2017, and for which data for Chinese infrastructure finance are available (see table A.1 in the appendix). Furthermore, to reveal subregional trends in economic progress for the Asia and the Pacific, the region is subdivided into five groups: Central Asia, South Asia, South-East Asia, North-East Asia and the Pacific.

Data on different socioeconomic indicators were taken from many secondary sources, including the World Development Indicators (WDI) data of the World Bank, World Integrated Trade Solutions data, the *United Nation's Human Development Report*, OECD data, Horn, Reinhart and Trebesch (2021b) and Custer and others (2021). Table A.2 in the appendix presents the definitions and sources of the variables used.

In terms of the method of analysis, simple statistical tools, such as ratio analysis, exponential growth and geometric mean, are used. For subregional trends, the data set is averaged over four-year intervals for each of the five subregions over five points: 2000–2003, 2004–2007, 2008–2011, 2012–2015, and 2016–2019. The time point 2016–2017 for Chinese infrastructure finance is a two-year average covering 2016–2017. For the analysis in this paper, the period 2000–2013 is used as the pre-Belt and Road Initiative years and the period 2013–2019 is used as the post-Belt and

[6] High-income countries in the Asia-Pacific region are excluded, such as Brunei Darussalam, Japan, Singapore and the Republic of Korea. Their inclusion distorts the development trends in the region (results including these countries are available upon request). The list of Belt and Road Initiative economies is from https://green-bri.org/countries-of-the-belt-and-road-initiative-bri/?cookie-state-change=1658280461455.

Road Initiative years. While 2020 is the most recent annual data for sample countries, this year was omitted due to the COVID-19 pandemic.

III. ECONOMIC OVERVIEW

Many countries in the Asia-Pacific region have progressed at a remarkable speed and scale. Most noticeably, Bangladesh, China, India and the Lao People's Democratic Republic, where growth appears to remain robust following the 2008 global financial crisis, which is encouraging. Nevertheless, along with China, the Asia-Pacific countries face formidable challenges, but they have demonstrated pragmatic growth strategies, facilitating a recovery after external shocks and the sustainability of future progress. The result has been unprecedented economic growth and a decline in poverty. As shown, this drastic evolution has been accompanied by structural transformation, especially industrialization, facilitated by FDI inflows and trade. Accordingly, the focus of this section is on the evolution of Belt and Road Initiative economies of the Asia-Pacific region in general, and trends in the subregions. Economic progress made by non-Belt and Road Initiative economies is also discussed.

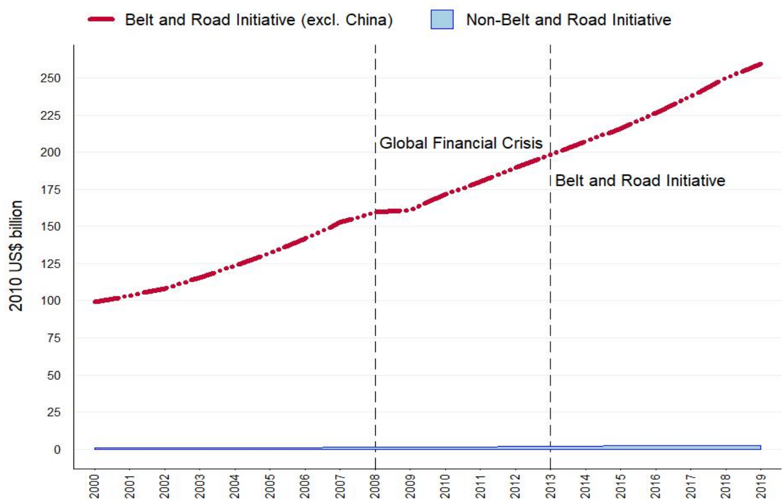
3.1 Economic growth and human development

Although some Belt and Road Initiative countries in North-East Asia and South-East Asia have been progressing rapidly since the late 1960s and early 1980s, most others' historic march towards rapid expansion started in the early 2000s. Panel A of figure 1 shows that the Belt and Road Initiative economies real gross domestic product (GDP) exceeded $200 billion in the post-Belt and Road Initiative years. Non-Belt and Road Initiative economies lagged far behind their counterparts; the difference is statistically significant at the 1 per cent level. The real GDP on non-Belt and Road Initiative economies crossed $2 billion over the same period.

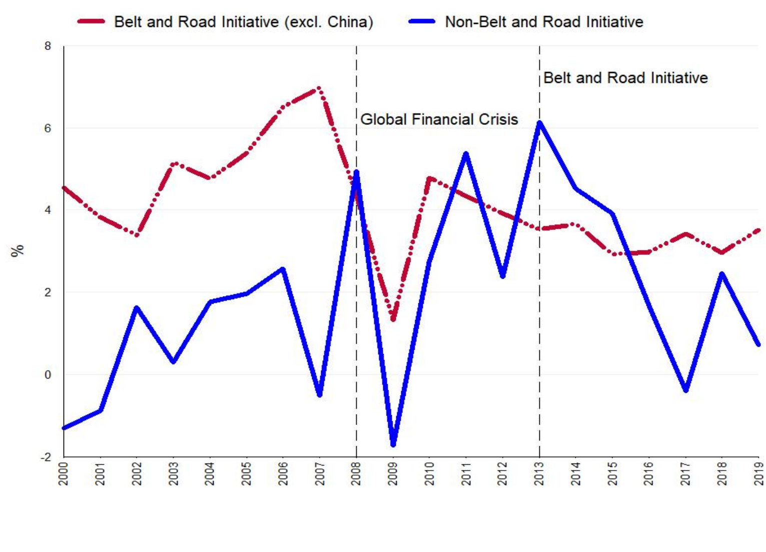
At the same time, the Initiative countries' economic growth was spectacular in the early 2000s (panel B, figure 1). Their per capita real GDP grew by 3 to 7 per cent, on average, from 2000 to 2007, which was much higher than their counterparts; their difference is statistically significant at the 1 per cent level. Similar to others, Initiative and non-Initiative countries' economic growth was also affected by the great financial crisis in 2008, but they recovered quickly. Despite a certain degree of recovery, per capita real GDP growth generally in Initiative countries failed to return to the pre-crisis level. This setback may be attributed to internal factors, such as environmental sustainability, demographic factors and rising inequality, and the outside world, such as global commodity price volatilities (ESCAP, 2014; Lall and Lebrand, 2020). Both Belt and Road Initiative and non-Belt and Road Initiative economies experienced a relatively downward trend in real GDP growth during the post-Belt and Road Initiative years. Still, growth in Initiative countries has been more stable and, on average, higher than in non-Initiative countries over that time period.

Figure 1. Real gross domestic product and economic growth, 2000–2019

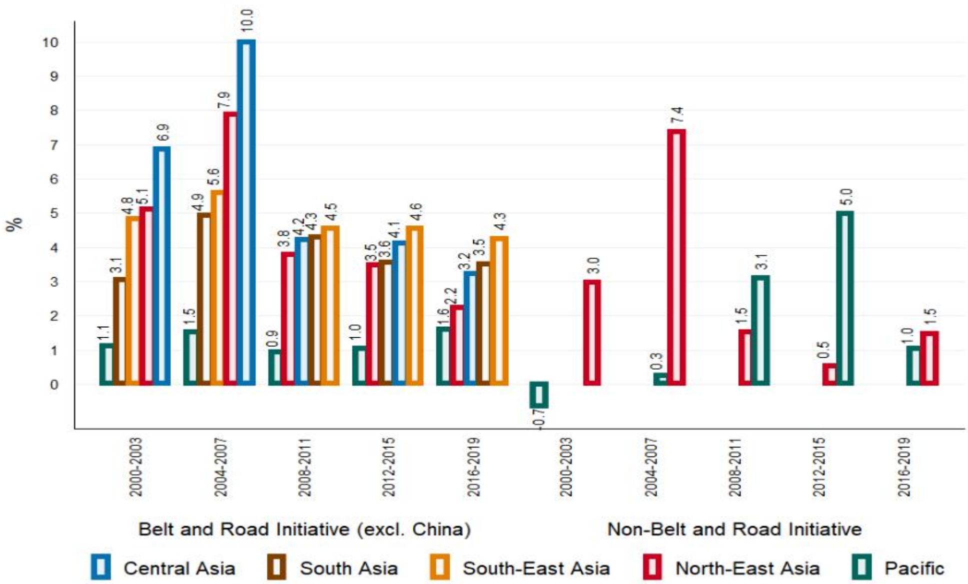
Panel A. Real gross domestic product



Panel B. Per capita real gross domestic product growth



Panel C. Per capita real gross domestic product growth by subregion



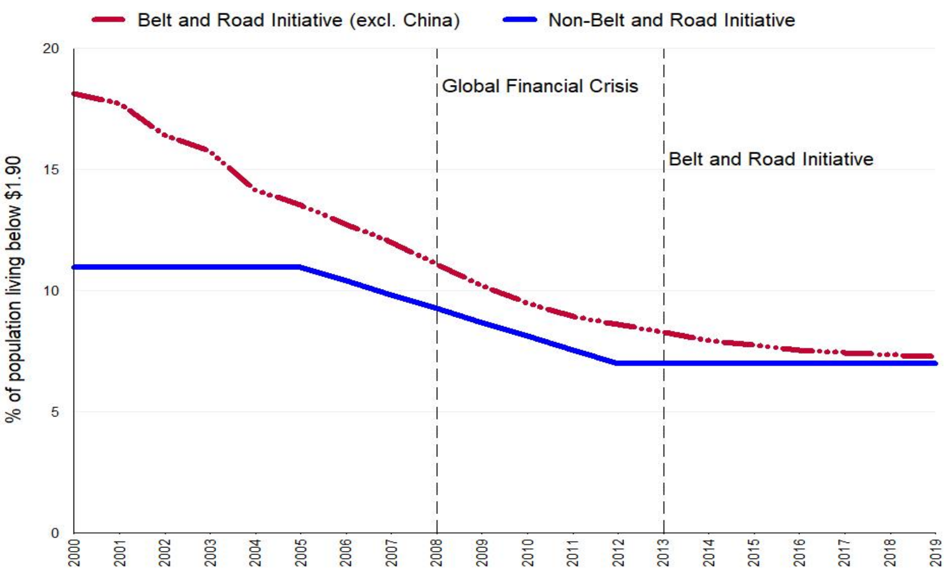
Source: Author's estimates based on World Bank (2021)

Panel C of figure 1 shows per capita real GDP growth in Belt and Road Initiative and non-Belt and Road Initiative economies by subregion. Belt and Road Initiative countries in South-East Asia recorded relatively higher real GDP growth than in other subregions in recent periods. The difference between subregions is statistically significant at the 5 per cent level. Infrastructure improvement, expansion in trade linkage and rising FDI inflows to South-East Asia contributed significantly to this achievement (Zhai, 2018; Bird, Lebrand and Venables, 2020; Yang and others, 2020). The same factors contributed to higher output growth in Central Asia in the early 2000s. Economic growth in North-East Asia has been dominated by Mongolia and the Russian Federation, where growth is mainly fuelled by the resource boom and has been marked by boom-and-bust cycles. Almost all subregions of the Asia-Pacific region experienced an economic slowdown between the periods 2012–2015 and 2016–2019. In the sample, six non-Belt and Road Initiative countries are in North-East Asia and the Pacific, and no noticeable pattern is observed for these countries.

Economic growth in the Asia-Pacific region is expected to accelerate human development by raising overall living standards. Indeed, panel A of figure 2 illustrates that the Belt and Road Initiative economies recorded rapid poverty reduction as early as the 2000s, measured by the percentage of people living in extreme poverty, on less than $1.90 a day. Although the global financial crisis and more rapid population growth slowed the pace of poverty reduction in these economies, the trend of decreasing poverty continued in later periods.[7] A similar downward trend is also observed in non-Belt and Road Initiative economies, but the poverty incidence difference between Initiative and non-Initiative economies is not statistically significant.

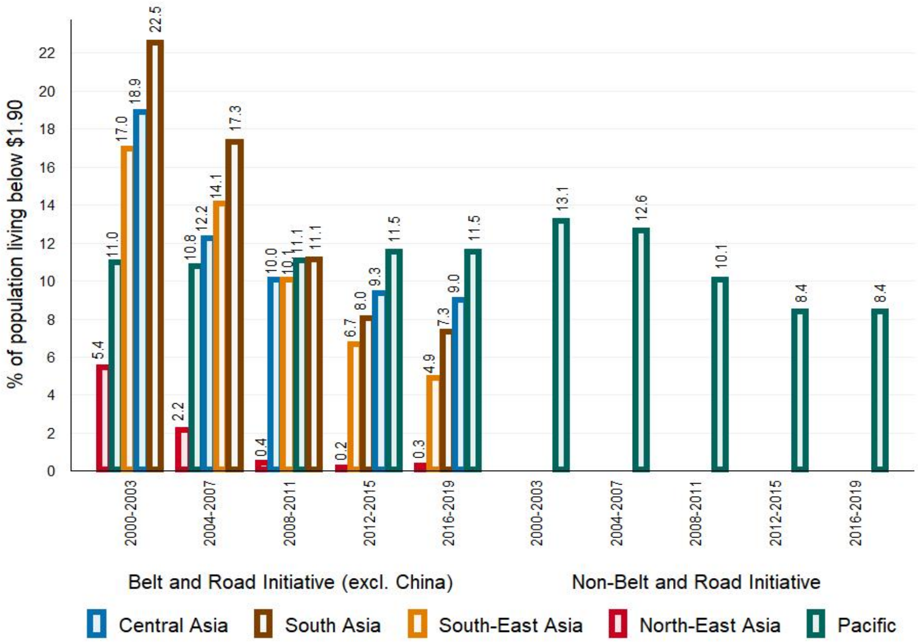
Figure 2. Human development, 2000-2019

Panel A. Poverty



[7] Note that few observations for poverty were taken in the post Belt and Road Initiative years, notably for India and Pacific Island countries. This caveat must be taken into account when interpreting the results.

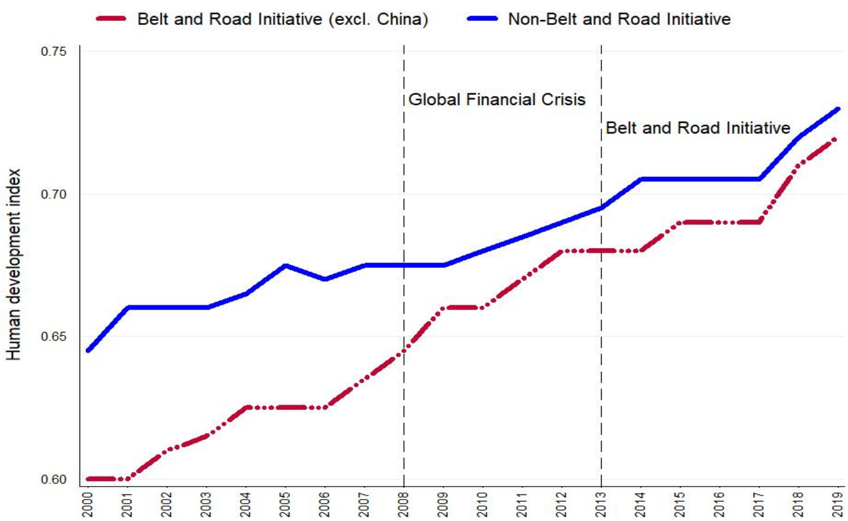
Panel B. Poverty by subregion



Panel B of figure 2 shows the incidence of poverty in Belt and Road Initiative and non-Belt and Road Initiative economies by subregion. Although the initial levels vary greatly, Initiative countries in most subregions have managed to reduce poverty over time. A similar trend has been observed for non-Belt and Road Initiative countries in the Pacific. Unprecedented economic growth, social safety nets and targeted initiatives have lifted a large proportion of the population out of poverty (Gao and He, 2022).

In general, Belt and Road Initiative economies in South Asia experienced relatively higher poverty than elsewhere for most of the period. More rapid population growth than poverty reduction coupled with inequality in income and assets, and corruption can be attributed to the relatively high poverty incidence in South Asian countries (Devarajan, 2005). The dramatic improvement in poverty reduction has been uneven in Belt and Road Initiative countries in the other subregions.

Panel C. Human development index



Panel D. Human development index by subregion

Source: Author's estimates based on World Bank (2021) and UNDP (2020).

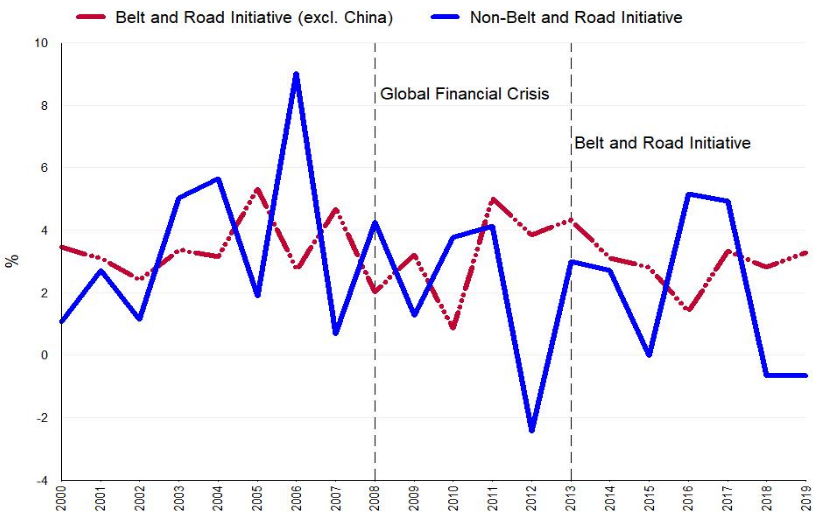
Furthermore, progress accelerated in Belt and Road Initiative and non-Belt and Road Initiative economies in education, health and income dimensions, as displayed in the human development index (HDI) (panel C, figure 2). There has been a noticeable convergence, but not statistically significant, in HDI values between Belt and Road Initiative and non-Belt and Road Initiative economies in the post-Belt and Road Initiative years. This also holds true when considering Initiative and non-Initiative economies by subregion (panel D, figure 2). Initiative economies and their counterparts in North-East Asia recorded the highest HDI value. Those in Central Asia also attained sizable HDI scores. On the other hand, Initiative countries in South and South-East Asia and the Pacific are on par and do not lag far from those in North-East and Central Asia. The relatively poor performance of these countries can be attributed to poverty, the crisis of governance, difficult geopolitical situations and an unfavourable external economic environment (Devarajan, 2005; ESCAP, 2014).

3.2 Industrialization

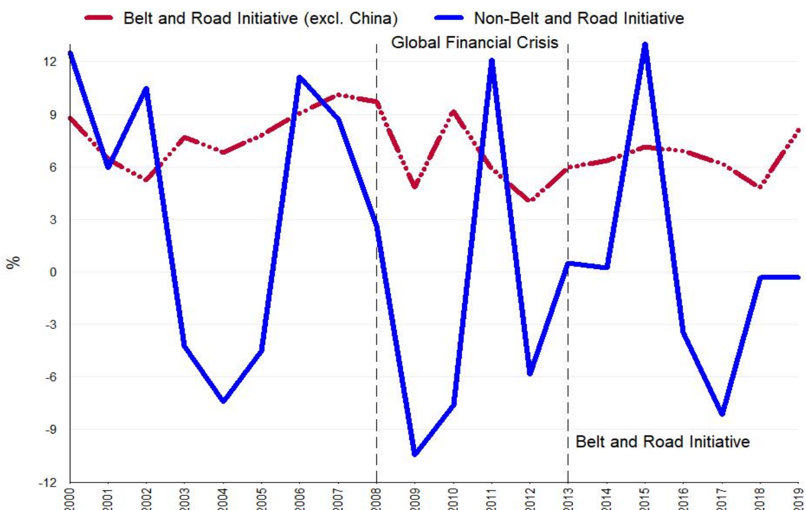
Rapid growth historically has always been associated with industrialization: moving out of low-productivity agriculture to higher-productivity industry (including construction) and, more notably, into services. This is particularly true for Belt and Road Initiative economies, typically in South-East Asia. Only a few other economies, such as Bangladesh and India, have been able to emulate this pattern. In recent decades, industrialization has been subdued in most Belt and Road Initiative economies. Even premature deindustrialization has been occurred in some lower- and upper-middle-income Belt and Road Initiative countries, such as Indonesia, the Lao People’s Democratic Republic and Thailand, due to globalization. Figure 3 tends to support this view. In the wake of the global financial crisis, industrial shares of real GDP ceded their place to services (panels B and C, figure 3). The shares of services often exceeded industrial shares in the period after the global financial crisis and have been a vital growth stimulus. Still, much of the shift in economic activity has occurred through industrial growth in the post-Belt and Road Initiative years, not necessarily at the expense of agricultural growth: the share of agriculture in real GDP rose by 1 to 5 percentage points between 2000 and 2019 (panel A, figure 3).

Figure 3. Share of real value added by industry, 2000-2019

Panel A. Agriculture

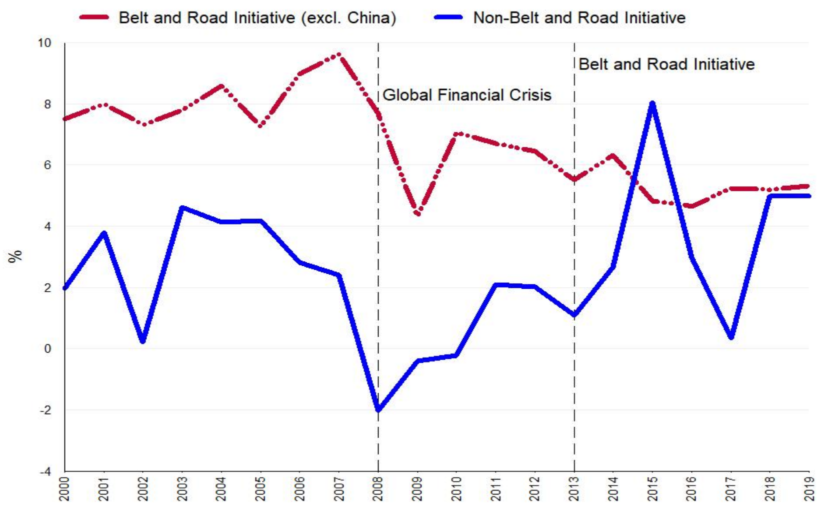


Panel B. Industry (including construction)



The pace of structural transformation in non-Belt and Road Initiative countries is very different from their Belt and Road Initiative counterparts, but it is only statistically significant (at the 5% level) for the industry and services components. Industrial shares surpassed services shares of real GDP, but real GDP in both sectors weakened during the post-Initiative years, with the share of agriculture in real GDP varying noticeably.

Panel C. Services

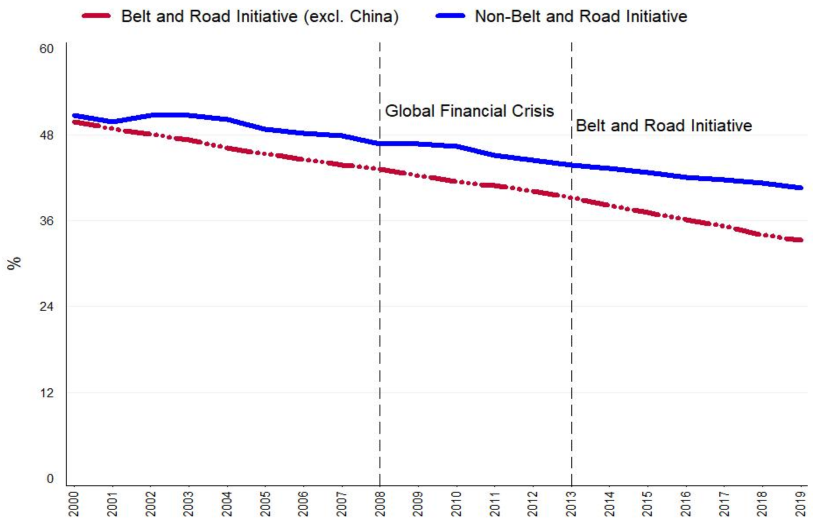


Source: Author's estimates based on World Bank (2021)

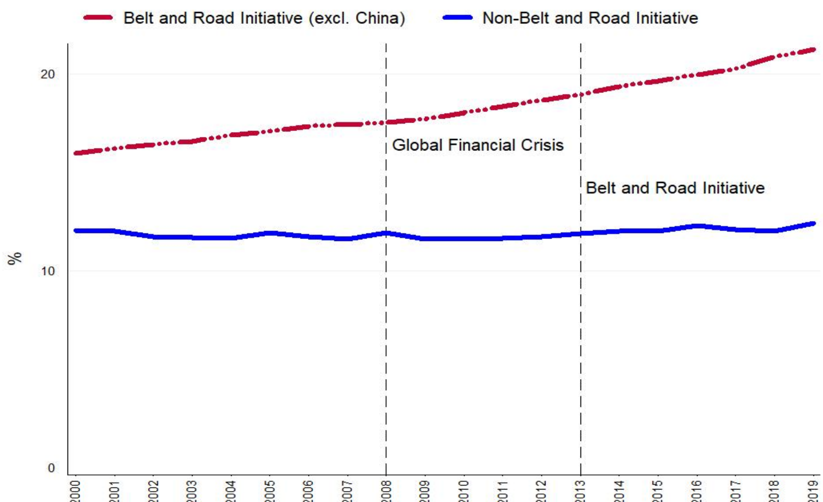
In Belt and Road and non-Belt and Road economies, structural change in employment is more apparent than in value added. In the Belt and Road economies, there has been a 17 percentage point decline in the agricultural share of employment being distributed across industry and services over the 2000–2019 period (panel A, figure 4). The industrial share of employment has barely changed in the post-Belt and Road Initiative years during which the services sector absorbed most of the labour force, transforming into a services economy (panel C, figure 4). However, the services sector markedly suffers from low labour productivity, reflecting the dominant role of traditional services in developing countries (Park and Noland, 2013). Non-Belt and Road economies have gone through a similar cycle of industrialization: the industrial share of employment remained at approximately 12 per cent; the services share rose slowly, reaching 47 per cent in 2019. The agricultural share of employment remained close to 43 per cent over that time period.

Figure 4. Share of employment by industry, 2000–2019

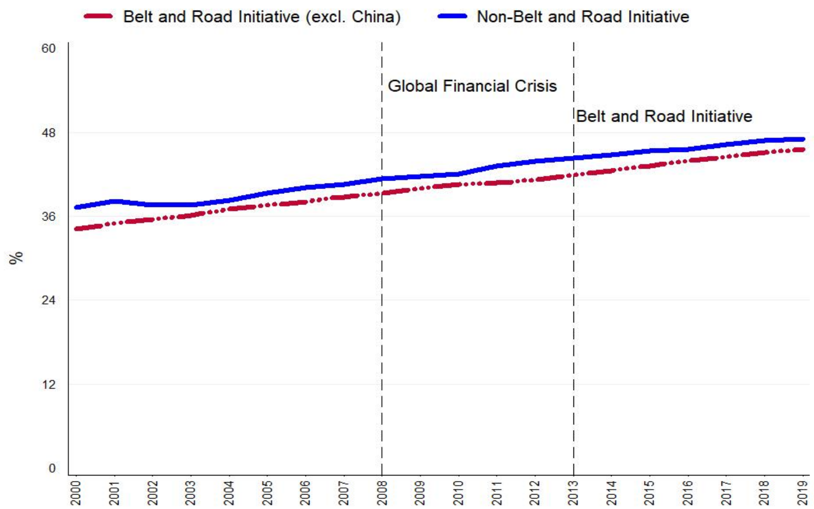
Panel A. Agriculture



Panel B. Industry (including construction)



Panel C. Services



Source: Author's estimates based on World Bank (2021).

3.3 Possible contributors to industrialization

Foreign direct investment inflows and trade relative to GDP over time appears to have facilitated the process of industrialization in Belt and Road Initiative economies and are important growth stimulus (Zhai, 2018; Foo, Lean and Salim, 2020; Yang and others, 2020). Panel A of figure 5 shows FDI in the Belt and Road Initiative economies expanded rapidly in the early 2000s, spurring economic growth in many Initiative countries over the same period (ESCAP, 2014). These investments generally involve links with local firms and technology transfers and use cheap labour and local materials. Due to slowing economic growth worldwide following the global financial crisis, FDI in Initiative economies declined well before the COVID-19 pandemic. Still, in post-Belt and Road Initiative years, their performance in attracting FDI has been more impressive as compared to non-Belt and Road Initiative counterparts, mainly fuelled by greenfield investment and expanding transport networks (Zhai, 2018; Chen and Lin, 2020).[8] The difference in trends between Initiative and non-Initiative economies is statistically significant at the 5 per cent level. Non-Initiative economies are not indifferent to this pattern of capital inflows. It may reflect their geographic

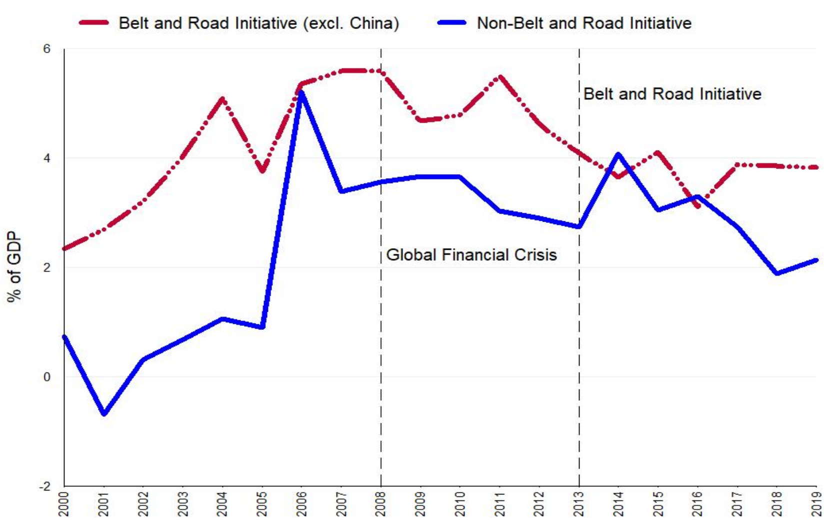
[8] The proliferation of direct flights, liner shipping, and high-speed rail have helped spur global investments.

proximity to the Belt and Road Initiative bloc along with improved measures for facilitating FDI inflows.

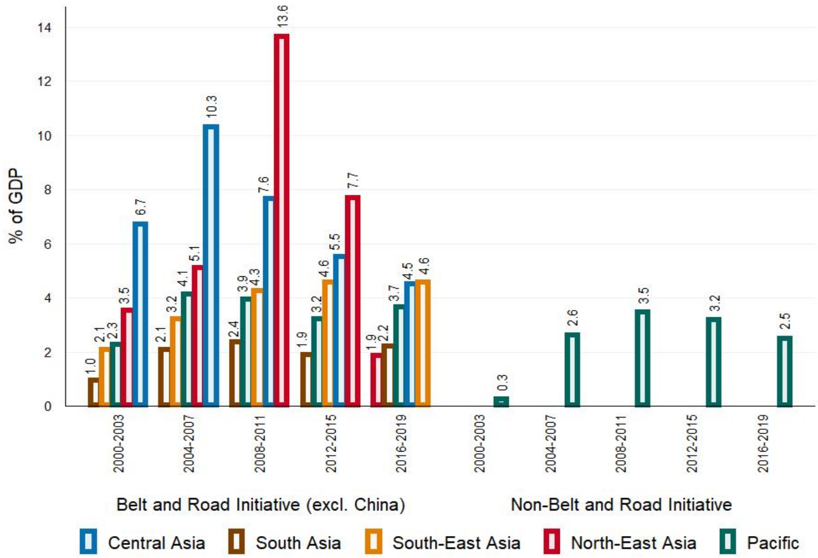
Panel B of figure 5 depicts FDI inflows relative to GDP in Belt and Road Initiative and non- Belt and Road Initiative economies by subregion. Turning to the Initiative countries, there is no consistent pattern across most subregion, but the figure does show a downward trend following the global financial crisis. The only exception is South-East Asian countries, which benefited from an increasing share of FDI over the study period due to their competitive advantages. Elsewhere, Central Asian countries are able to attract FDI inflows due to their strength in natural wealth in addition to favourable policies for foreign investment (Arazmuradov, 2015). A similar downward trend following the global financial crisis is observed for non-Belt and Road Initiative economies in the Pacific.

Figure 5. Foreign direct investment and trade, 2000–2019

Panel A. Net inflows of foreign direct investment

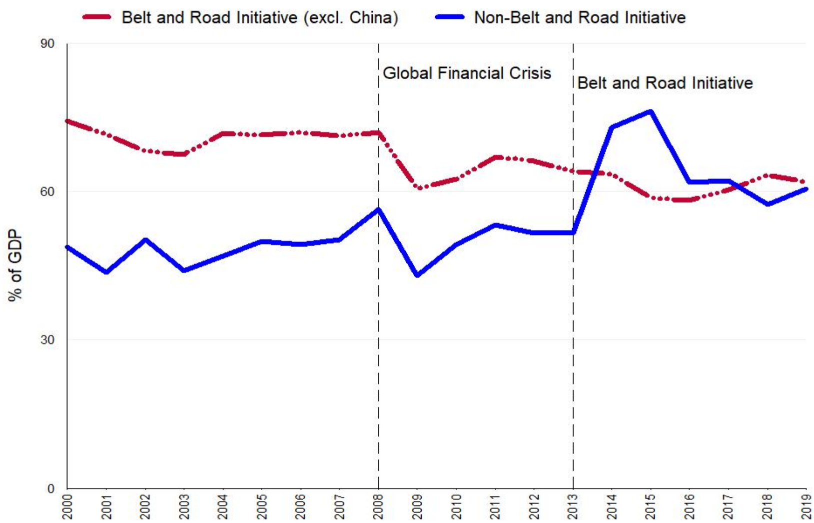


Panel B. Net inflows of foreign direct investment by subregion



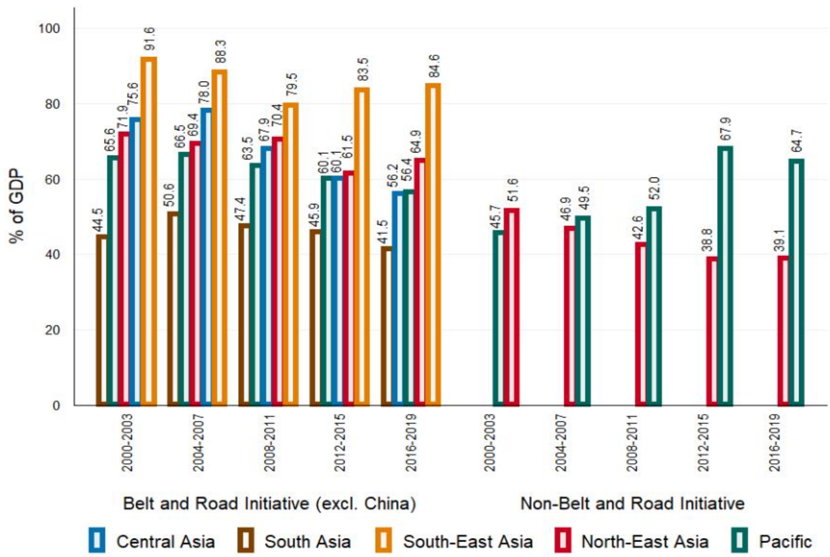
Panel C of figure 5 shows that Belt and Road Initiative economies experienced a larger increase in merchandise trade relative to GDP than their counterparts over much of the observation period. The difference in the trend is statistically significant at the 5 per cent level. Growing trade linkages among Belt and Road Initiative countries, trade liberalization and easing of the bottlenecks in trade procedures are the main factors supporting this result (Zhai, 2018; Foo, Lean and Salim, 2020). In pre-Belt and Road Initiative years, trade relative to GDP averaged 70 per cent. It declined to approximately 60 per cent in post-Belt and Road Initiative years due to the global economic downturn and trade tension. Despite an unstable trend in the early 2000s, there was modest spillover benefits to non-Initiative members to the point that they even surpassed their counterparts (statistically significant only at a 10 per cent level) during the period 2014-2016. These results highlight the trade creation effect of infrastructure being built along the Belt and Road Initiative bloc, which serves as an important tool to stimulate economic integration outside the bloc.

Panel C. Trade



Turning to two-way merchandise trade relative to GDP, in Belt and Road Initiative and non- Belt and Road Initiative economies by subregion, it appears that Initiative economies in South-East Asia experienced greater trade expansion than in other subregions during the 2000-2019 period (statistically significant at a 1% level) (panel d, figure 5). The geographic proximity of South-East Asian countries to economic corridors and improvement in the trade facilitation process are the main factors supporting this result (Zhai, 2018; Yang and others, 2020); the trade gains, on average, have ranged from 84 to 86 per cent of GDP in post-Belt and Road Initiative years. Zhai (2018) shows that a large trade boost increased real income in many Initiative countries in South-East Asia. Initiative countries in Central and North-East Asia also have experienced an upward trend in merchandise trade due to their sizeable intraregional trade linkages (Yang and others, 2020). The pattern of trade promotion is mixed for non-Initiative countries in North-East Asia and the Pacific.

Panel D. Trade by subregion



The analysis indicates that Belt and Road Initiative and non-Belt and Road Initiative members have increased their real GDP and experienced economic growth, but the overall performance was better for Initiative economies. The rapid industrialization of some Initiative economies in the early 2000s and labour movement to the service sector accompanied economic growth. As the service sector is dominated by low productivity, improving it via regulatory infrastructure and human capital can contribute to poverty reduction and inclusive growth in the Asia-Pacific region. The qualitative analysis recognizes the availability of FDI inflows, and that interplay with trade is likely to affect economic growth and accordingly, positively contribute to human development in Initiative economies. Notwithstanding, other trends on the horizon might contribute to the heterogeneity of the performance between Initiative and non-Initiative economies. Section 4 provides more details about this alternative trend.

IV. DOES THE BELT AND ROAD INITIATIVE MAKE ANY DIFFERENCE?

More than 100 countries are covered by the Belt and Road Initiative. They are primarily low-income countries that have underinvested substantially in infrastructure, mainly in the energy and transport sectors (OECD, 2018). Despite record investment in infrastructure ($2.5 trillion to 3.8 trillion per year) through bilateral and multilateral donors, developing Asian countries alone require $14 trillion until 2030 (OECD, 2018). The highest investment needs in infrastructure, as per cent of GDP, within the Asia-Pacific region are for the Pacific (9.1%). This is followed by South Asia (8.8%), Central Asia (7.8%), South-East Asia (5.7%), and North-East Asia (5.2%).

Against this backdrop, the Belt and Road Initiative fills a significant gap: from 2005 to 2016, infrastructure finance extended by China for the Belt and Road Initiative economies in the Asia-Pacific region was approximately $230.26 billion (AEI, 2021). The highest investment was in South-East Asia (46%), followed by South Asia (37.3%), Central Asia (15.3%) and the Pacific (1.5%). These vast investments from China are indispensable to laying the foundation for sustainable growth and increasing living standards for other countries along the Belt and Road Initiative, which account for approximately 65 per cent of the world population (Huang, 2016). In particular, commitments made by China to infrastructure financing to bottleneck-releasing sectors, such as energy, transport and communication, can significantly affect growth. Recent empirical studies tend to support this view (Zhai, 2018; de Soyres, Mulabdic and Ruta, 2020; Yang and others, 2020).

Accordingly, in this section, the growing role of China in infrastructure finance before and after the commencement of the Belt and Road Initiative is reviewed. The "anticipation" effect of such an initiative is investigated by comparing trade expansion with China between Initiative members and non-member countries before and after the commencement of the Belt and Road Initiative This exercise is restricted to the period between 2000 and 2017 because 2017 is the most recent year from which data on trade and Chinese infrastructure finance are available at the time of writing.

4.1 Infrastructure finance

Highlighting its own experience, China included infrastructure construction under Belt and Road Initiative projects. Intuitively, infrastructure builds a foundation for exchange in activities in the long run between countries with growth potential but are constrained due to physical limitations. Much of the infrastructure deficit in the Initiative economies is related to energy, transport and telecommunications (OECD, 2018). Accordingly, the massive investment made by China was in these key connectivity sectors. In this paper, infrastructure finance refers to official Chinese flows to the energy, transport and telecommunications sectors.

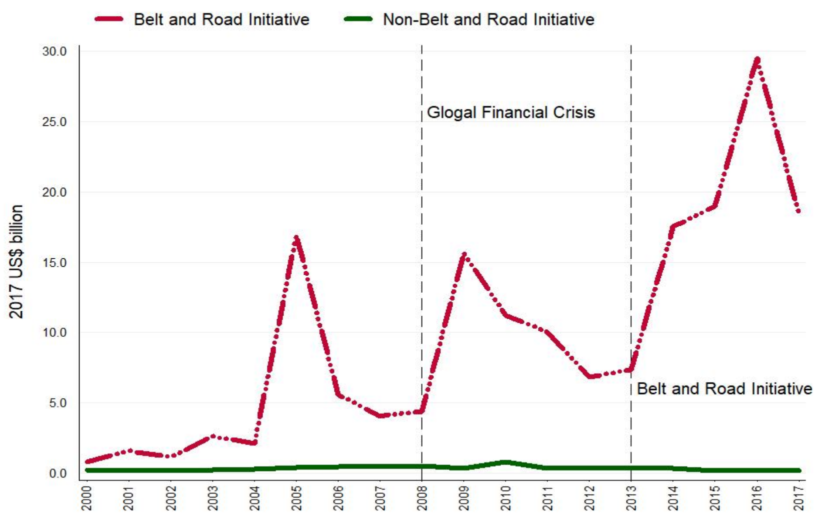
Panel A of figure 6 shows infrastructure project finance extended by China in Belt and Road Initiative and non-Belt and Road Initiative countries from 2000 to 2017.[9]

[9] Bhutan, Kiribati, Tuvalu, and Solomon Islands are not included in the Chinese official finance database.

It displays significant fluctuations from year to year, reflecting multimillion-dollar deals involving China, mainly in the energy and transport sectors. There appears to be a significant increase in the volume of infrastructure finance to Belt and Road Initiative countries in 2014, followed by a substantial increase (statistically significant at the 1% level) in the annual finance trend compared to non-Belt and Road Initiative countries. Infrastructure finance increased to approximately $29 billion (in 2017$) in 2016 before falling in 2017. Moreover, there are signs that non-Belt and Road Initiative economies, primarily Pacific States, managed to attract only marginal funding from China. China may target Pacific countries that adhere to the "One China Policy"[10] (Dornan and Pryke, 2017).

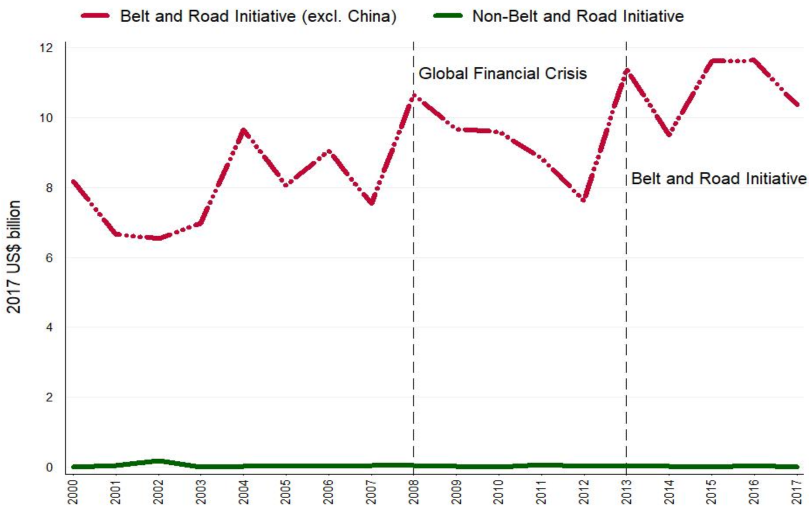
Figure 6. Infrastructure finance, 2000–2017

Panel A. From China



[10] Recipient countries that do not recognize Taiwan Republic of China as an independent country and have established diplomatic relations with China are Cook Islands, the Federated States of Micronesia, Fiji, Niue, Papua New Guinea, Samoa, Tonga and Vanuatu.

Panel B. From Development Assistance Committee members



Source: Author's estimates based on OECD (2021) and Custer and others. (2021).

Western bilateral donors are increasingly looking to leverage more resources to finance infrastructure for developing countries to enhance market access and competition, which will directly boost incentives for their investment. Similar to China, more than half of the finance from Western donors was directed to the Asia-Pacific region (McKinsey, 2016). Accordingly, for this paper, infrastructure funding from China is compared with the funding from the entire OECD Development Assistance Committee (DAC)[11] donors in panel b of figure 6.[12] The figure displays that the DAC finance for infrastructure (covering sectors mentioned above) to Belt and Road Initiative economies was substantial in the early 2000s due to the availability of project finance globally and that it peaked in 2013 to almost double the total Chinese infrastructure finance. With the onset of the global financial crisis and then a tighter global financial environment, DAC commitments to infrastructure projects dried up.

[11] DAC members are Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Ireland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, the Republic of Korea, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, the United Kingdom, the United States and European Union Institutions.

[12] It is worth noting that DAC infrastructure finance is not similar to that of Chinese finance. Most DAC members only include ODA and do not report on other official flows (OOF). In addition, DAC imposes policy conditionality in official financing.

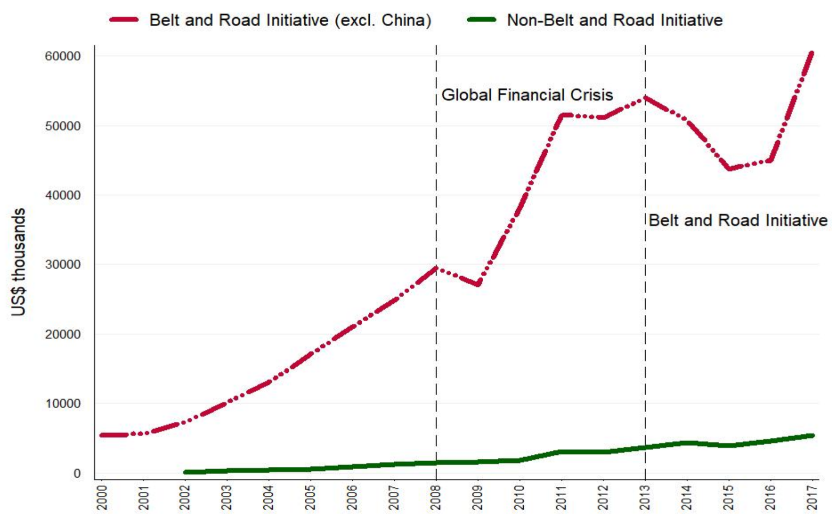
Some DAC donors released funds to Belt and Road Initiative countries' infrastructure projects in response to the global financial crisis. In 2016, approximately $11 billion (in 2017$) were released, which is less than half of the total of Chinese finance over the same year (panel A, figure 6). Thus, China is filling a growing infrastructure financing gap in the region. It should be noted, however, that there was no noticeable trend in DAC infrastructure finance to non-Belt and Road Initiative countries during the period 2000–2017.

4.2 Trade with China

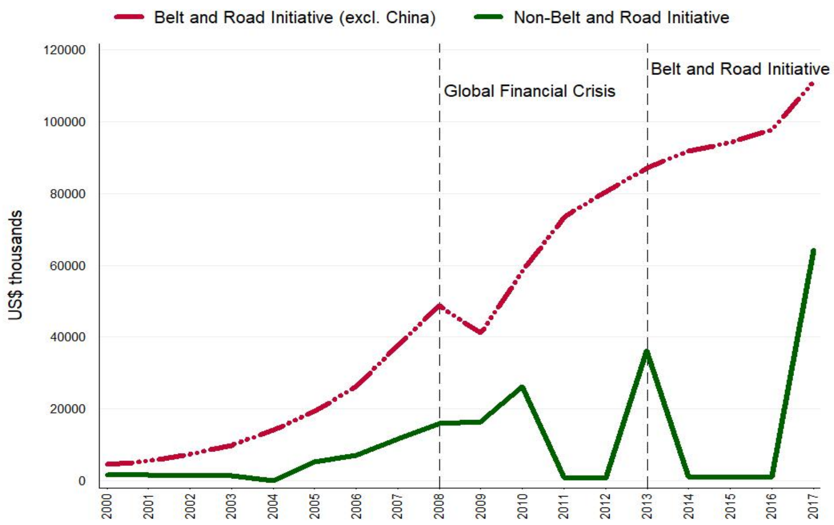
Intuitively, infrastructure finance under the Belt and Road Initiative could enhance recipient countries' trade with China and among member countries aided by upgraded logistic conditions, a reduction in transportation costs and the availability of physical infrastructures. Recent empirical work on the effectiveness of the Initiative's infrastructure finance supports this claim (Zhai, 2018; de Soyres and others, 2019; Ramasamy and Yeung, 2019; de Soyres, Mulabdic and Ruta, 2020; Yang and others, 2020).

Figure 7. Trade with China, 2000-2017

Panel A. Exports to China



Panel B. Imports from China



Source: Author's estimates based on World Bank (2020).

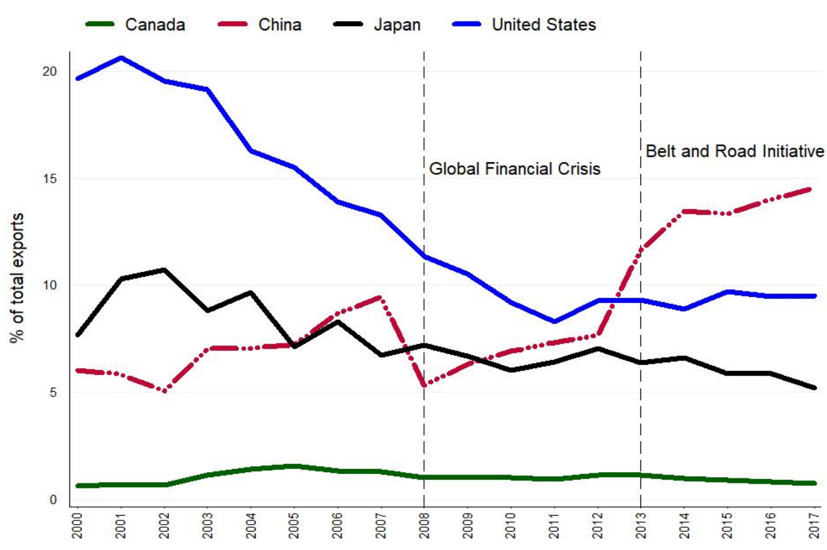
Figure 7 shows bilateral trade of China between Belt and Road Initiative and non-Belt and Road Initiative countries. The figure projects upward trends in the dollar volume of exports and imports for Initiative economies. In both components of trade, the difference between Initiative and non-Initiative countries is statistically significant (at the 1% level) in pre- and post-Belt and Road Initiative years. Panel A of figure 7 indicates that the Initiative-China dollar volume of bilateral exports rose by 73 per cent between 2009 and 2013. Exports to China decreased during 2014-2015; however, the rising trend has returned since 2016. The dollar volume of imports outstripped the dollar volume of exports over that time period (panel b, figure 7). Increasing infrastructure finance by China in the Initiative countries since 2013 might support the local economy's growth and indirectly increase the Initiative countries' demand for imports, particularly capital goods from China (Luo and others, 2021). In this sense, imports may help promote exports in post-Initiative years through structural transformation or rising demand for labour in countries along the Belt and Road Initiative (see panel b, figure 3).

Lower costs resulting from upgraded logistic conditions and transportation is also applicable to trade with non-Belt and Road Initiative countries, given their geographic proximity to the Belt and Road Initiative bloc or advanced economies. However, the non-Belt and Road Initiative area only indicates gains in imports from China. The Pacific island States of Palau and Solomon Islands predominantly drive this result.

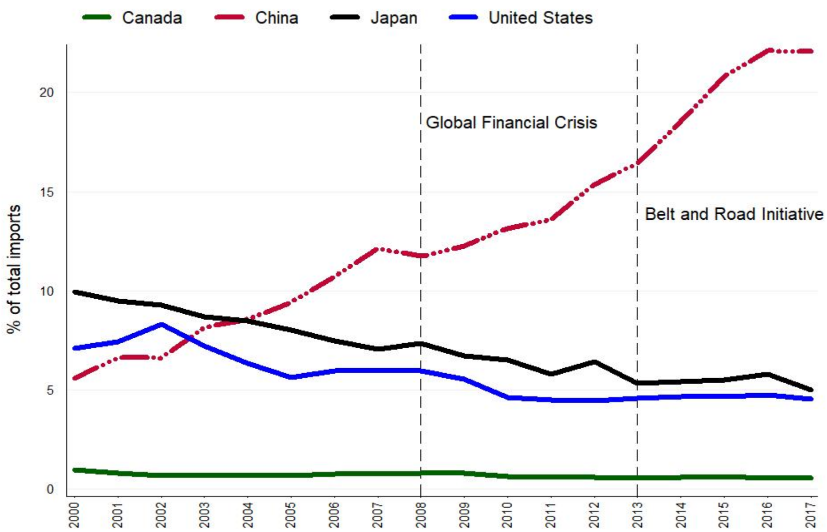
While China has become the key trading partner of countries in the Asia-Pacific region, the increase in trade may not be at the expense of other major trading partners (such as Canada, Japan and the United States). This is explored in the present study by comparing export share to and import share from the Canada, China, Japan and the United States for only Belt and Road Initiative countries. The values are shown in figure 8. In general, there is a downward trend in the share of the Belt and Road Initiative countries' total imports and exports to the United States and Japan (panels A and B), which has continued in the post-Belt and Road Initiative years. There is no noticeable trend regarding the shares of Canada in this regard. In contrast, a rising trend is observed in the shares of China, which echoes previous observations. The shares of imports and exports of China in the post-Belt and Road Initiative years have been in a range of 25 to 36 per cent. This data imply that, other than China, the relative role of other major economies in terms of trade ties has become less important to Belt and Road Initiative countries. To some extent, it is consistent with the findings of Zou and others (2021).

Figure 8. Trade with Canada, China, Japan and the United States, 2000–2017

Panel A. Export share



Panel B. Import share



Source: Author's estimates based on World Bank (2020).

The analysis suggests that the Belt and Road Initiative helped promote trade ties with China, influencing socioeconomic development in member countries. The transmission mechanism from infrastructure finance to trade expansion is enabled through an increase in the quantity and quality of infrastructure for the Initiative countries, which are mostly underdeveloped. Nevertheless, countries outside the Belt and Road Initiative bloc will continue to benefit from the investment, indicating that networking facilities driven by the Initiative have remarkable development prospects.

V. CASE EXAMPLES

It is useful to consider the qualitative picture for individual Belt and Road Initiative countries to explore the robustness of the conclusions. It can also help inform expectations about policy behaviour in each case. Five Initiative countries were chosen for this study, one from each subregion: Kyrgyzstan, Pakistan; Cambodia; Mongolia; and Papua New Guinea. All five are low-and middle-income countries and have followed very different policies, with diverse structural transformation and growth outcomes. While there are some commonalities among them, these marked differences draw attention to their socioeconomic development in pre-and post-

Belt and Road Initiative years. Furthermore, all five are structurally weak in terms of connectivity; basically, they do not receive significant support for infrastructural sectors from bilateral and multilateral donors; China has become the leading investor in their Initiative-related infrastructure projects. Given the debt-related aspects of the Initiative, there is an immediate concern in Initiative countries about the hidden costs of this debt to China.[13] While currently considered to be at a "low" to "moderate" risk of debt distress, all five countries remain vulnerable to external shocks (Hurley, Morris and Portelance, 2019). Against this backdrop, public debt owed to China is examined and the lending by China to the five countries with the largest official creditors, such as the Paris Club members, International Monetary Fund (IMF) and the World Bank.[14]

Table 1 shows that Cambodia has performed strongly in this group in terms of economic growth, measured by per capita real GDP. Its performance is similar to that of Mongolia and Papua New Guinea. Economic growth was an increasingly mixed picture in the post-Belt and Road Initiative years. Although Cambodia has outperformed others in the group, the difference in real GDP growth among these countries is not statistically significant.

The lower panels of table 1 show FDI inflows relative to GDP. Of the five countries, Cambodia and Mongolia are the most open to foreign investment, as indicated by FDI inflows, but the differences in FDI are not statistically significant. FDI fell sharply in Pakistan and Mongolia with the onset of the Belt and Road Initiative, but it recovered in recent years. The analysis further indicates that FDI inflows had not provided a welcome cushion to Pakistan and Papua New Guinea as real GDP growth contracted.

A review of the human development aspect provides a mixed picture. Although the initial levels vary greatly, except for those for Papua New Guinea, there has been impressive progress in achieving poverty reduction, as measured by the poverty line of $1.90 a day. The relative values of HDI of the five countries have improved considerably since 2000. Kyrgyzstan and Mongolia have higher HDI values and lower poverty incidence than its peers; the differences in both indicators are statistically significant among the five countries. HDI has been closely aligned with economic growth, particularly in the post-Belt and Road years. A similar observation, with

[13] The Belt and Road Initiative has raised important questions about the risk of debt problems in poorer countries, especially after Sri Lankan debt crisis. This issue is discussed later in the article.

[14] Paris Club members are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Israel, Italy, Japan, the Netherlands, Norway, the Russian Federation, Spain, Sweden, Switzerland, the United Kingdom and the United States. World Bank finance includes lending from the International Bank for Reconstruction and Development (IBRD) and International Development Association (IDA).

the exception of Cambodia, can be made with respect to poverty, implying that the prevalence of inequality in income and opportunity is a concern (World Bank, 2021).

Regarding infrastructure finance, the countries' experience varied in pre- and post-Belt and Road Initiative years, and the difference in trends is statistically significant at the 1 per cent level (table 2). Finance extended for infrastructure from DAC countries rose significantly to Kyrgyzstan, Mongolia and Papua New Guinea in 2015 but it declined in the following years. Similarly, Pakistan and Cambodia experienced a decline in DAC finance for infrastructure over that time but benefited from considerable flows of Chinese finance at the onset of the Initiative. Despite this, Cambodia lagged considerably behind Pakistan, the group's top recipient of Chinese infrastructure finance. Pakistan serves as the centrepiece for the Initiative. The country provides geographic access to more Belt and Road countries in Asia and the Middle East (Ahmed, Rasmussen and Sheehan, 2022). As a result, it enjoys being the largest investment recipient from China, notably in infrastructure and energy projects.

Table 1. Social and economic indicators in selected countries

Country	Pre-Belt and Road Initiative			Post-Belt and Road Initiative	
	2000	2005	2010	2015	2019
	Per capita real GDP growth (%)				
Kyrgyzstan	4.19	-1.30	-1.65	1.76	2.44
Pakistan	1.54	4.10	-0.60	2.57	-1.03
Cambodia	7.56	11.48	4.34	5.41	5.52
Mongolia	0.25	5.98	4.56	0.39	3.37
Papua New Guinea	-4.69	4.04	7.63	4.46	3.81
	Poverty (%)				
Kyrgyzstan	35.10	12.10	2.80	1.80	0.60
Pakistan	31.00	18.70	8.30	4.00	4.40
Cambodia	-	22.10	-	18.0	-
Mongolia	9.50	4.52	0.70	0.35	0.50
Papua New Guinea	38.0	38.0	38.0	38.0	38.0

Table 1. *(continued)*

Country	Pre-Belt and Road Initiative			Post-Belt and Road Initiative	
	2000	2005	2010	2015	2019
			HDI		
Kyrgyzstan	0.59	0.62	0.64	0.67	0.70
Pakistan	0.45	0.50	0.53	0.55	0.56
Cambodia	0.43	0.47	0.51	0.55	0.56
Mongolia	0.59	0.65	0.70	0.74	0.74
Papua New Guinea	0.45	0.48	0.52	0.54	0.56
			FDI (% of GDP)		
Kyrgyzstan	-0.17	1.73	9.86	17.13	3.14
Pakistan	0.38	1.83	1.14	0.62	0.80
Cambodia	3.24	6.03	12.49	10.10	13.52
Mongolia	4.72	7.43	23.53	0.80	17.46
Papua New Guinea	2.74	0.82	0.25	0.98	1.35

Source: World Bank (2021).

This information shows that trade with China rose sharply following increases in infrastructure finance by China. Improvement in trade-related infrastructure in terms of quality and quantity (see table a.3 in the appendix), along with complementary policies, support this result. Pakistan performed comparatively well and was the leading country among the group with regard to export and import volumes, followed by Cambodia, Kyrgyzstan, Mongolia and Papua New Guinea. In addition to the development of infrastructure via the Belt and Road Initiative, China-Pakistan bilateral trade deals covering energy and transport sectors drove this result. Similar trade deals involved Cambodia, Kyrgyzstan and Mongolia.

Table 2. Trade and infrastructure finance in selected countries

Country	Pre-Belt and Road Initiative			Post-Belt and Road Initiative	
	2000	2005	2010	2015	2017
	DAC infrastructure finance (2017 US$ billion)				
Kyrgyzstan	0.05	0.06	0.03	0.12	0.05
Pakistan	0.00	0.10	0.48	0.30	0.28
Cambodia	0.04	0.16	0.31	0.30	0.38
Mongolia	0.08	0.03	0.13	0.29	0.02
Papua New Guinea	0.18	0.04	0.07	0.31	0.08
	Chinese infrastructure finance (2017 US$ billion)				
Kyrgyzstan	0.0	0.0	0.0	0.29	0.04
Pakistan	0.00	0.65	2.00	7.4	4.26
Cambodia	0.04	0.0	2.12	0.21	1.05
Mongolia	0.0	0.0	0.14	0.19	0.0
Papua New Guinea	0.0	0.0	0.0	0.0	0.47
	Exports to China (US$ thousands)				
Kyrgyzstan	44129.8	26572.2	28255	35876.9	97473.6
Pakistan	0.0	435681.6	1440000	1930000	1510000
Cambodia	24155.3	14258.9	65007.6	405515.2	0.0
Mongolia	266997.8	512379.6	0.0	3900000	5270000
Papua New Guinea	12869.4	0.0	0.0	0.0	0.0
	Imports from China (US$ thousands)				
Kyrgyzstan	279534	0.0	2840000	5070000	5500000
Pakistan	0.0	2350000	5250000	11000000	15400000
Cambodia	114508.5	424151.6	1190000	3930000	0.0
Mongolia	109517.8	295037.4	0.0	1360000	1410000
Papua New Guinea	20826.3	0.0	0.0	0.0	0.0

Source: Author's estimates based on Cluster and others (2021), OECD (2021) and World Bank (2020)

Figure 9 shows four debt series (Chinese, Paris Club, IMF and the World Bank loans) for each country from 2000 to 2017. The first insight of figure 9 suggests debt-driven growth in each country, except for Kyrgyzstan and Pakistan. China has become an active international lender following the global financial crisis, surpassing its multilateral partners, notably in post-Belt and Road Initiative years. As a result, the shares of Chinese debt relative to all three large multilateral creditors increased to 70 per cent by 2017 (see also Horn, Reinhart and Trebesch, 2021a). Pakistan was the largest borrower among the group of countries, followed by Cambodia and Kyrgyzstan. China, for example, provided $28 billion worth of loans to Pakistan in 2017, which is approximately 45 per cent of the total multilateral loans; the corresponding figures for Cambodia and Kyrgyzstan were $6 billion (66%) and $2.2 billion (58%), respectively. The other significant information is that the overseas lending by multilateral creditors to the group of countries, except for Pakistan and Mongolia, has been subdued, reflecting the degree of dependency on China as a creditor.

These findings have important implications for debt sustainability in developing countries because State-driven lending abroad by China differs strongly from other official lenders, such as the World Bank or OECD Governments. In particular, the absence of governance reform conditionality on Chinese financing is viewed by some authorities as threatening concerted efforts to improve debt sustainability in poor Belt and Road Initiative countries (Marson and Savin, 2022). An example of this notion is the role of the Belt and Road Infrastructure projects that result in rising public debt-to-GDP ratios, which is not suitable for growth, and, as a result, makes debt more unsustainable (Hurley, Morris and Portelance, 2019; Bandiera and Tsiropoulos, 2020).

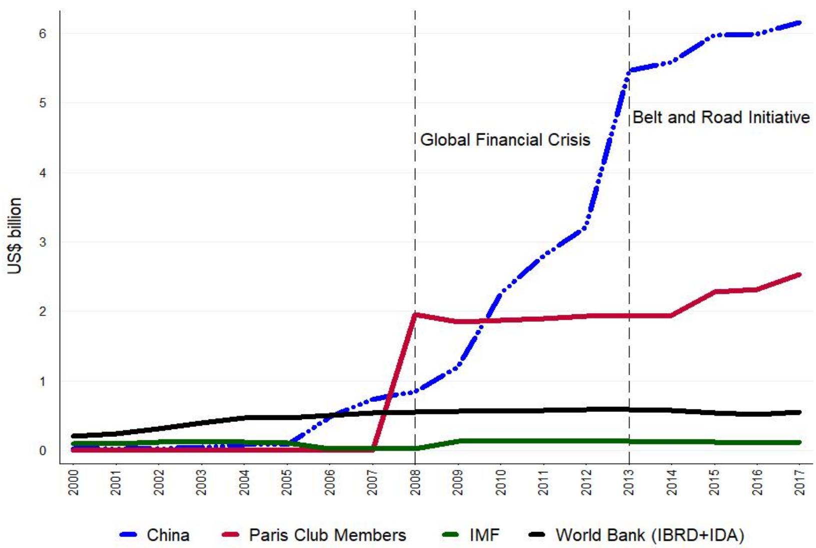
To summarize, the five case examples confirm that with the onset of Belt and Road Initiative, some developing countries managed to enhance real GDP growth and human development. The analysis further reveals that parallel trends in trade and FDI inflows, to some extent, have complimented the Belt and Road Initiative platform. The findings for trade creation are not surprising if the weak infrastructure connectivity in countries along the Initiative is taken into account. This underlines the importance of improving connectivity in the Initiative. The whole point of it is to reduce this source of weakness through infrastructure investment which, if successful, will improve connectivity. The rising trade ties create income effects and interconnections that benefit countries outside the bloc.

Nevertheless, the apparent lack of transparency and country-specific detailed data have raised concerns about the effectiveness of Chinese development finance. Some observers, such as Chellaney (2017), has accused China of conducting so-called “debt-trap diplomacy”. However, much of the conventional wisdom about the effect of Chinese aid on recipient economies rests on anecdotal evidence (Cooper, 2019). Independent studies conducted by, for example, Rajah and others (2019) and Jones and Hameiri (2020), have not found any evidence of China engaging in deliberate "debt trap" diplomacy. They find that debt crises are mostly the result of policy errors, misgovernance and poor project selections by recipient countries. A meta-regression analysis of 473 estimates from 15 studies conducted by IMF (Mandon and Woldemichael, 2022) indicate that, on average, foreign assistance extended by China has had a positive impact on economic and social outcomes in recipient countries, but an opposite effect on governance, albeit negligible in size.

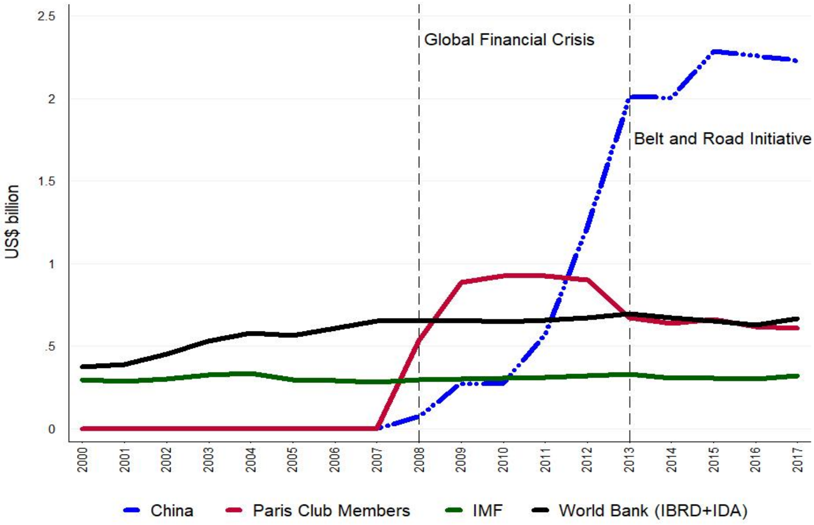
Individual countries may experience problems in repaying their foreign debt obligations when economic growth and revenue generation does not accompany government borrowing. The risks are especially acute for the small and fragile economies to which Chinese lending is more intense as a share of GDP. However, Rajah and others (2019, p.22) noted, "the sheer scale of lending by China and its lack of strong institutional mechanisms to protect the debt sustainability of borrowing countries poses clear risks". Accordingly, project selections based on their economic viability and contributions are vitally important. This requires transparency, accountability, monitoring and governance competence.

Figure 9. Public debt owed to different creditors, 2000-2017

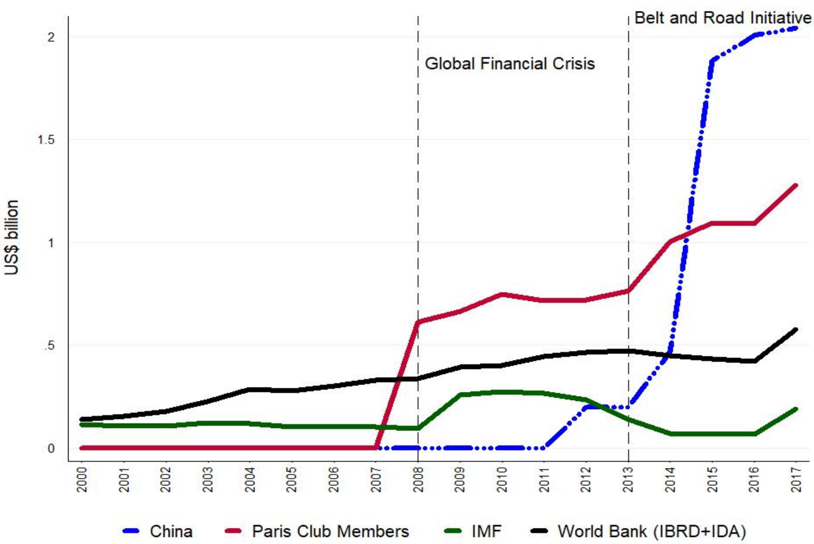
Panel A. Cambodia



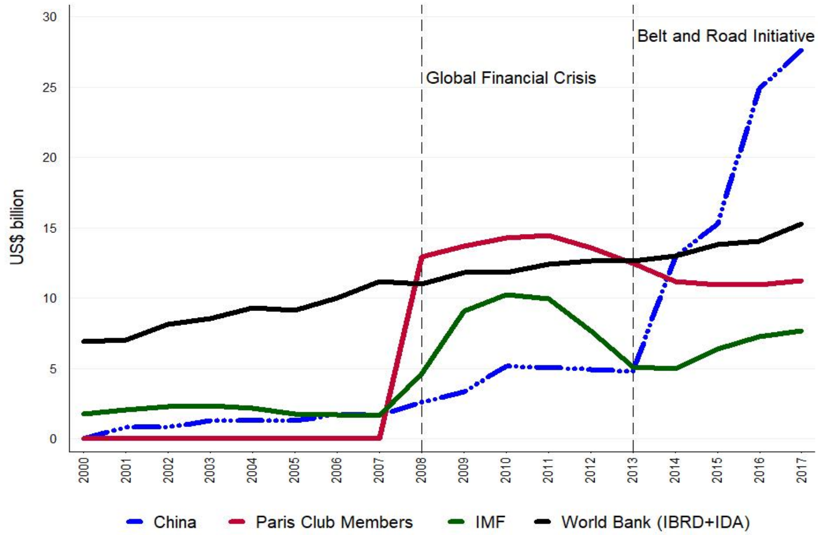
Panel B. Kyrgyzstan



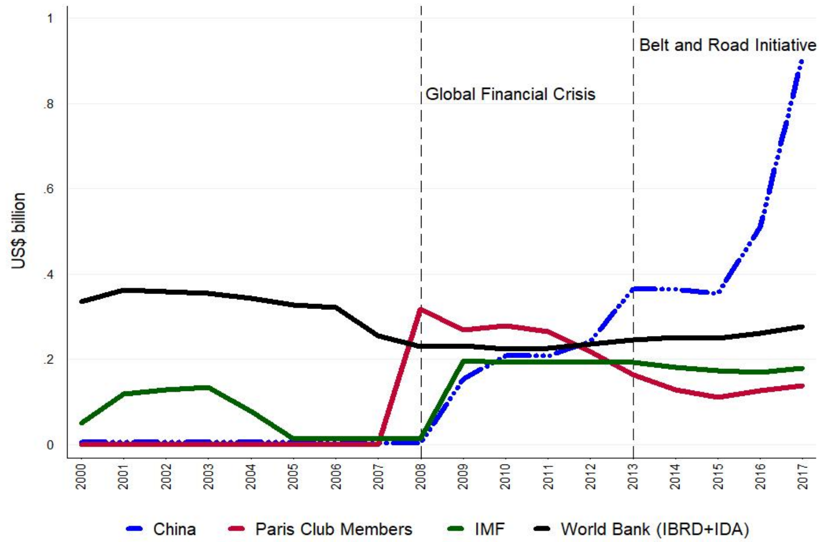
Panel C. Mongolia



Panel D. Pakistan



Panel E. Papua New Guinea



Source: Author's estimates based on Horn, Reinhar and Trebesch (2021b).

Note: IBRD, International Bank for Reconstruction and Development; IDA; International Development Association.

VI. CONCLUDING REMARKS

This paper presents a comprehensive picture of 40 Belt and Road Initiative and non-Belt and Road Initiative countries in the Asia-Pacific region over the 2000–2019 period. These countries have experienced a fundamental structural change from as early as the 2000s, which had boosted economic growth and human development. The growth of industry in terms of value added is noticeable in post-Initiative years, while growth of services have far outpaced industry in terms of employment throughout the observation period. FDI and merchandise trade, to some extent, has contributed to this remarkable progress. Turning to findings by subregion, Belt and Road Initiative countries in South-East Asia have reaped the most significant benefits in terms of economic growth, mainly fuelled by bilateral trade due to their geographic proximity to economic corridors and competitive advantages. Progress related to poverty reduction by subregion is somewhat ambiguous.

In these dynamics, the respective importance of the Belt and Road Initiative cannot be overlooked, as it has demonstrated the potential of transforming economically underdeveloped countries into a vibrant group of economies. On this notion, the role of Chinese infrastructure finance in response to the formation of this great policy initiative is worth noting. The analysis demonstrates that many of the recipients along the Initiative expanded trade with China via increased connectivity relative to non-Initiative countries. Despite large trade deficits with China, economic growth has been higher and more stable in Initiative countries compared to their counterparts after the announcement of the Initiative.

Nonetheless, similar to any large undertaking, there are significant economic challenges. The Belt and Road Initiative projects were debt-funded and many countries within the Belt and Road Initiative bloc already had a high debt burden before the investment (Bandiera and Tsiropoulos, 2020). As a result, vulnerable Belt and Road Initiative countries with relatively poor growth prospects may exacerbate their debt burden and delay domestic spending on economic and social development. Selective country case studies have supported this notion. In response, China is making an effort to guard against debt problems associated with the Initiative and is likely to remain a major development financier. In April 2019, the country's Ministry of Finance released a debt sustainability framework for the Initiative at the second Belt and Road Forum for International Cooperation, which was held in Beijing from 25 to 27 April 2019. The new debt sustainability framework is virtually identical to the World Bank-IMF debt sustainability framework, which governs lending operations for multilateral institutions and, to some degree, many bilateral lenders. More importantly, all lenders – Chinese and non-Chinese – and borrowers should follow the principles of responsible sovereign lending and borrowing developed by the United Nations.

While the lending countries should be more diligent, the borrowing countries also have must be careful in their project selections and ensure their economic viability. As China continues to emphasize host-country regulation, Belt and Road Initiative partners must bolster their laws and regulatory environment (Jones and Hameiri, 2020).

Moreover, the risks that come with the Belt and Road Initiative could heighten the sensitivity of economic growth in China and affect the rest of the Belt and Road Initiative economies, given the gravity effects of the Chinese economy. In addition, in line with Western bilateral and multilateral donors, China is beginning to restrict the expansion of credit in order to focus on domestic needs in poorer regions of the country (OECD, 2018). This is likely to mean the Belt and Road Initiative countries may run into constraints on their ability to fund more of their infrastructure sectors. Accordingly, they should diversify their funding sources, including multilateral lending institutions, and enhance their negotiation power to meet the investment gaps.

Finally, external shocks, such as technological innovations and significant shifts towards better institutions or in the political landscape that has not been considered in this paper might lead to a different trajectory than described. This should be noted as a caveat to the conclusions about the impact of Belt and Road Initiative in the Asia-Pacific region. This calls for further research on the interdependence of the Initiative and domestic issues, and a more detailed analysis of the effects of possible future trends.

NOTE ON CONTRIBUTOR

Salma Ahmed is a Development Economist at Victoria University and a Visiting Fellow at Deakin University in Melbourne. She holds MPhil and PhD in economics, both from Monash University, Australia. Her research interests include gender and labour market, maternal and child health, evaluation of welfare policies and development finance programmes.

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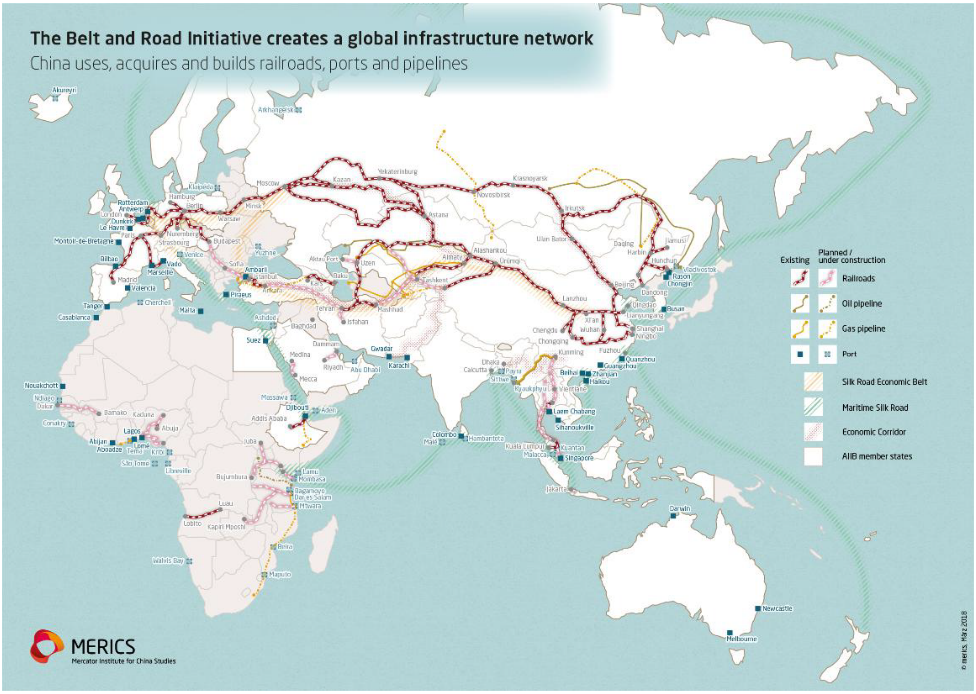
Appendix

Figure A.1. Map of the Belt and Road Initiative



Source: https://merics.org/en/tracker/mapping-belt-and-road-initiative-where-we-stand

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Table A.1. List of countries in the Asia-Pacific region

Region	Belt and Road Initiative	Non-Belt and Road Initiative
Central Asia	Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan	

Table A.1. *(continued)*

Region	Belt and Road Initiative	Non-Belt and Road Initiative
South Asia	Afghanistan, Bangladesh, Bhutan, India	
	Maldives, Nepal, Pakistan, Sri Lanka	
South-East Asia	Cambodia, Indonesia, Lao People's Democratic Republic	
	Malaysia, Myanmar, Philippines	
	Thailand, Timor-Leste, Viet Nam	
North-East Asia	China, Russian Federation, Mongolia	Democratic People's Republic of Korea
Pacific	Fiji, Micronesia (Federated States of), Papua New Guinea	Kiribati, Nauru, Palau
	Samoa, Tonga, Vanuatu	Solomon Islands, Tuvalu

Source: Green Belt and Road Initiative Center (n.d.)

Table A.2. Variables, definitions and data sources

Variables	Unit of measurement	Description	Source
Per capita real GDP growth	Annual percentage growth	The annual percentage growth rate of GDP per capita is based on constant local currency. Aggregates are based on constant 2010 US$.	World Development Indicators (WDI)
Real GDP	2010 US$ trillion	The volume of GDP is the sum of value-added, measured at constant prices, by households, government, and industries operating in the economy.	World Development Indicators (WDI)

Table A.2. *(continued)*

Variables	Unit of measurement	Description	Source
Poverty headcount ratio	Percentage of population	The percentage of the population living on less than $1.90 per day at 2011 international prices.	World Development Indicators (WDI)
Agriculture, value added	Percentage of GDP	Agricultural value added based on constant local currency. Aggregates are based on constant 2010 US$.	World Development Indicators (WDI)
Services, value added	Percentage of GDP	Services value added based on constant local currency. Aggregates are based on constant 2010 US$.	World Development Indicators (WDI)
Industry, value added	Percentage of GDP	Industry value added based on constant local currency. Aggregates are based on constant 2010 US$.	World Development Indicators (WDI)
Employment in agriculture	Percentage of total employment	Working age populations engaged in activities in agriculture for pay or profit.	World Development Indicators (WDI)
Employment in industry	Percentage of total employment	Working age populations engaged in activities in industrial sectors for pay or profit.	World Development Indicators (WDI)
Employment in services	Percentage of total employment	Working age populations engaged in activities in various service sectors for pay or profit.	World Development Indicators (WDI)
Export	2010 US$ thousand	Export to China	World Integrated Trade Solutions (WITS)

Table A.2. *(continued)*

Variables	Unit of measurement	Description	Source
Import	2010 US$ thousand	Import from China	World Integrated Trade Solutions (WITS)
Export partner share	Percentage of total exports	The export partner share is the percentage of exports to the countries of interest (the source) from the countries under study (the destination) in the total exports of the destination.	World Integrated Trade Solutions (WITS)
Import partner share	Percentage of total imports	The import partner share is the percentage of imports from the countries of interest (the source) to the countries under study (the destination) in the total imports of the destination.	World Integrated Trade Solutions (WITS)
Foreign direct investment, net inflows	Percentage of GDP	Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments.	World Development Indicators (WDI)

Table A.2. *(continued)*

Variables	Unit of measurement	Description	Source
Trade	Percentage of GDP	Trade as a share of GDP is the sum of merchandise exports and imports divided by the value of GDP measured in current US$.	World Development Indicators (WDI)
Chinese infrastructure finance	2017 US$ billion	Chinese infrastructure finance under CRS code 200	Custer and others
DAC infrastructure finance	2017 US$ billion	DAC infrastructure finance under CRS code 200	OECD.stat
Debt	US$ billion	Outstanding public debt to official creditors	Horn, Reinhart and Trebesch
Human development index	Index	A composite index combining longevity, knowledge and income.	United Nation's Human Development Report

Table A.3. Logistics performance index and subindices for five Belt and Road Initiative countries, 2000-2017

Pre-Belt and Road Initiative (2000-2012)							
Country	**LPI**	**Custom**	**Infrastructure**	**International Shipments**	**Logistics & Quality**	**Timeline**	**Tracking & tracing**
All Belt and Road Initiative countries	2.52	2.28	2.29	2.56	2.43	3.03	2.52
Cambodia	2.48	2.26	2.21	2.42	2.42	2.95	2.60

Table A.3. *(continued)*

Pre-Belt and Road Initiative (2000-2012)							
Country	**LPI**	**Custom**	**Infrastructure**	**International Shipments**	**Logistics & Quality**	**Timeline**	**Tracking & tracing**
Kyrgyzstan	2.44	2.36	2.21	2.51	2.32	2.85	2.34
Mongolia	2.19	1.93	2.03	2.36	1.97	2.60	2.24
Pakistan	2.66	2.44	2.38	2.83	2.59	3.05	2.61
Papua New Guinea	2.39	2.00	2.04	2.49	2.22	3.13	2.41
	Post-Belt and Road Initiative (2013-2017)						
All Belt and Road Initiative countries	2.62	2.44	2.45	2.66	2.56	2.98	2.59
Cambodia	2.71	2.55	2.36	2.91	2.56	3.07	2.71
Kyrgyzstan	2.31	2.19	2.13	2.25	2.15	2.67	2.41
Mongolia	2.41	2.27	2.15	2.49	2.28	2.99	2.23
Pakistan	2.72	2.54	2.52	2.88	2.73	2.98	2.64
Papua New Guinea	2.37	2.42	2.17	2.36	2.23	2.65	2.37

Source: World Bank (2021)

Note: LPI, logistics performance index. The LPI records a country's trade logistics performance and is summarized on a five-point scale, with a higher score representing a better performance.

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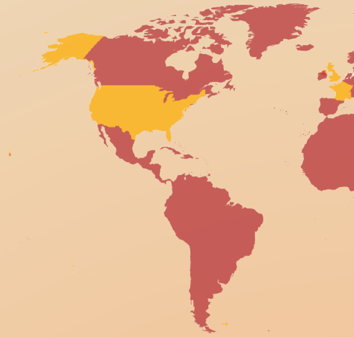

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