Title: The economic impacts of low-carbon transition in Asia: NDC and Net Zero Transition with International Carbon Market in Asia[1]

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Introduction

In the past decades, the greenhouse gas emissions of developing Asian countries have been growing substantially, and the growing trends are expected to continue in the next decades, led mainly by their economic growth. After COVID-19 crisis, the developing Asian economies are projected to grow over 5% in 2022 and 2023, according to (ADB, 2022). The special focus on the low-carbon transition of the developing Asian countries should be emphasized, and the decoupling of the economic growth and greenhouse gas emissions becomes a significant challenge to achieving the global 1.5-degree target and reaching the Net Zero eventually.

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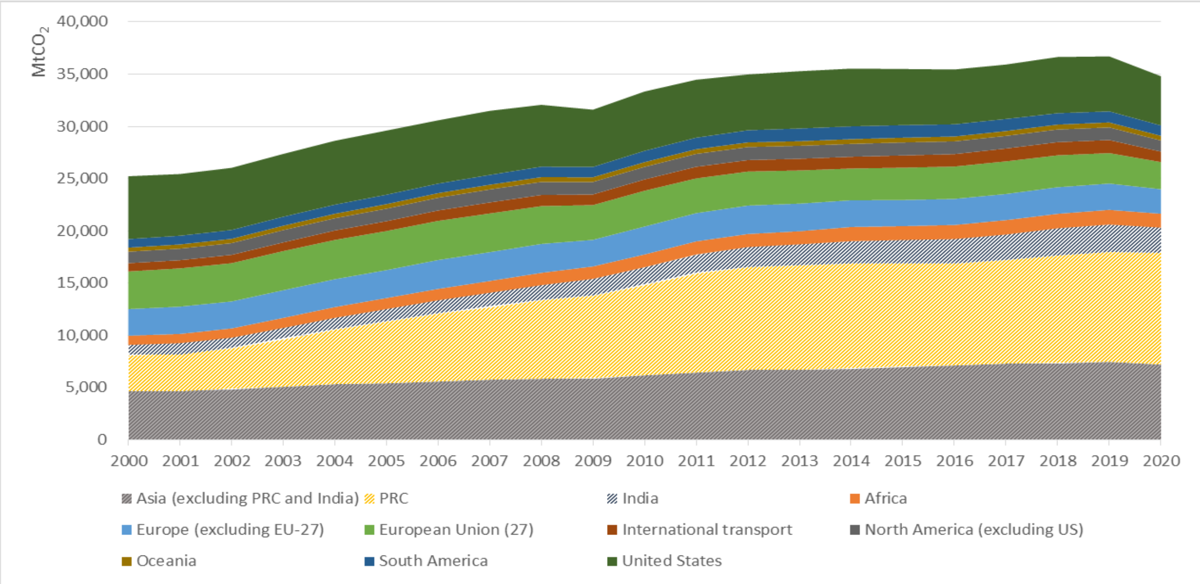

Figure 1. Global Annual CO2 emissions from fossil fuel (source: Our World in Data, 2022)

The Net Zero transition would require the Asian economies to shifting their development paradigm to a low-carbon economy, which can continue economic development while reducing greenhouse gas emissions. This transition can bring opportunities and challenges to developing Asian economies at the same time. For instance, the transition could encourage new industries and employment, but this could discourage other industries, particularly the existing carbon-intensive industries. Considering the key roles of these carbon-intensive industries in economic development of developing Asian economies, it is necessary to understand the economic impacts of net zero transition on developing Asian economies, and the cost and benefit of the net zero transition should be considered an important focus. This study applies a global dynamic recursive CGE (computable general equilibrium) model (Jung et al, 2021) and analyzes the economic impacts of the low-carbon transition, including achieving Nationally Determined Contribution targets and reaching Net Zero, particularly focusing on Asia. Moreover, in order to analyze the impacts of transitions, the study reflects the NDC information of all individual Asian economies and OECD countries, from NDC documents, and emission information from other official documents, including Biennial Update Reports and National Inventory Reports.

Data and Methodology

To establish concrete transition scenarios, the study collects information, including

NDC targets and base year emissions, of all individual Asian countries and OECD countries, from NDC documents and other official documents, such as biennial update reports, if necessary. The study focuses the emissions from the energy sector based on the IPCC classification, and if no data available, the study uses the economy-wide emission and targets. Based on the information collected, the study sets the level of emission reductions of OECD and Asian regions announced in NDCs by 2030.

The global CGE model with GTAP 10 Power database sets 7 aggregate regions, which reflect the five ADB sub-regional classifications, and aggregates the sectors into 19 sectors. This analysis is to focus on the impacts on Asian economies, especially the developing Asian economies, so the seven aggregated regional classification indicates five Asian regions (Caucasus and Central Asia, East Asia, South Asia, Southeast Asia, and the Pacific), OECD region, and the other Developing Country region. In addition, in order to analyze the impacts of low-carbon transition on skilled and unskilled labor, the study adopts the labor classification and associated data by GTAP database, and separates unskilled and skilled labor demands in the model nesting structure. As the transition toward a low-carbon economy would lead to the sectoral reallocation, the understanding of the impacts of low-carbon transition on skilled and unskilled labor is important.

Table 2: Regional Classification

Label	Description	GTAP Regions Code
OECD	Organisation for Economic Co-operation and Development (except the Republic of Korea): Europe region (European Union member countries, rest of Europe, rest of European Free Trade Association, and United Kingdom) + Australia, Canada, Japan, New Zealand, and United States	ALB, AUS, AUT, BEL, BGR, CAN, CHE, CYP, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HRV, HUN, IRL, ITA, JPN, LTU, LUX, LVA, MLT, NLD, NOR, NZL, POL, PRI, PRT, ROU, SVK, SVN, SWE, TUR, USA, XEF, XER
CCA	Caucasus and Central Asia	KAZ, KGZ, TAJ, ARM, AZE, GEO, XSU
EAsia	East Asia: Hong Kong, China; Mongolia; People's Republic of China; Republic of Korea; and Taipei,China;	PRC, HKG, ROK, MON, TAP, XEA

SAsia	South Asia: Bangladesh, India, Nepal, Pakistan, and nearby countries (Afghanistan, Bhutan, Maldives, and Sri Lanka)	BAN, IND, NEP, PAK, SRI, XSA
SEAsia	Southeast Asia: 10 Association of Southeast Asian Nations members and Timor-Leste	BRU, CAM, INO, LAO, MAL, PHI, SIN, THA, VIE, XSE
Pacif	The Pacific: Mostly small island countries	XOC
DC	The other developing economies: Countries not included in OECD and five Asian subregions	MEX, XNA, ARG, BOL, BRA, CHL, COL, ECU, PRY, PER, URY, VEN, XSM, CRI, GTM, HND, NIC, PAN, SLV, XCA, COM, JAM, TTO, XCB, BLR, RUS, UKR, XEE, BHR, IRN, ISR, JOR ,KWT, OMN, QAT, SAU, ARE, XWS, EGY, MAR, TUN, XNF, BEN, BFA, CMR, CIV, GHA, GIN, NGA, SEN, TGO, XWF, XCF, XAC, ETH, KEN, MDG, MWI, MUS, MOZ, RWA, TZA, UGA, ZMB, ZWE, XEC, BWA, NAM, ZAF, XSC, XTW

GTAP = Global Trade Analysis Project, OECD = Organisation for Economic Co-operation and Development.

Sources: Author's elaboration

This study sets the year 2014 as the baseline year based on GTAP 10 database (Aguiar et al, 2019). The net zero target year of each country is set based on the information from Net Zero Scorecard of the Energy and Climate Intelligence Unit (ECIU) (ECIU, 2022). For the OECD countries, the net zero target year is set to year 2050, and the study set the year 2070 for the countries with no specific net zero target year (even proposed/in discussion) as their net zero target year. Moreover, the definition of net zero emission is not about zero emission but about reaching a balance between GHG emissions and absorption. The estimate of the potential of carbon removal, including carbon capture and storage, significantly varies by studies. IEA's Net Zero scenario indicated the gross CO2 emissions in 2050 would be 1.94 GtCO2, and the remaining emissions would be removed by BECCS (Bioenergy with carbon capture and storage) and DACCS (Direct air carbon capture and storage). This study indicated that the 78.5% reduction of emissions in the energy sector for achieving Net Zero. IPCC Special Report on Global Warming of 1.5-degree suggested the range of remaining emissions in 2050 as [10.5 GtCO2, 13.4 GtCO2]. To achieve this, it would require about 59% ~ 69% reductions from the 2010 emission level (IPCC 2018). With consideration of these studies, the study considers 70% reductions from 2014-level necessary for achieving Net Zero.

A global multiregional dynamic recursive CGE model has been constructed and applied in this study. A CGE model is an economic model representing interactions among the parts of an economy and finds the economy-wide equilibrium mathematically (Burfisher, 2016). Also, this dynamic recursive CGE makes intertemporal decision-making, incorporates dynamic behaviors, and solves each time period sequentially. The model finds a set of equilibrium conditions for all regions and commodities in (i) market equilibrium conditions, (ii) consumption demand functions; (iii) current account balance conditions, budget constraints, and capital stock dynamic equations; (iv) zero-profit conditions; and (v) factor supply functions (Jung et al. 2021). Production function employs a nested constant elasticity of substitution (CES) technology, and the nesting structure of this CGE model is designed based on OECD's ENV-Linkages model (Château et al. 2014).

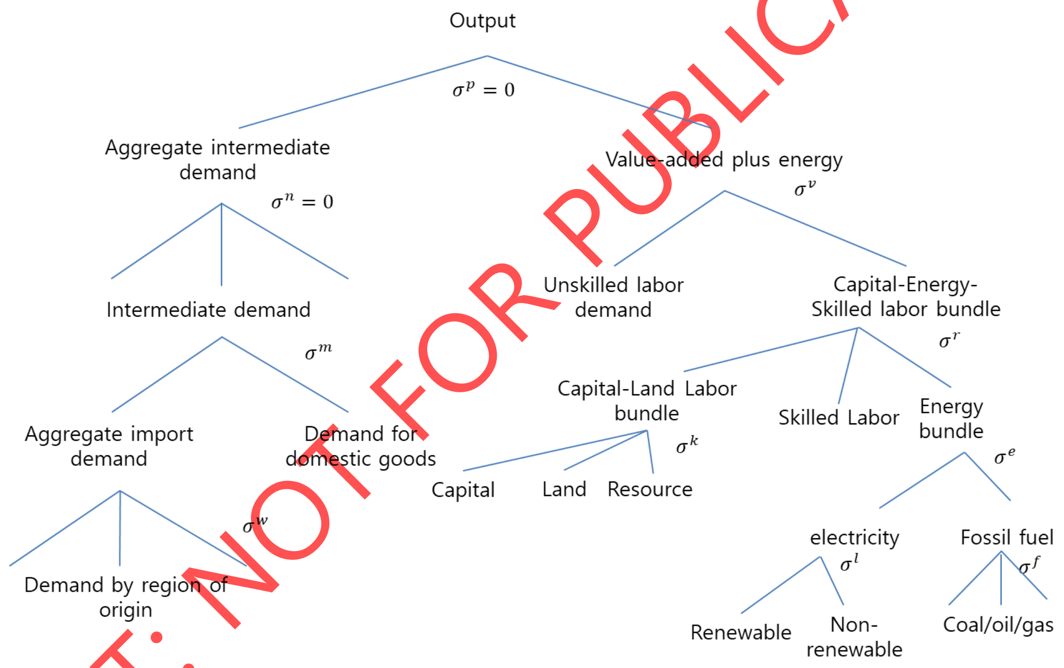

Figure 2. Nesting Structure
Source: author's elaboration

CES function in calibrated share form is as follows:

$$Q = \bar{Q}\left[\sum_i \theta_i \left(\frac{X_i}{\bar{X_i}}\right)^{\rho}\right]^{1/\rho}, \ \rho = \frac{\sigma - 1}{\sigma},$$

Q: amount of output

Xi: i-th input

σ: constant of elasticity of substitution between inputs

Upper bars indicate the base year value

$\boldsymbol{\theta_i}$: value share of i-th input

The equilibrium conditions to the CES technologies are as follows:

$$\boldsymbol{X_i} = \boldsymbol{\lambda_i^{\sigma-1}\theta_i}\left(\frac{\bar{\beta}}{\bar{P}_i}\right)^{1-\sigma}\left(\frac{\beta}{P_i}\right)^{\sigma} Q,\ \boldsymbol{\beta} = \boldsymbol{\bar{\beta}}\left[\sum_i \boldsymbol{\theta_i}\left(\frac{P_i}{\bar{P}_i}\right)^{1-\sigma}\right]^{1/(1-\sigma)},$$

P_i the price of i-th input

β : the output price.

The set of equilibrium conditions described above applies to all the CES technologies including all the sub-nodes of the nested CES functions and other relationships such as substitution between domestic versus imported goods, transformation between domestic versus export demands, and competitions among regions for international transport services. Moreover, the Armington specification is applied to the international trade block by using a two-level nested CES structure. The domestic agents determine the optimal combination of the domestically produced goods and aggregated imported goods at the top nest, and the agents allocate demand for the aggregate import across the trading partners at the subsequent nest (Jung et al, 2021). The Cobb-Douglas utility is assumed for the household. The government collects a variety of taxes, such as income taxes, factor taxes, consumption taxes, and tariffs, and makes consumption decision based on the Cobb-Douglas production function, while its aggregate level is fixed to be constant share of the real GDP. The government budget surplus/deficit is set at its base year level and the income tax rates are adjusted endogenously accordingly. The current account surplus/deficit of each region is also assumed to be constant at its base year level.

Key parameters used in this study is shown in the following table:

Parameter	Notation	Value
Substitution between labor and KTRE bundle	σ^v	0.2 for coal, oil and gas, 1.26 for p_c and gdt, 0.24 for agr, 1.26 for ely, ren and hom, 1.2 for mfr, 1.4 for cnt, 1.37 for ser, 1.68 for trn; GTAP data (esubva) is used
Substitution between KTR bundle and energy	σ^r	0.5
Substitution between capital, land, and natural resources	σ^k	0

Substitution between electricity and fossil fuel	σ^e	0.5
Substitution between renewable and non-renewable electricity	σ^l	1
Substitution between fossil energies	σ^f	1
Armington elasticity: domestic versus import	σ^m	GTAP data (esubdm) is used: 3.8–16.0, depending on sectors
Armington elasticity: import sources	σ^w	GTAP data (esubm) is used: 3.8–34.4, depending on sectors
Substitution between KTR bundle, energy, and skilled labor	σ^r	1.5
Substitution between capital, land, and natural resources	σ^k	0.2
Substitution between electricity and fossil fuel	σ^e	4
Substitution between renewable and nonrenewable electricity	σ^l	4
Substitution between fossil energies	σ^f	1

Figure 3. Key Parameters

GTAP = Global Trade Analysis Project, KTR = Capital-Land-Natural Resource, KTRE = Capital-Land-Natural Resource-Energy

Source: Author's elaboration

The study used the population projections from UN Population Prospect 2019 and GDP projections from IPCC SSP 2 scenario (IIASA) for model calibration. The model adjusts total factor productivity to reproduce the SSP 2 GDP projection, and the learning rate of 15% is applied to the productivity of renewable energy technologies.

Label	Description	GTAP Sectors Code
AGR	Agriculture	PDR, WHT, GRO, V_F, OSD, C_B, PFB, OCR, CTL, OAP, RMK, WOL, FRS, FSH
Chemical	Chemical	CHM, BPH, RPP, NMM
Cloth	Cloth	TEX, WAP, LEA
Constuc	Construction	CNS
Dwell	Dwellings	DWE
ELY	Electricity (nonrenewable)	TnD, NuclearBL, CoalBL, GasBL, OilBL, OtherBL, GasP, OilP,
Food	Food	CMT, OMT, VOL, MIL, PCR, SGR, OFD, B_T
ICT	Information and communication technology, and computer	ELE, EEQ
Machine	Machinery, equipment, and other manufacturing, including furniture.	OME, OMF
Metal	Metal	I_S, NFM, FMP
Mineral	Mineral	OXT
Coa	Coal	Coa
Oil	Oil, gas, and gas distribution	OIL, GAS, GDT

P_c	Petroleum and coal product	P_c
Paper	Wood and paper products	LUM, PPP
REN	Electricity (renewable)	WindBL, HydroBL, HydroP, SolarP
Service	Services	OSG, EDU, HHT, WTR, AFS, TRD, WHS, CMN, OFI, INS, RSA, OBS, ROS
Trans	Transport	OTP, WTP, ATP
Vehicle	Vehicle	MVH, OTN

Figure 4. Model Sectors and Global Trade Analysis Project (GTAP) code

76 sectors of GTAP 10-Power database, including 12 power technologies, are aggregated into 19 sectors. It tries to keep the major energy sectors, such as coal, oil, and gas, as the original GTAP classification (Aguiar et al, 2019), and most of the industries are aggregated into broad categories. 12 power technologies are aggregated into two groups as renewable and non-renewable power generation.

Policy Scenarios

For the analysis, the study establishes four different scenarios, which are Business-as-Usual, NDC Extension, Net Zero Transition, and Orderly Net Zero transition scenarios. BAU scenario is the baseline scenario that each country follows its own pathways. BAU scenario indicates that the global emissions would reach their peak around year 2034 and gradually decrease afterward. NDC Extension scenario is established based on the information of all Asian and OECD countries, from NDC and other relevant documents, and it assumes that each country achieves the NDC targets by 2030 and continues its mitigation efforts though not sufficient to reach Net Zero by the targeted year announced or planned. It follows the emission trajectories to achieve about 64% of emissions reductions relative to the 2014 emission level, until its net zero target year. As this study sets the timeframe from 2014 to 2050, the study assumes the emissions reduce linearly from 2030 to the specific net zero target year.

While this scenario includes emission constraints, the other two Net Zero scenarios incorporate differentiated carbon prices for reaching Net Zero suggested by IEA Net Zero Emissions (NZE) scenario with some modification. To distinguish Orderly Net Zero from Net Zero Transition scenario, the study defines the Orderly Net Zero scenario as introducing an international carbon market in Asia, and it leads to a single carbon price in Asian regions. This study adopted IEA's classification of 'advanced economies', 'selected emerging market and developing economies', and 'other emerging market and developing economies.' Instead of fully taking the country classification of IEA, the study considered some countries[2], located in Europe and classified as OECD under SSP country group, but identified as emerging economies under IEA country classification, as 'advanced economies.' Also, in addition to the IEA's classification of 'selected emerging market and developing economies', the study considered additional eight countries (Argentina; Brunei Darussalam; Costa Rica; Indonesia; Kazakhstan; Malaysia; Singapore; and Taipei,China) as 'selected emerging market and developing economies.' The regional average carbon price and transition pathways are shown as below:

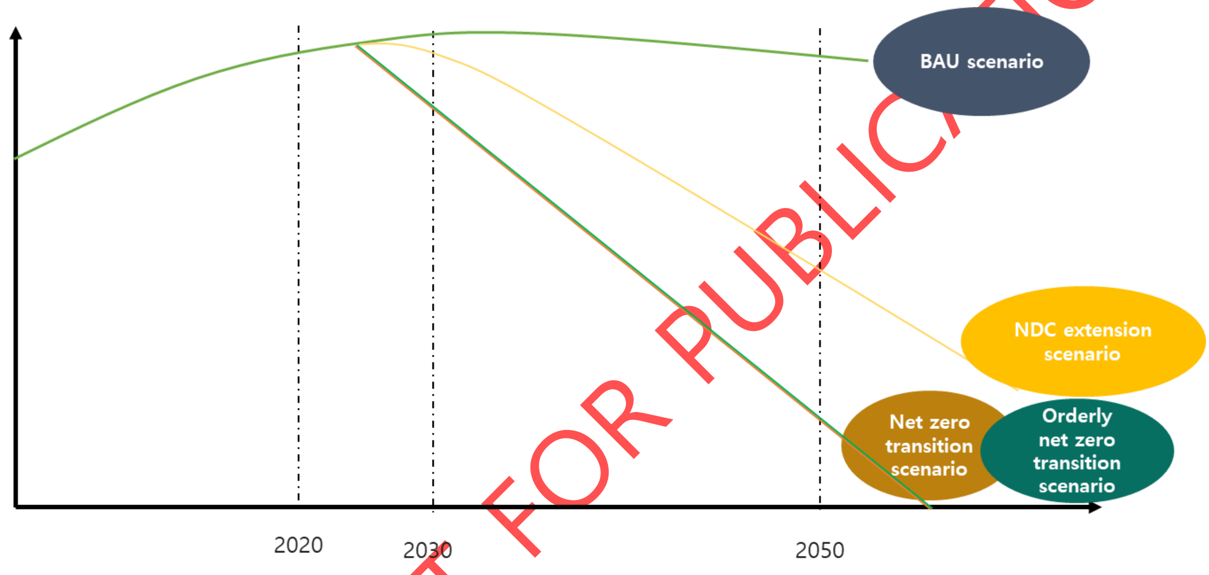

Figure 5. Graphical Illustration of Transition Pathways

Source: Author's elaboration

Table 1. Regional Average Carbon Price (Unit: USD)

Region	2030	2050
Organisation for Economic Co-operation and Development	129.11	248.48
Caucasus and Central Asia	56.22	134.69
East Asia	92.07	202.40
South Asia	15.00	55.00
Southeast Asia	56.40	135.05
The Pacific	15.00	55.00
Developing economies	57.83	134.90

[2] Albania, Bosnia and Herzegovina, Montenegro, Serbia, and North Macedonia

Results

The study compares the economic indicators under BAU scenario and the other three low-carbon transition scenarios. The result indicates the low-carbon transition would lead to a mild decrease in economic indicators, such as real GDP and real GDI. The GDP losses of Net Zero transitions relative to BAU level remains in -3% in all regions and scenarios.

Despite some economic losses, the low-carbon transition would lead to a significant reduction in greenhouse gas emissions in Asia. When achieving Net Zero, Orderly Net Zero scenario suggests some relatively positive economic effects in Asian regions in general, but there are some mixed results across regions.

Moreover, the study indicates the transition would increase the total employment, including both skilled and unskilled, and the international carbon market in Asia would have some positive impacts on both skilled and unskilled labor. However, it shows some mixed results at the sectoral and regional levels. From the sectoral perspective, the economic indicators, such as GDP, GDI, production, investment, and employment, show significant losses in fossil-fuel-related, carbon-intensive industries, such as coal, non-renewable electricity, oil and gas, while those indicators of renewable energy sector show a substantial increase, and the other sectors remain relatively stable. Particularly, the coal sector would receive the most significant damages.

At the regional level, the impacts of low-carbon transition would not be uniform. Although all regions experience mild GDP and GDI losses, most of the Asian regions, except for Caucasus and Central Asia, indicate a slight increase in employment. Among Asian sub-regions, Caucasus and Central Asia region would experience relatively larger economic losses and employment. However, the introduction of an international carbon market in Asia would generally provide positive economic impacts in Asia when achieving Net Zero though varying results across regions.

To check the robustness of the results, the study conducts two different sensitivity analyses on learning rates and elasticities of substitutions. First, the study assumes the learning rate of 15% to the productivity of renewable energy technology, and it conducts sensitivity analysis with higher (17.5%) and lower (12.5%) learning rates. Next, the study reduces the elasticities of substitutions between electricity and fossil fuel and between renewable and non-renewable electricity. Initially, both elasticities of substitutions are 4, and they are reduced to 2 in this sensitivity analysis.

The sensitivity to the learning rate suggests a higher learning rate to the productivity of renewable energy technology would reduce economic losses by transition and lead to better results when achieving Net Zero. The sensitivity to different elasticities of substitution parameters indicates the smaller elasticity of substitution parameters would lead to larger economic losses (relative to BAU level) but mixed results in employment.

Based on the analysis, the study suggests some implications. Contrary to the perceived perceptions, the economic losses from the low-carbon transition would not be significant in developing countries, and total employment would be benefited from the transition. Also, Orderly Net Zero transition, which is defined as an international carbon market in Asia, would lead to better results, in general, compared to the other scenarios. Moreover, a substantial sectoral allocation of production, investment, and employment would happen during the transition. Specifically, significant damages would be a focus on fossil-fuel-related and carbon-intensive industries, while the renewable energy sector would be largely benefited. This stresses that it is necessary and important to consider Just Transition and requires the policy actions and social safety net to address social and economic challenges, particularly in those carbon-intensive sectors, including financial and technological supports, re-education and training of unemployed workers, and addressing stranded assets.