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Socio-economic and environmental impact of Intended decarbonization policies in the East Asia region

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Abstract

Given the rising levels of carbon emissions, governments in the East Asia region are exploring effective decarbonization policies. This study examines the socio-economic and environmental implications of these policies using a closed-loop multi-country computable general equilibrium model that captures key linkages between the economy and climate change. Our findings suggest that the intended decarbonization policy, aimed at accelerating technology transfer, may not always reduce carbon emissions. However, incorporating Carbon Capture and Storage (CCS) technology into existing coal power plants and implementing a carbon tax could significantly reduce carbon emissions in all countries in the region. The paper suggests implementing carbon tax policy to reduce carbon emissions, retrofitting CCS technology in coal-based electricity power plants, and developing renewable electricity at the same time as controlling emissions from non-renewable energy. These policies, however, need some supplement policy strategies to compensate for the potential output contraction due to the tax.

Key words: decarburization, climate change, East Asia, Computable General Equilibrium

JEL Codes: D58, H23, Q54

* The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Indonesian Ministry of Finance

1. Introduction

In the early 1990s, the United Nations Framework Convention on Climate Change (UNFCCC) was established with the aim of stabilizing greenhouse gas (GHG) concentrations and preventing anthropogenic interference with the climate system. Since then, there has been a global effort to implement decarbonization policies to reduce carbon emissions. The 1997 Kyoto Protocol, which came into force in 2005, aimed to limit and reduce GHG emissions from industrialized countries through emissions trading, a clean development mechanism, and joint policy implementation. Another significant initiative was the 2015 Paris Agreement, which sought to bind all nations to reduce their GHG emissions according to their nationally determined contributions (NDCs) (United Nations, 2015).

Carbon emissions are a significant component of GHG emissions, and studies have shown that their increase has adverse effects on economies due to global warming. This warming can harm agricultural output, water supply, economic growth, and income per capita (Dell, Jones, and Olken, 2009; Garnaut, 2011; Stern, 2007). Despite growing evidence of the negative impacts of carbon emissions, effective decarbonization policies have not been implemented in many countries until recently (Watson et al., 2019). In fact, global carbon emissions increased by approximately 1.35% in 2017 and slightly more in 2018 at approximately 2.03% (Global Carbon Project, 2020).

Carbon emissions in the East Asia region have followed a similar trend, as shown in Figure 1.[1] Between 1990 and 2016, there was a significant increase in carbon emissions in the region, with East Asia's proportion of global emissions doubling from around 21% in 1990 to 45% in 2016. The majority of these emissions were a result of fossil fuel combustion.

[1] In this paper, the East Asia region includes Australia, China, Japan, India, South Korea, Indonesia, Malaysia, Singapore, the Philippines, Thailand, Vietnam, and the rest of the Southeast Asian countries. The selection of these countries is based on an agreement reached during the 2005 East Asian Summit on energy market integration (Wu, Kimura, and Shi, 2013).

<< Figure 1 here>>

The increase in carbon emissions in the East Asia region has been attributed to rapid economic and population growth leading to rising electricity demand (Chang et al., 2019; Lean and Smyth, 2010). However, other factors have also been identified in the literature as contributing to the increase in carbon emissions from fossil fuel combustion in the region. Firstly, fossil fuel subsidies provided by countries in East Asia have led to a fall in fossil fuel prices, an increase in demand for fossil fuels, and a subsequent rise in carbon emissions. In the 2010s, governments in East Asia provided approximately USD 100 billion per year in fossil fuel subsidies, which accounted for around 20% of global fossil fuel subsidies (IEA, 2021). Fossil fuel subsidies also reduce incentives to develop renewable energy and can negatively impact government budgets (Plante, 2014; UNEP, 2008).

Secondly, there has been a lack of sufficient commitments to reduce carbon emissions in the East Asia region, beyond their global commitments at the UNFCCC, the Kyoto Protocol, and the Paris Agreement. However, several studies have argued that these global agreements have not had a significant impact on carbon emission reduction (Nordhaus, 2019; Watson et al., 2019). A report by Watson et al. (2019) states that among countries in the East Asia region, only Australia, Japan, and South Korea have partially sufficient decarbonization targets, while other countries in the region have insufficient carbon emission reduction targets.[2]

Finally, there has been limited solid analysis of the socio-economic and environmental impacts of intended decarbonization policies in the East Asia region. This uncertainty leaves leaders and the public uncertain about the potential effects of such policies on their economic, social, and environmental conditions (Nurdianto and Resosudarmo, 2016). Previous studies

[2] A commitment to reduce carbon emissions by 20-40% in a country is considered to have sufficient decarbonization targets. On the other hand, partially sufficient implies that a country has no target for carbon emissions reduction, relies more on international financial support to reduce carbon emissions, uses emissions per GDP targeting, or uses carbon emissions reduction against business as usual (Watson et al., 2019)

either do not cover the general equilibrium impacts of intended decarbonization policies or do not fully model the links between economic changes resulting from a policy, carbon emissions, and the feedback loops from global warming due to carbon emissions on the economy (Dejuán et al., 2020; Oyewo et al., 2020; Fujimori, Masui, and Matsuoka, 2014; Zhang, Guo, and Hewings, 2014).

The purpose of this paper is to conduct a comprehensive analysis of the socio-economic and environmental impacts of intended decarbonization policies in the East Asia region. To achieve this, the paper utilizes a Computable General Equilibrium (CGE) model that includes a closed-loop model between the economy and global warming resulting from carbon emissions. It is worth noting that there are relatively few CGE models with closed-loop models between the economy and the environment. This paper analyzes indicators of the socio-economic and environmental impacts, including Gross Domestic Products (GDPs), sectoral outputs, household incomes, poverty incidents, income distributions, and carbon emissions. Furthermore, this paper presents the results of simulating three specific policies intended to reduce carbon emissions and their effects on socio-economic conditions and levels of carbon emissions among countries in the East Asia region. The three intended decarbonization policies include providing subsidies for renewable electricity sectors, providing subsidies for Carbon Capture and Storage (CCS) technology in the coal power plants sector, and implementing a carbon tax on fossil-based fuel commodities. The first two policies aim to accelerate technology transfer in the region, while the last policy intends to restrict the outputs of carbon-intensive sectors.

This paper makes several significant contributions to the existing literature. Firstly, the study develops one of the few CGE models that fully models the links between economic changes resulting from a policy, carbon emissions, and the feedback loops from global warming due to carbon emissions on the economy. Secondly, it sheds light on the impact of decarbonization policies on economic, social, and environmental conditions.

The findings of this paper suggest that the intended decarbonization policy, specifically the technology transfer policy, may not always reduce carbon emissions. Subsidizing renewable electricity sectors may lead to a slight increase in carbon emissions for most countries in the East Asia region, due to the positive spillover of renewable electricity sector development to other sectors. However, incorporating Carbon Capture and Storage (CCS) technology into existing coal power plants could significantly reduce carbon emissions for all countries in the region, and implementing a carbon tax could also lead to carbon emissions reductions.

Regarding macroeconomic impacts, implementing an intended decarbonization policy would likely cause most East Asian economies to contract, particularly since governments would need to reallocate some of their spending to subsidize renewable electricity sectors or provide CCS technology. In the carbon tax implementation scenario, the economy would also contract due to rising commodity prices.

With regard to microeconomic impacts, poverty incidences in most countries would decrease if governments implemented the technology transfer policy by subsidizing renewable electricity sectors and providing CCS technology for the existing coal electricity sector. However, carbon tax implementation could lead to an increase in poverty incidence due to rising commodity prices, leading to a reduction in household expenditures.

The rest of the paper is organized as follows. The next section provides a literature review on the socio-economic and environmental impacts of intended decarbonization policies. This is followed by a section describing the construction of a CGE model, and a section on the datasets utilized in this paper. The next sections describe the intended decarbonization policy simulations conducted, followed by a discussion on the socio-economic and environmental impacts of intended decarbonization policies in each East Asian country. Finally, the last section concludes with policy implications.

2. Literature Review

There is a growing body of empirical evidence demonstrating the adverse economic effects of global warming at both the country and household level. For instance, studies by Tol (2009), Dell, Jones, and Olken (2012), and Burke, Hsiang, and Miguel (2015) have shown the economic impacts of climate change. Furthermore, increasing temperatures have led to reduced income (Dell, Jones, and Olken, 2009) and agricultural output (Aragón, Oteiza, and Pablo, 2021) at the household level. However, while there are partial equilibrium models that estimate the economic outcomes of decarbonisation policies, such as the work by Oyewo et al. (2020) on West Africa, there is a gap in the literature regarding solid models and analyses that examine the socio-economic and environmental impacts of intended decarbonisation policies in a comprehensive manner. It is worth noting that Oyewo et al.'s study did not cover the economy-wide impacts of their proposed decarbonisation policy.

There is limited literature available that analyses the economy-wide impacts of intended decarbonisation policies using general equilibrium models such as input-output analysis models, computable general equilibrium (CGE) models, or integrated assessment models (IAMs). Some studies have used a hybrid multi-regional input-output model to estimate the impacts of an intended decarbonisation policy, such as Dejuán et al. (2020), who found that it leads to a reduction in energy consumption and carbon emissions, a fall in value-added, and higher unemployment. Another example is a study by Fujimori, Masui, and Matsuoka (2014), which showed that climate change mitigation constraining carbon emissions would require carbon taxes and higher energy prices.

Most of the general equilibrium literature related to this topic has focused on analyzing the impacts of climate change on the economy rather than examining the impacts of intended decarbonisation policies. For example, Bosello, Roson, and Tol (2007) evaluated the impacts of rising sea levels as an exogenous shock through potential losses of land and coastal protection costs using a CGE model. Similarly, Kompas and Van Ha (2019) incorporated climate change shock into four categories, including changes in land for land losses due to sea level rises, shifts in productivity variables due to changes in crop yields, heat on labour productivity and human health, and shifts in demand for selected goods.

While there are general equilibrium models that include links between economic activities and carbon emissions, very few have included models simulating the feedback links from global warming due to carbon emissions to economic activities. These feedback loops are crucial for understanding the complete cycle from climate change to productivity and back to climate change again, creating a closed-loop between the economy and climate change model within a CGE model. The impacts of climate change on human life are well documented, including falling crop yields, decreasing water supply, species extinction, and increasing intensity of storms, forest fires, droughts, flooding, and heatwaves. (Garnaut, 2011; Stern, 2007).

Few CGE models in the general equilibrium literature include a closed-loop between the economy and the environment. For instance, Resosudarmo (2002) developed a CGE model that links the economy and ambient air pollutant levels, modelling how increasing economic production activities would lead to an increase in air pollutants and health problems associated with air pollution that affect productivity in urban production sectors. Resosudarmo (2008) also constructed a CGE model that links agricultural production activities and pesticide use, modelling how pesticide-related health issues among farmers affect productivity and result in declining agricultural production.

Climate change models that include a closed-loop between the economy and global warming are mostly Integrated Assessment Models (IAMs), such as DICE (Dynamic Integrated Climate–Economy) by Nordhaus and Sztorc (2013), FUND (Climate Framework for Uncertainty, Negotiation and Distribution) by Tol (2002), and WITCH (World Induced Technical Change Hybrid Model) by Bosetti et al. (2006). These models quantify relationships between carbon emissions, concentration, and temperature in a carbon cycle (Pindyck, 2013).[3] However, the main issue with IAMs is that they assume only one composite commodity in the economy, which is at a worldwide level (Gillingham et al., 2018), following a neoclassical growth model (Solow, 1956; Swan, 1956). As a result, these models are too aggregated and do not allow for specific sectoral policies in a particular country. While a regional IAM called the Regional Integrated Model of Climate and the Economy (RICE) addresses this issue, it also assumes one composite commodity in the economy, similar to DICE (Nordhaus and Yang, 1996).

This study develops a CGE model that includes closed links between economic activities and climate changes represented by changes in global temperature, addressing a gap in the current literature. The model, called a closed-loop Inter-Regional System of Analysis for East Asia (IRSA-EA) model, adopts the model between climate change and the economy from DICE and RICE into a multi-sector and multi-country CGE model for the East Asia region.

3. Methodology

The closed-loop IRSA-EA model developed in this paper is derived from two existing multi-sector and multi-country CGE models: the inter-regional system of analysis for ASEAN

[3] The carbon cycle process is a sequence of events in which increased carbon emissions lead to the accumulation of carbon in the atmosphere, trapping heat and resulting in climate change through global warming (Ikefuji, Masui, and Matsuoka, 2021; Nordhaus and Sztorc, 2013; Stern, 2008).

(IRSA-ASEAN) model (Nurdianto and Resosudarmo, 2016) and the inter-regional system of analysis for Indonesia five regions (IRSA-Indonesia5) model (Resosudarmo et al., 2011; Resosudarmo et al., 2020). These models are based on earlier CGE models developed by Dervis, de Melo and Robinson (1982), Adelman and Robinson (1988), and Thorbecke (1991).

The closed-loop IRSA-EA model, like the IRSA-ASEAN and IRSA-Indonesia5 models, incorporates producer and consumer optimizations at the country level, allowing for price and quantity variations in each country. This feature is crucial in conducting simulations in this study. Additionally, countries are interconnected through the trade of goods and services, both within the region and with external countries. The model also accounts for foreign savings investments and transfers of funds between countries. The closed-loop IRSA-EA model also includes a household income microsimulation model that disaggregates total expenditures of urban and rural households into 100 households in each area within each country. The division of households into rural or urban areas is based on the percentile distribution of household expenditures (Nurdianto and Resosudarmo, 2016). Poverty rates in rural and urban areas are calculated based on these expenditures (Yusuf and Resosudarmo, 2015).

The closed-loop IRSA-EA model has two main distinctions from its precursors (IRSA-ASEAN and IRSA-Indonesia5). First, it incorporates a closed-loop model between the economy and climate change by adopting a model from DICE or RICE, which is not covered by its precursors. Figure 2 shows the closed-loop model between the economy and climate change in the closed-loop IRSA-EA model, where carbon emissions come from industrial sectors, households, and deforestation in the forestry sector. Total carbon emissions accumulate and become concentrated carbon in the atmosphere, leading to higher temperatures that affect sectoral productivities. As a result, sectoral outputs and final demands of industries and households also change.

<< Figure 2 here>>

The closed-loop IRSA-EA model requires several additional equations, including total emissions, carbon concentration, temperature, and an abatement-damage function. Total emissions (XCO) in Equation (1) are defined as the sum of carbon emissions from industry $(XCOI)$ using fossil fuel type *e* in industry *i* at country *d*, households $(XCOH)$ using fossil fuel type *e* in household *h* at country *d*, and forestry $(XFOR)$ as a fraction of forestry sector output. Equations (2) and (3) represent carbon emissions from industry and households, respectively, while carbon emissions from forestry are calculated using Equation (4) as a proportion of the forestry sector output, represented by parameter τ. These equations are similar to those used in previous studies by Ikefuji et al. (2021) and Nordhaus and Sztorc (2013).

$$XCO_d = \sum_e \sum_i \mathrm{XCOI}_{e,i,d} + \sum_e \sum_h \mathrm{XCOH}_{e,h,d} + \mathrm{XFOR}_d \quad (1)$$

$$\mathrm{XCOI}_{e,i,d} = (1 - \mu1_{i,d}).\mathrm{cci}_{e,i,d}.XINT\_S_{e,i,d} \quad (2)$$

$$\mathrm{XCOH}_{e,h,d} = (1 - \mu2_{h,d}).\mathrm{cch}_{e,h,d}.XHOU\_S_{e,h,d} \quad (3)$$

$$XFOR_d = \tau.XTOT_{'frs',d} \quad (4)$$

where $XINT\_S_{e,i,d}$ is intermediate energy inputs, $XHOU\_S_{e,h,d}$ is household energy consumption and $XTOT_{'frs',d}$ is total forestry output.

Terms $\mu1_{i,d}$ and $\mu2_{h,d}$ in Equation (2) and Equation (3) indicate emission control rates for industry i and household h respectively. Both emission control rates are equal to zero in the baseline and are exogenous. Furthermore, terms $\mathrm{cci}_{e,i,d}$ and $\mathrm{cch}_{e,h,d}$ denote carbon content for energy used in industries and carbon content for that in households, respectively.

In terms of carbon concentration in the atmosphere, this paper assumes that it comes from initial carbon concentration $(CDC0)$ and additional carbon from carbon emissions

(XCO) as shown in Equation (5). Parameter κ converts the units of carbon emission from tonnes of CO_2 into parts per million (ppm) carbon concentration in the atmosphere. This paper calibrates initial carbon concentration $(CDC0)$ from 2011 carbon concentration in the atmosphere (CDC).

$$CDC_d = \phi 1_d . CDC0_d + \phi 2_d . \left(\frac{XCO_d}{\kappa}\right) \tag{5}$$

In terms of temperature, this paper assumes that current temperature (TEMP) is a function of initial temperature (TEMP0) and the logarithm of carbon concentration in the atmosphere (CDC), as shown in Equation (6). The current temperature is calculated as the difference between the average yearly temperature from 2002 to 2011 and the average yearly temperature from 1891 to 1900.

$$TEMP_d = \eta 0_d + \eta 1_d . TEMP0_d + \eta 2_d . log(CDC_d) \tag{6}$$

The damage function in Equation (7) is defined as a function of the productivity damage coefficient, which corresponds to temperature. As per the DICE model, a higher temperature leads to a higher damage level, represented by a lower value of the damage coefficient.

$$DAM_{i,d} = \frac{1}{1 + \xi_d . \; TEMP_d^2} \tag{7}$$

The productivity damage coefficient is incorporated into the top nest of the production function to apply the closed-loop in the IRSA-EA model, as shown in Equation (8).

$$\mathrm{XTOT_{i,d}} = DAM_{i,d} \; . \alpha_{\mathrm{i,d}}^{\mathrm{tot}} . \left(\delta_{\mathrm{i,d}}^{\mathrm{tot}} . \mathrm{XINT\_SC1_{i,d}}^{-\rho^{tot}} + \left(1 - \delta_{\mathrm{i,d}}^{\mathrm{tot}}\right) . \mathrm{XPRIMEN_{i,d}}^{-\rho^{tot}}\right)^{-\frac{1}{\rho^{tot}}} \tag{8}$$

All parameters for the model ($\phi 1$, $\phi 2$, $\eta 0$, $\eta 1$, $\eta 2$, and ξ) are taken from a simplified DICE (Ikefuji et al., 2021). The parameter values are as follows: $\phi 1_d$= 0.9902; $\phi 2_d$= 0.6001; $\eta 0_d$ =-2.8672; $\eta 1_d$= 0.8954; $\eta 2_d$= 0.4622; and ξ_d=0.00265. In DICE, these parameters represent an annual change. Hence, the closed-loop IRSA-EA model provides a short to medium term analysis, i.e., a change between one to five years.

Additional closures are required to ensure that the closed-loop IRSA-EA model is square, meaning the number of variables equals the number of equations, and can represent a short-to-medium-term analysis. The model uses the following default closures:

- The output price index is the numeraire;
- World export and import prices are exogenous;
- Household and corporate savings rates are exogenous;
- Government savings are exogenous;
- Indirect tax and import tax rates are exogenous;
- Factor supplies are exogenous;
- Land, capital, and natural resources are immobile; and
- Labour is mobile and fully employed.

This model assumes that non-labor inputs are immobile, with fixed average rents across industries. Labor, on the other hand, is mobile, able to move between sectors while maintaining sector-specific wages. This assumption allows for short- to medium-term analyses (Löfgren, Robinson, and Harris, 2002), consistent with the coefficients used in the closed-loop carbon emission model.

The closed-loop IRSA-EA model has a second distinction from its precursors as it enables industries to substitute between various energy sources and sources of electricity, including renewable and non-renewable energies. To model these substitutions, the model uses nested constant elasticity of substitution (CES) production functions.[4]

[4] The detailed modelling of the closed-loop IRSA-EA can be found in Effendi and Resosudarmo's (2022) publication, available at http://ceds.feb.unpad.ac.id/wopeds/202201.pdf.

4. Data

This paper analyzes the social, economic, and environmental impacts of decarbonization in East Asia, using five datasets. The primary dataset is the inter-regional social accounting matrix for East Asia (EA-IRSAM), constructed from the Global Trade Analysis Project (GTAP) Power version 9 database with a reference year of 2011 and a currency of United States billion dollars (McDonald and Thierfelder, 2004 and 2013). The EA-IRSAM includes modifications such as disaggregating the regional household account into urban and rural households, firm, and government accounts, and recalculating subsidies for fossil fuels in each country. The EA-IRSAM covers 12 countries in East Asia and includes 33 production sectors for each country (Table 1). Selected socio-economic indicators of the EA-IRSAM are presented in Table 2.

<< Table 1 here>>

<< Table 2 here>>

The second dataset comprises of several household surveys conducted in countries across the East Asia region. These datasets are necessary to estimate income distribution among urban and rural households, as well as government transfers to households. Additionally, these datasets are utilized to calculate expenditure shares for various commodities among both urban and rural households. Specifically, the 2011 socio-economic survey (SUSENAS) is used for Indonesia, the 2011 Annual Poverty Indicators Survey (APIS) for the Philippines, the 2011 Household Socio-Economic Survey (SES) for Thailand, the 2014 Vietnam Household Living Standards Survey (VHLSS) for Vietnam, the 2012 China Family Panel Survey (CFPS) for China, the 2009–2010 Household Expenditure Survey for Australia, the 2009 Family Income and Expenditure Survey for Japan, and the 2011–2012 Household Consumer Expenditure NSS-68th Round for India. Due to insufficient data, for South Korea, the share of urban and rural expenditure by commodity is assumed to be similar to that of Indonesia.

The third dataset includes parameters of elasticity of substitution derived from various studies. The top-level parameters for the elasticity of substitution between the composite of non-electricity and non-energy intermediate inputs and the composite of primary, energy, and electricity intermediate inputs are obtained from Resosudarmo (2002). At the lower level, the parameter for the elasticity of substitution between the composite of intermediate energy inputs and primary inputs, as well as the parameters of elasticity of substitution between energy and electricity intermediate inputs, are derived from Yusuf and Resosudarmo's (2015) study. Finally, the parameters of elasticity of substitution for value-added and Armington are sourced from the GTAP Power 9 database.

The fourth dataset comprises of carbon emissions by sector and country, extracted from the GTAP Power 9 database. This dataset covers carbon emissions resulting from the consumption of electricity, coal, oil, gas, petroleum products, and gas manufactured distribution by each sector in every country.

The fifth dataset pertains to climate change and includes two components. Firstly, carbon concentration in the atmosphere is obtained from the NASA dataset, specifically using the AIRS/Aqua monthly CO_2 in the free troposphere dataset.[5] This dataset provides monthly gridded data at a 2.5 times 2-degree grid cell size. Although carbon concentration may be mixing globally in the atmosphere, there is a difference in concentration among countries according to the NASA dataset. To extract country-level carbon concentration data, this paper overlaps the carbon concentration dataset with country boundaries and reduces the grid size to 0.25 times 0.2 degrees to fit within the boundaries. The paper then calculates the average value

[5] NASA 2021. AIRS/Aqua L3 Monthly CO_2 in the free troposphere (AIRS-only) 2.5 degrees x 2 degrees V005 (AIRS3C2M). GES DISC data. Accessed on 8 January 2021 at https://disc.gsfc.nasa.gov/datasets/AIRS3C2M_005/summary?keywords=airs%20version%207. The original data is in mole fraction units. This paper converts the unit into part per millions (ppm) unit of carbon concentration.

of the monthly dataset for each country in the East Asia region.[6] Secondly, temperature is defined as the difference in temperature between the average of 10 years from 2011 and the average of 10 years from 1900, measured in degrees Celsius. The temperature dataset is obtained from Berkeley Earth analysis.[7]

5. Policy Simulations

Using the closed-loop IRSA-EA model, this paper simulates three intended decarbonisation policies aimed at reducing carbon emissions in the East Asia region. The first two policies aim to accelerate the implementation of new technology or technology transfer, while the third policy restricts the outputs of carbon-intensive sectors. The policies are as follows:

- ***Supporting the development of renewable electricity (SIM1)***: In this policy, the government provides an additional five per cent subsidy rate to each renewable electricity sector. The model includes three renewable electricity sectors: wind, hydro, and solar power plant sectors. Since wind and solar power plants are relatively new technologies in the region, subsidies are expected to decrease the prices of electricity from renewable electricity power plant sectors, leading to an increase in demand and adoption of these technologies. However, to provide subsidies for renewable electricity, each government must reduce its spending on other goods and services.
- ***Supporting the installation of Carbon Capture and Storage (CCS) technology in the coal electricity sector (SIM2)***: This policy provides full government subsidies to certain coal electricity power plant sectors for the installation of new CCS technologies. This is also a technology transfer case for the region, with the

[6] Thanks to Dr. Sandra Potter (ANU CartoGIS) for providing consultation and help with extracting the NASA dataset.
[7] Berkeley 2021, Berkeley Earth Analysis. Accessed on 8 January 2021 at http://berkeleyearth.lbl.gov/country-list/.

assumption that the technology is obtained from China.[8] As a result, there is a flow of funding from governments in all countries in the East Asia region to manufacturing sectors in China. The total funding for the technology from each country is equal to the total subsidy for renewable development in SIM1. Incorporating CCS technology into existing coal electricity sectors should reduce carbon emissions from the coal electricity sector. However, due to limited funds, not all coal power plants will be installed with CCS technologies. Table 3 provides information on the potential carbon emission reductions under SIM2. Column (1) shows the total available funds, equivalent to the total subsidies of renewable electricity sectors in SIM1. Column (2) presents the size of the coal electricity sectors in each country. The percentage of coal-electricity power plants that could be installed with CCS technologies is shown in Column (3). The potential carbon emission reduction for each country in Column (4) is a multiplication of Column (3) with carbon emission reductions due to installed CCS technologies (IPCC 2005).

<< Table 3 here>>

- ***Carbon tax implementation on fossil fuel commodities (SIM3)***: This policy involves the government collecting a carbon tax from energy sectors that generate carbon emissions. Enforcing the carbon tax on coal, petroleum products, and distributed gas is a way to reduce carbon emissions while also conserving fossil fuels. As fossil fuel prices increase due to the carbon tax, consumption of fossil fuels is expected to decrease, resulting in lower carbon emissions generated by industries and households. In this scenario, the paper assumes that each government collects a carbon tax from energy commodities used by industries and households, with the total value of the

[8] The decision to import CCS technology from China is based on China's dominance in supplying electric power plant technology in the East Asian region during the 2010s.

carbon tax collected by each government being similar to the amount of renewable electricity subsidies in SIM1.

An important assumption in this paper is that government savings remain constant. Thus, any additional spending on renewable electricity development must come from the reallocation of government spending. Similarly, if there is additional revenue, the government will allocate it proportionally to current spending.

6. Results

6.1 Sectoral Output Changes

Table 4 illustrates the short to medium-term aggregated sectoral output changes resulting from the intended decarbonisation policy. In SIM1, the government provides an additional subsidy for the renewable electricity sector, resulting in a lower cost for producers to generate renewable electricity. As a result, renewable electricity outputs increase in most countries. For instance, in SIM1, the outputs of renewable electricity in Japan, India, Vietnam, and the rest of ASEAN increase by more than 1 per cent.

<< Table 4 here>>

Apart from expanding renewable electricity output, this policy has two other main implications. The first implication is the positive spillover impacts on other sectors in the economy, which depend on the economic structure of each country and the linkages from renewable electricity sectors to other sectors. Based on these spillover impacts, some countries experience positive spillover impacts on their agriculture sectors, such as India, Malaysia, the Philippines, Thailand, and the rest of ASEAN. Almost all countries in the East Asia region experience positive trade spillover impacts on their manufacturing sectors, leading to an expansion in manufacturing outputs. In response to the rise in their manufacturing outputs, most of these countries also experience positive spillover impacts on their energy or fossil fuel electricity sectors.

The second implication is a reduction in government spending, with governments reallocating some of their spending to subsidize the renewable electricity sector while proportionally reducing spending on other sectors. Consequently, outputs in the services sector in all countries in the East Asia region decrease.

In SIM2, the government's focus is on reducing carbon emissions by deploying CCS technology for the coal electricity sector. There are two implications of this policy. The first is an expansion in China's manufacturing, energy, and electricity sectors, which has a positive trade spillover to other countries in the East Asia region. The extent of the positive spillover depends on trade linkages between China and other countries in the region. In Japan, the Philippines, and Vietnam, the spillovers are channeled to the manufacturing, energy, and fossil fuel electricity sectors. For South Korea and Singapore, the spillovers go to the manufacturing and fossil fuel electricity sectors, while for Malaysia and Thailand, they are concentrated in the manufacturing sector only.

The second implication is that governments buy CCS technologies from China's manufacturing sectors, resulting in less spending on other goods and services. As a result, the injection into the domestic economy is less than in the base situation or SIM1, resulting in a reduction in sectoral outputs in the services sector in most countries in the East Asia region. Meanwhile, the manufacturing sectors in China produce more outputs, with manufacturing output in China increasing by 0.18 per cent. The manufacturing sector also demands more inputs, including energy and electricity commodities, leading to an increase in these two sectors in China by more than 0.03 per cent.

In SIM3, the government collects a carbon tax from coal, petroleum products, and manufactured gas. Implementing a carbon tax on fossil fuel commodities results in an immediate rise in fossil fuel prices and production costs. As a result, producers respond to the increase in production costs by reducing their output. This paper finds that there is a reduction in most sectors in each country, particularly in the manufacturing, energy, and fossil fuel electricity sectors, all of which heavily rely on fossil fuels.

6.2 Macroeconomics and Carbon Emissions Changes

Table 5 provides the aggregate impacts of the intended decarbonisation policy on macroeconomic and carbon emissions changes for each simulation in each East Asian country. In SIM1, most countries experience a rise in carbon emissions ("rebound effect") while their economies shrink.[9] Except for Japan, all countries in the East Asia region, particularly Vietnam, India, Malaysia, the Philippines, and the rest of ASEAN, experience this situation, in which their carbon intensities increase by more than 0.01 per cent. The expansion in their manufacturing sectors due to spillovers from the renewable electricity expansion, as mentioned before, increases the fossil fuel electricity sectors, which in turn raises carbon emissions. This situation indicates that countries' economies in the East Asia region are relatively fossil fuel electricity-intensive. The increase in emissions occurs particularly in countries whose electricity generation is intensively using coal.

<< Table 5 here>>

In Japan, however, not only is its economy less coal-electricity intensive, but the spillover impact of renewable electricity sectors on other sectors is also relatively small. Therefore, the economy remains relatively unchanged, while carbon emissions decrease due to the decreased output of the fossil fuel energy sector.

In SIM2, a significant reduction in carbon emissions occurs due to the installation of CCS technology in the coal power sectors for all countries in the East Asia region. The largest

[9] A discussion of the rebound effect can be found in the work by Nurdianto and Resosudarmo (2016), among others.

reduction in carbon intensity occurs in Australia and the rest of ASEAN, by more than one per cent. These results suggest that providing CCS technology to a dominant carbon emitter sector is more effective than providing subsidies for renewable electricity.

However, most countries in the East Asia region, except India, experience a decline in their economies under SIM2. The contraction in the economy in this simulation is mainly due to the need for the government to buy the CCS technology directly from the Chinese government. Hence, their domestic spending declines, causing a reduction in the outputs of their services sectors. In contrast, in India, there is a double dividend effect where carbon emissions decrease and the economy expands. The economy in India expands mainly due to the expansion of the services sector.

In SIM3, all countries in the East Asia region experience a reduction in carbon emissions. This reduction is mainly caused by a contraction in sectoral output due to the implementation of a carbon tax on fossil fuel commodities. In Japan and Vietnam, the reduction in carbon emissions in SIM3 is larger than in SIM2, but not for other countries in the East Asia region.

6.3 Household Expenditure and Poverty Incidence Changes

Table 6 displays changes in the real household expenditure for urban and rural households for each simulation. Changes in commodity prices and household income are two drivers of change in real household expenditure shown in the table. In SIM1, the prices of all renewable electricity decrease as a result of reducing indirect taxes. Therefore, with lower prices, there should be an increase in renewable electricity consumption by households. The second driver, changes in household income, includes changes in income factors and government transfers.

<< Table 6 here>>

This paper's findings suggest that in SIM1, most countries in the East Asia region could increase their aggregate spending, except for urban and rural households in China and Thailand,

and rural households in Indonesia and Malaysia. The aggregate household expenditure reduction in these countries implies that the falls in renewable electricity prices cannot compensate for the fall in government transfers to households, making it difficult for households to afford to consume more renewable electricity.

In SIM2, however, most households in countries in the East Asia region could increase their expenditure, except for rural households in Vietnam. The expansion of household expenditure is mainly because governments can transfer more to households. As a result, real household expenditure is relatively higher, and poverty incidence is lower in SIM2. On the other hand, there is a reduction in government transfers to households in Vietnam, leading to a fall in rural households' expenditure.

Furthermore, implementing a carbon tax, as indicated in SIM3, reduces real household expenditure for all countries in the East Asia region. The main reason for the declining household expenditure is a rise in commodity prices across all sectors, causing the households to reduce their consumption. Across simulation results, this paper finds that there is an apparent tension between environmental policy and poverty issues in many of the countries being evaluated.

This paper also examines the impact of the intended decarbonisation policy on household expenditure by percentile in both rural and urban areas, as presented in Figure 3 for SIM1, Figure 4 for SIM2, and Figure 5 for SIM3. The pattern of changes in household expenditure in each percentile depends on the share of household demand for each commodity, with a progressive pattern indicating more positive changes in expenditure for poor households, a regressive pattern indicating more benefits for rich households, and a neutral pattern indicating a similar impact on both poor and rich households.

The results show that the impacts of subsidizing renewable electricity sectors (SIM1 in Figure 3) can be classified into three categories. China and Singapore experience a progressive pattern of changes in household expenditure, while India and Thailand exhibit a regressive pattern. Other countries in the region have relatively neutral changes. SIM2 in Figure 4 shows that there are two groups of countries: one with a progressive pattern of changes in household expenditure, including India, Indonesia, Thailand, and the rest of ASEAN, and one with a regressive pattern, including China, Malaysia, and Vietnam. In the Philippines, there is a slightly regressive pattern in urban households, while rural households show a progressive pattern of expenditure changes.

<< Figure 3 here>>

<< Figure 4 here>>

SIM3 in Figure 5 shows that carbon tax implementation leads to a regressive pattern in China, India, Malaysia, Thailand, Vietnam, and the rest of ASEAN. In urban households in Indonesia and the Philippines, there is a U-shaped pattern, indicating that poor and rich households are affected less than middle-income households. However, poverty incidence increases for all households due to a reduction in consumption caused by rising commodity prices.

<< Figure 5 here>>

Based on these patterns of changes in household expenditure, poverty incidences in these countries also change (Table 6). In SIM1, subsidizing renewable electricity sectors generally leads to a decline in poverty incidence, except for China, Thailand, and rural households in Indonesia and Malaysia. Providing CCS technology for the coal electricity sector (SIM2) reduces poverty incidence for almost all countries, except for rural households in Vietnam. Overall, technology transfer policies are found to be beneficial for the poor, while carbon tax implementation (SIM3) increases poverty incidence for all households.

6.4 Sensitivity Analysis

A sensitivity analysis toward two parameters in the closed-loop IRSA-EA model is necessary to examine the reliability of the results in this paper. The two main parameters are the elasticity of substitution among different intermediate electricity inputs ($\sigma_{i,d}^{ely}$) and elasticity of substitution between energy and composite electricity intermediate inputs ($\sigma_{i,d}^{en}$). They are centered in determining adaptation of more renewable electricity among industries. The sensitivity analysis is done by changing the parameters as much as 50 per cent higher and lower than the baseline parameter values simultaneously. For example, in case of higher parameter value than the baseline, the sensitivity analysis is conducted by increasing both values of $\sigma_{i,d}^{ely}$ and $\sigma_{i,d}^{en}$.

<< Table 7 here>>

The results of sensitivity analysis are presented in Table 7, which indicates that they are less sensitive to different values of elasticities of substitution. Therefore, the results in this paper are robust to different values of substitution elasticity.

7. Conclusions

This paper presents an analysis of the socio-economic and environmental impacts of intended decarbonisation policies in the East Asia region, aiming to determine the best approach to reduce carbon emissions in the region. The paper utilises a multi-country CGE model that takes into account links between economic activities and climate changes, represented by changes in global temperature, and vice versa, with closed-links between the economy and climate change. The three intended decarbonisation policies analysed in this paper are subsidising renewable electricity powerplant sectors, installing CCS technology into existing coal powerplant boilers, and collecting carbon taxes from fossil-based fuel commodities.

The findings suggest that, in the short to medium-term, intended decarbonisation policies do not necessarily lead to lower carbon emissions. Subsidising the renewable electricity sector could even increase carbon emissions, as it could create a rebound effect, except in Japan. However, installing CCS technology in the existing coal-based electricity powerplants and carbon tax does reduce carbon emissions.

The macroeconomic impact of intended decarbonisation policies tends to reduce the economy, mainly due to less government spending on goods and services. In terms of microeconomic impacts, it is difficult to generalise the regressivity or progressivity of the policies on household expenditures. However, the impact on income distribution would likely be small. Technology transfer policies, such as subsidising renewable electricity powerplant sectors or retrofitting CCS technology in coal-based electricity powerplants, is likely to reduce poverty incidence, while enforcing carbon tax could lead to a higher poverty level.

The findings of this paper are relatively robust towards possible variations of elasticity parameter for substitution among different intermediate electricity inputs and for substitution between energy and composite electricity intermediate inputs. The paper suggests implementing carbon tax policy to reduce carbon emissions, retrofitting CCS technology in coal-based electricity powerplants, and developing renewable electricity at the same time as controlling emissions from non-renewable energy. These policies, however, need some supplement policy strategies to compensate for the potential output contraction due to the tax.

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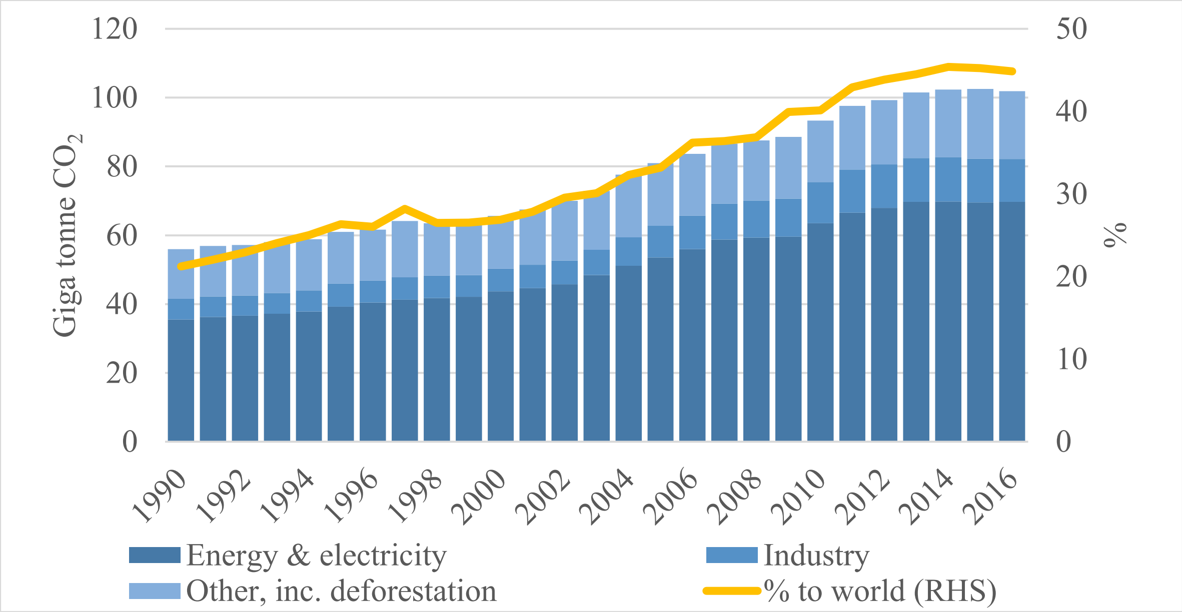


Source: WRI (2020).

Figure 1. Carbon Emissions in the East Asia Region

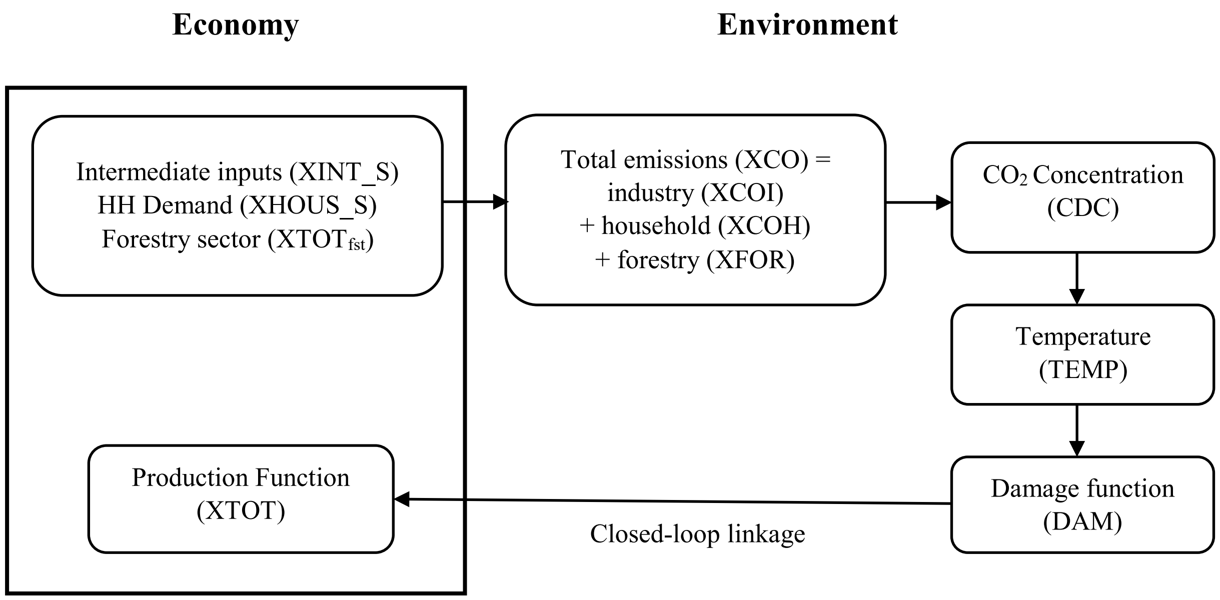
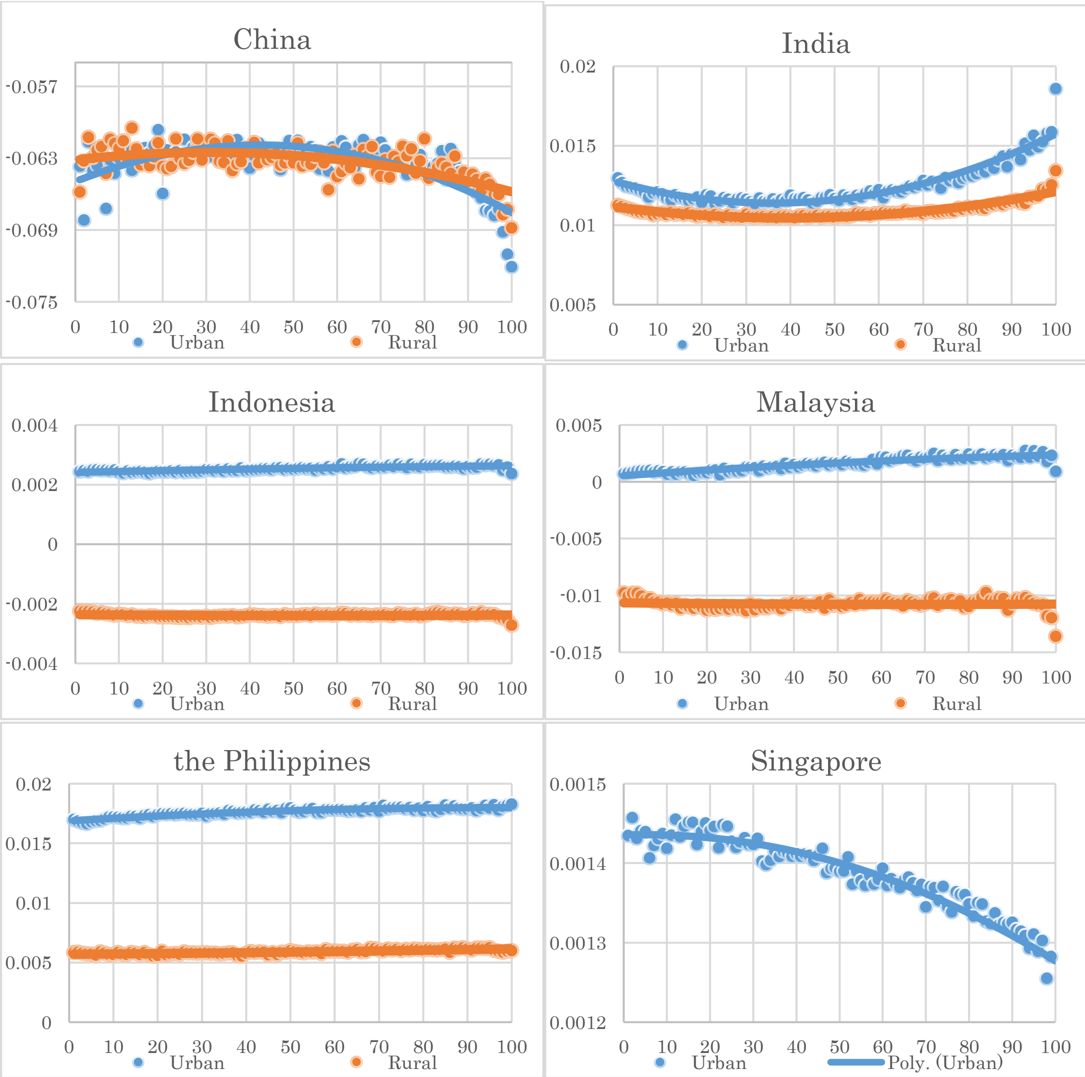


Figure 2. A Simplified Closed-Loop IRSA-EA Model in Each Country


China
-0.057
-0.063
-0.069
-0.075
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
India
0.02
0.015
0.01
0.005
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
Indonesia
0.004
0.002
0
-0.002
-0.004
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
Malaysia
0.005
0
-0.005
-0.01
-0.015
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
the Philippines
0.02
0.015
0.01
0.005
0
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
Singapore
0.0015
0.0014
0.0013
0.0012
0 10 20 30 40 50 60 70 80 90 100
Urban
Poly. (Urban)

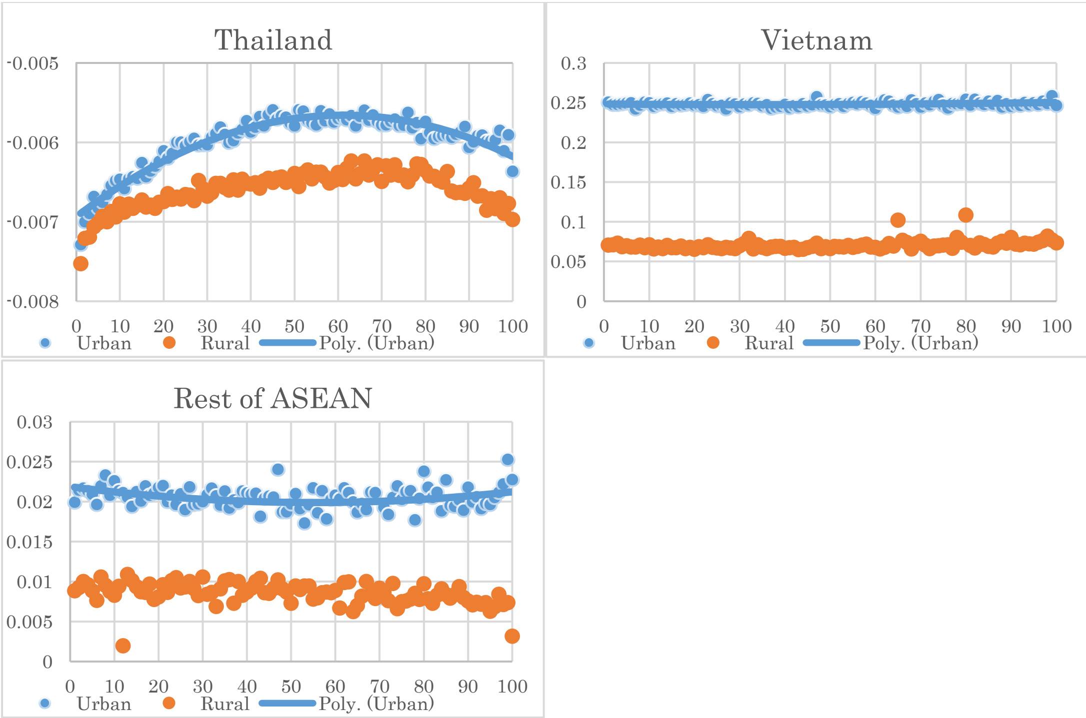
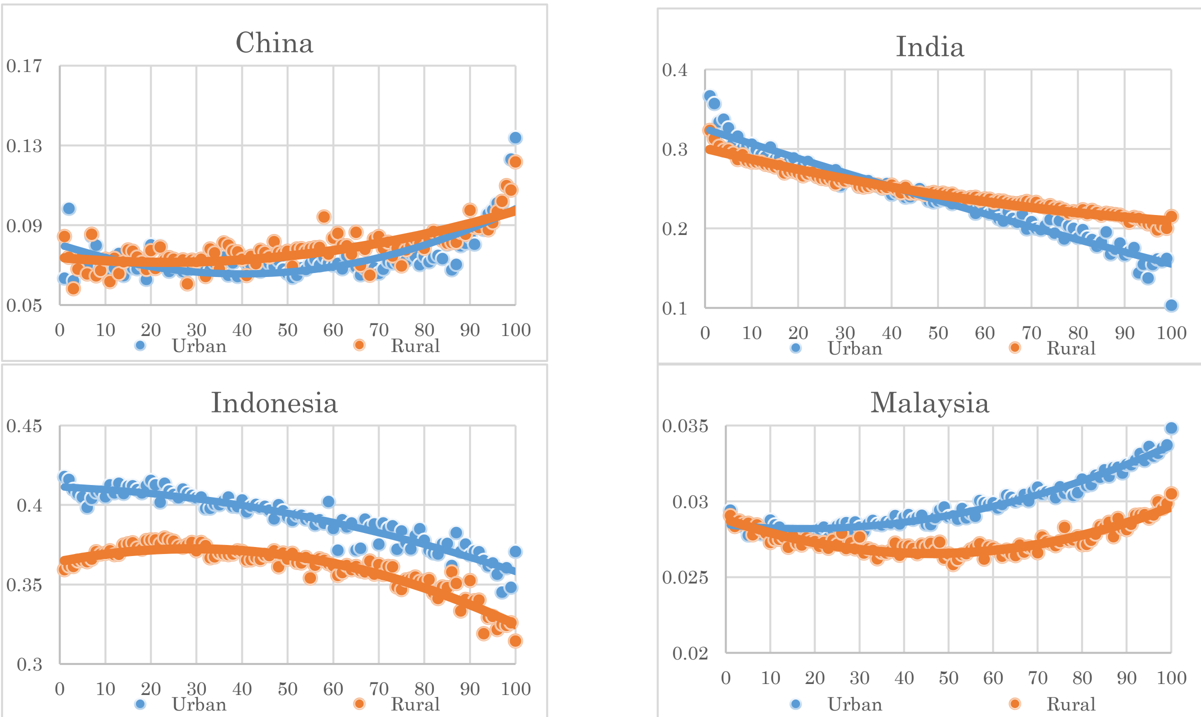


Figure 3. Real Household Expenditure Changes in SIM1 (in percentage)



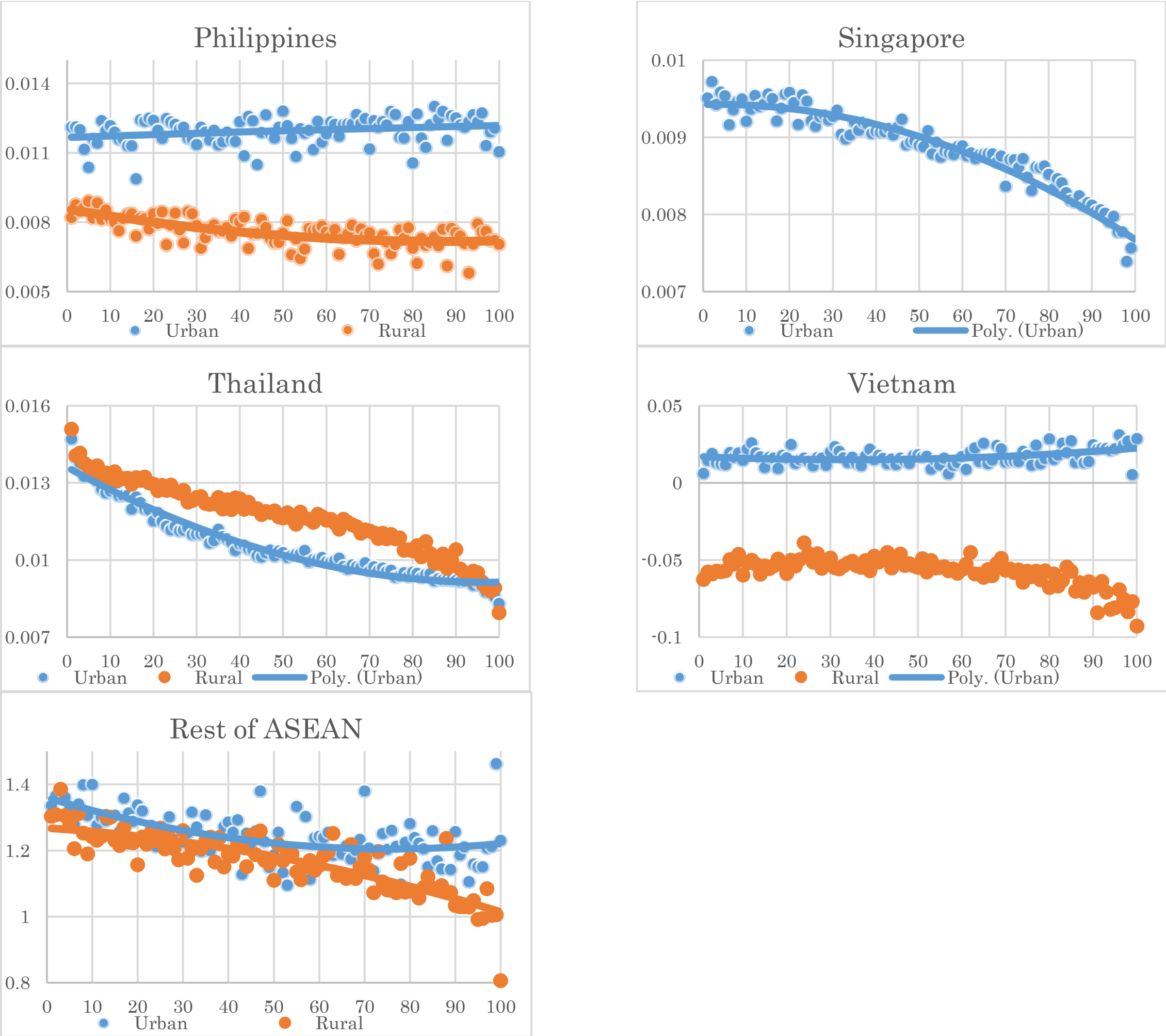


Figure 4. Real Household Expenditure Changes in SIM2 (in percentage)

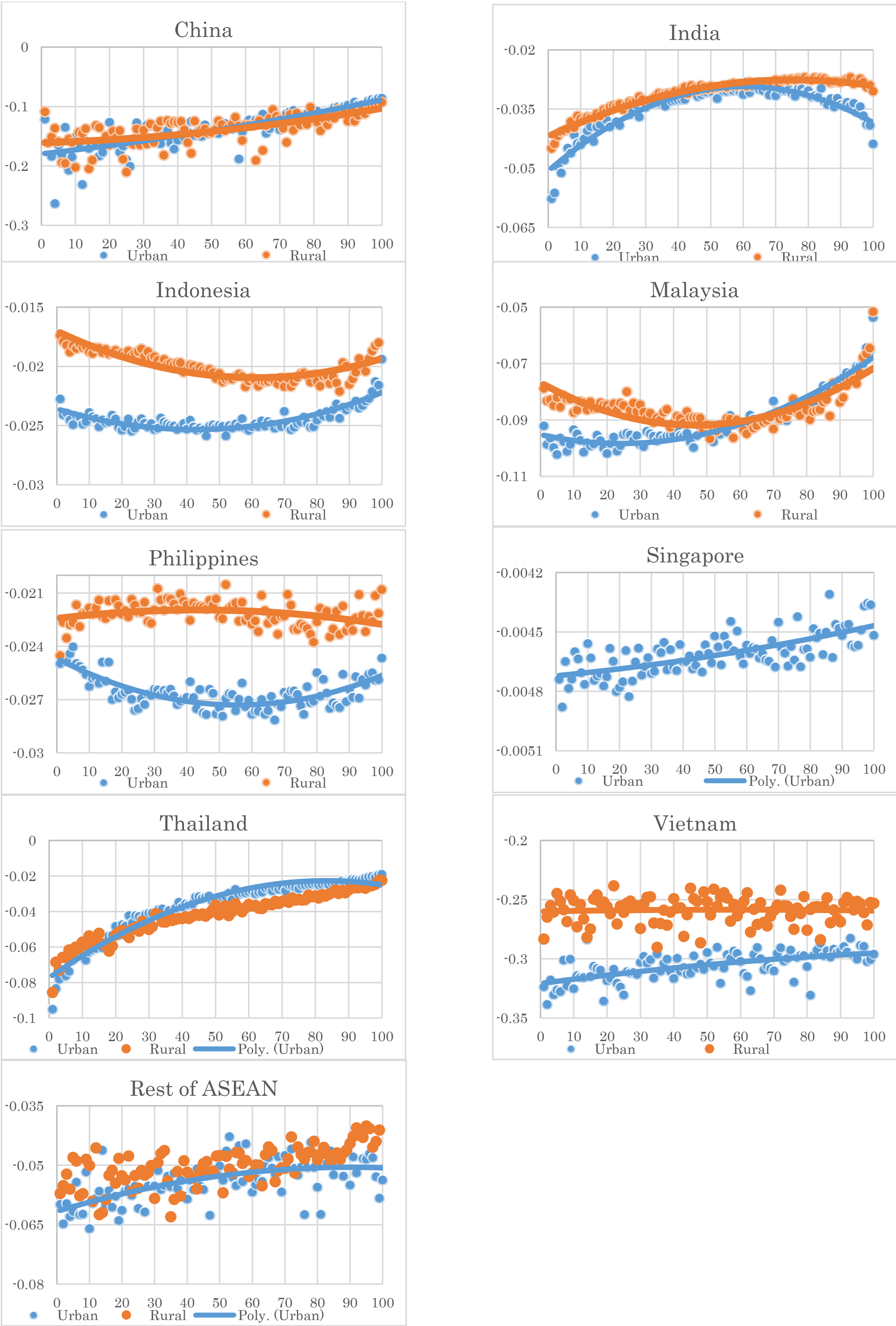

China
0
-0.1
-0.2
-0.3
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
India
-0.02
-0.035
-0.05
-0.065
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
Indonesia
-0.015
-0.02
-0.025
-0.03
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
Malaysia
-0.05
-0.07
-0.09
-0.11
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
Philippines
-0.021
-0.024
-0.027
-0.03
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
Singapore
-0.0042
-0.0045
-0.0048
-0.0051
0 10 20 30 40 50 60 70 80 90 100
Urban
Poly. (Urban)
Thailand
0
-0.02
-0.04
-0.06
-0.08
-0.1
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
Poly. (Urban)
Vietnam
-0.2
-0.25
-0.3
-0.35
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
Rest of ASEAN
-0.035
-0.05
-0.065
-0.08
0 10 20 30 40 50 60 70 80 90 100
Urban
Rural
Poly. (Urban)

Figure 5. Real Household Expenditure Changes in SIM3 (in percentage)

Table 1. Accounts in EA-IRSAM

Production Sectors		**Regions**
Agriculture	Gas manufacture distribution	Australia
Farming	Water	China
Forestry	Construction	Japan
Fishing	Trade	India
Coal	Transportation	South Korea
Oil	Communication	Indonesia
Gas	Financial services	Malaysia
Minerals *nec*	Public administration,	Philippines
Food and beverages	defence, health, and	Singapore
Textile and leather products	education	Thailand
Wood and paper products	Dwellings and other services	Vietnam
Petroleum products		Rest of ASEAN
Chemical, rubber, and plastic products		Rest of the World
Mineral products *nec*	**Factors**	
Metal products	Unskilled Labour	**Institutions**
Manufacturing	Skilled Labour	Rural household
Wind power electricity	Land	Urban household
Hydropower electricity	Natural resources	Corporate
Solar power electricity	Capital	Government
Coal power electricity		
Oil power electricity	**Other Accounts**	
Gas power electricity	Indirect Tax	
Other power electricity	Import Tax	
Transmission and Distribution	Savings-Investment	

Table 2. Selected 2011 Socio-Economic Indicators from the IRSA-EA Model

	AUS	CHN	JPN	IND	KOR	IDN	MYS	PHL	SGP	THA	VNM	XSE
Macroeconomic indicators (in billion USD)												
Gross Domestic Product	1394.05	7310.26	5883.50	1862.92	1219.62	823.33	289.59	224.55	268.51	347.12	136.98	95.25
Sectoral disaggregation (in billion USD)												
Agriculture	30.56	679.04	67.94	311.60	42.03	101.22	23.17	31.42	0.22	27.17	26.39	33.39
Manufacturing	215.61	2493.19	1022.64	365.85	333.62	214.44	86.63	60.53	70.44	119.82	38.63	16.74
Energy	51.07	102.49	81.18	10.79	10.94	64.91	23.84	1.88	1.41	15.51	14.44	9.89
Fossil-fuel electricity	9.10	35.32	41.69	15.51	6.83	0.07	0.10	1.77	0.91	1.15	2.08	0.07
Renewable electricity	10.35	142.71	18.00	20.33	6.66	1.69	4.45	0.89	N/A	2.22	4.55	0.46
Services	1077.37	3857.52	4652.04	1138.84	819.55	441.01	151.39	128.07	195.54	181.25	50.89	34.70
Population (in million people)												
Urban	19.06	678.93	116.42	391.04	40.91	124.02	20.52	43.51	5.18	30.18	27.62	20.07
Rural	3.28	665.20	11.42	859.25	9.03	121.10	8.13	52.06	N/A	37.34	61.25	52.20
Poverty Incidence (in percentage)												
Urban	N/A	0.54	N/A	13.39	N/A	10.75	1.00	4.10	N/A	8.80	5.10	7.15
Rural	N/A	15.44	N/A	24.83	N/A	15.96	3.40	20.50	N/A	15.95	15.90	38.02
Carbon Emissions												
Total emissions (in million tonnes CO_2)	307.00	6243.00	334.00	1314.00	125.00	259.00	95.00	35.00	24.00	149.00	77.00	14.00
Carbon intensity (in kg CO_2 per USD)	0.22	0.85	0.06	0.70	0.10	0.31	0.33	0.16	0.09	0.43	0.57	0.16

Notes: AUS= Australia, CHN=China, JPN=Japan, IND= India, KOR=South Korea, IDN=Indonesia, MYS=Malaysia, PHL=the Philippines, SGP=Singapore, THA=Thailand, VNM=Vietnam, XSE=rest of ASEAN covers Cambodia, Myanmar, Brunei Darussalam, Lao PDR, and Timor-Leste. N/A = not available.

Table 3. Estimation of Carbon Emission Reduction

Country	Total Fund Available (Billion USD)	Electricity Generated From Coal (GWH)	Estimated Converted Coal Powerplant Capacity (in percentage)	Estimated Total Emission Reduction (in percentage)
	(1)	(2)	(3)	(4)
Australia	0.24	23,625	16.93	6.62
China	8.05	4,115,215	3.23	1.26
Japan	1.26	348,830	2.90	1.13
India	0.61	202,452	10.27	4.01
South Korea	0.20	231,500	1.39	0.54
Indonesia	0.09	120,332	1.17	0.46
Malaysia	0.22	55,827	6.60	2.58
The Philippines	0.05	33,054	2.45	0.96
Thailand	0.11	37,579	4.88	1.91
Vietnam	0.32	34,563	15.26	5.96
Rest of ASEAN	0.03	1,149	43.16	16.87

Notes: Total funds available in column 2 are similar to the funds that governments reallocate for subsidising renewable electricity in SIM1. Electricity generated in GWH from World Research Institute (https://datasets.wri.org/dataset/globalpowerplantdatabase).

Table 4. Sectoral Output Changes (in percentage)

	SIM1						SIM2						SIM3					
	AGR	MNF	ENR	FFE	REE	SRV	AGR	MNF	ENR	FFE	REE	SRV	AGR	MNF	ENR	FFE	REE	SRV
AUS	-0.004	0.002	*	0.023	0.803	*	-0.033	-0.124	-0.069	-0.378	-0.013	0.034	-0.006	-0.003	-0.062	-0.144	-0.002	-0.012
CHN	-0.017	0.001	-0.008	0.010	0.625	-0.004	-0.010	0.186	0.034	0.039	-0.011	-0.050	-0.026	-0.101	-0.576	-0.785	0.001	0.003
JPN	-0.006	0.005	-0.003	0.019	1.028	-0.001	-0.008	0.239	0.048	0.101	0.005	-0.006	-0.016	-0.040	-0.295	-0.137	-0.001	-0.005
IND	0.004	0.019	0.003	0.046	1.031	-0.003	-0.012	-0.410	0.014	-0.166	-0.144	0.169	-0.006	-0.039	-0.130	-0.214	-0.022	-0.004
KOR	*	0.005	*	0.001	0.045	-0.001	-0.002	0.035	-0.013	0.089	*	0.007	-0.007	-0.022	-0.141	-0.119	*	-0.001
IDN	*	0.003	*	-0.002	0.029	*	-0.041	-0.419	-0.347	-0.304	-0.004	0.200	*	-0.007	-0.018	-0.130	*	-0.007
MYS	0.007	0.020	0.005	-0.003	0.005	-0.012	0.002	0.010	-0.045	-0.011	*	-0.022	-0.017	-0.046	-0.085	-0.540	*	-0.021
PHL	0.004	0.009	0.005	0.020	0.430	-0.005	0.001	0.012	0.004	0.003	0.001	-0.001	-0.005	-0.015	-0.072	-0.142	-0.004	-0.006
SGP	*	0.003	0.001	0.001	N/A	-0.001	-0.003	0.021	-0.093	0.004	N/A	-0.003	0.001	-0.006	-0.115	-0.002	N/A	0.001
THA	0.001	0.009	0.003	0.001	0.023	-0.001	-0.002	0.002	-0.022	-0.007	*	-0.005	-0.014	-0.028	-0.082	-0.057	*	-0.015
VNM	-0.002	0.078	0.010	0.124	1.433	-0.146	-0.002	0.132	0.020	0.061	0.037	0.038	-0.022	-0.204	-0.337	-0.751	-0.050	-0.071
XSE	0.004	0.009	0.001	0.005	1.196	-0.018	0.178	-0.706	0.850	-4.364	-0.009	0.281	-0.005	-0.018	-0.039	-0.225	-0.003	-0.012

Notes: * = negligible value; N/A=not available; AUS=Australia, CHN=China, JPN=Japan, IND=India, KOR=South Korea, IDN=Indonesia, MYS=Malaysia, PHL=the Philippines, SGP=Singapore, THA=Thailand, VNM=Vietnam, XSE=rest of ASEAN covers Cambodia, Myanmar, Brunei Darussalam, Lao PDR, and Timor-Leste; AGR= agriculture which consists of agriculture, farming, forestry, and fishing; MNF=manufacturing which consists of minerals nec, food and beverages, textiles, wood products, chemical rubber plastic products, mineral products, metal products, and manufacturing; ENR= energy which consists of coal, crude oil, gas, petroleum products, gas manufacture distribution; FFE= fossil fuels electricity which consists of coal power electricity, oil power electricity, gas power electricity, other electricity; REE = renewable electricity which consists of wind power electricity, hydropower electricity, and solar power electricity; SRV= services which consists of transmission and distribution of electricity, water, construction, trade, transport, communication, financial services, dwellings and other services, public administration, defence, and health; Outputs are in constant 2011 prices.

Table 5. Changes in Macroeconomic and Carbon Emissions Indicators (in percentage)

	SIM1			SIM2			SIM3		
	CO_2	GDP	Carbon Intensity	CO_2	GDP	Carbon Intensity	CO_2	GDP	Carbon Intensity
AUS	0.003	*	0.003	-1.786	-0.006	-1.780	-0.105	-0.005	-0.100
CHN	0.003	-0.003	0.006	-0.643	-0.016	-0.627	-0.491	-0.025	-0.467
JPN	-0.001	*	-0.001	-0.125	*	-0.125	-0.159	-0.012	-0.147
IND	0.014	-0.001	0.015	-0.588	0.015	-0.602	-0.119	-0.009	-0.109
KOR	0.002	-0.001	0.003	-0.133	-0.005	-0.128	-0.077	-0.005	-0.072
IDN	0.001	*	0.001	-0.253	-0.015	-0.238	-0.055	-0.002	-0.053
MYS	0.011	*	0.011	-0.461	*	-0.461	-0.342	-0.019	-0.323
PHL	0.012	*	0.012	-0.137	*	-0.137	-0.113	-0.007	-0.106
SGP	*	*	*	-0.014	*	-0.014	-0.012	*	-0.012
THA	0.004	*	0.003	-0.133	*	-0.133	-0.090	-0.011	-0.079
VNM	0.057	-0.009	0.066	-0.249	-0.018	-0.231	-0.832	-0.061	-0.772
XSE	0.010	-0.001	0.011	-1.536	-0.030	-1.507	-0.235	-0.009	-0.226

Notes: * = negligible value; AUS= Australia, CHN=China, JPN=Japan, IND=India, KOR=South Korea, IDN=Indonesia, MYS=Malaysia, PHL=the Philippines, SGP=Singapore, THA=Thailand, VNM=Vietnam, XSE=rest of ASEAN covers Cambodia, Myanmar, Brunei Darussalam, Lao PDR, and Timor-Leste; GDPs are in constant 2011 prices.

Table 6. Changes in Household Expenditure and Poverty Incidence (in percentage)

	SIM1				SIM2				SIM3			
	HH Exp.		Poverty		HH Exp.		Poverty		HH Exp.		Poverty	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
AUS	-0.004	-0.005	N/A	N/A	0.042	0.043	N/A	N/A	-0.039	-0.039	N/A	N/A
CHN	-0.065	-0.065	*	0.023	0.085	0.089	*	-0.026	-0.117	-0.121	*	0.053
IND	0.018	0.018	-0.018	-0.089	0.151	0.201	-0.407	-1.055	-0.036	-0.036	0.062	0.177
KOR	0.003	-0.006	N/A	N/A	0.006	0.006	N/A	N/A	-0.0170	-0.019	N/A	N/A
IDN	0.003	-0.002	-0.006	0.001	0.376	0.346	-0.764	-0.219	-0.024	-0.020	0.055	0.011
MYS	0.002	-0.011	*	0.001	0.032	0.029	*	-0.003	-0.077	-0.077	0.005	0.009
PHL	0.019	0.007	-0.002	-0.007	0.012	0.007	-0.001	-0.010	-0.030	-0.021	0.003	0.027
SGP	0.001	N/A	N/A	N/A	0.008	N/A	N/A	N/A	-0.005	N/A	N/A	N/A
THA	-0.006	-0.007	0.016	0.068	0.010	0.011	-0.031	-0.504	-0.028	-0.040	0.160	0.203
VNM	0.295	0.102	-0.051	-0.019	0.033	-0.029	-0.003	0.015	-0.320	-0.255	0.067	0.069
XSE	0.028	0.015	-0.003	-0.022	1.178	1.077	-0.189	-0.836	-0.054	-0.049	0.008	0.172

Notes: * = negligible value; N/A = not available; AUS=Australia, CHN=China, JPN=Japan, IND=India, KOR=South Korea, IDN=Indonesia, MYS=Malaysia, PHL=the Philippines, SGP=Singapore, THA=Thailand, VNM=Vietnam, XSE=rest of ASEAN covers Cambodia, Myanmar, Brunei Darussalam, Lao PDR, and Timor-Leste; Household expenditures are in constant 2011 prices.

Table 7. Sensitivity Analysis of Macroeconomic Indicators Changes (in percentage)

		Baseline				High				Low			
		CO_2	GDP	HH. Exp.		CO_2	GDP	HH. Exp.		CO_2	GDP	HH. Exp.	
				Urban	Rural			Urban	Rural			Urban	Rural
SIM1	AUS	0.003	*	-0.004	-0.005	-0.004	*	-0.005	-0.005	0.013	*	-0.004	-0.004
	CHN	0.003	-0.003	-0.065	-0.065	0.001	-0.003	-0.065	-0.065	0.006	-0.003	-0.065	-0.065
	JPN	-0.001	*	-0.012	-0.012	-0.011	*	-0.012	-0.013	0.011	*	-0.011	-0.012
	IND	0.014	-0.001	0.018	0.018	0.002	-0.002	0.018	0.017	0.029	-0.001	0.018	0.018
	KOR	0.002	-0.001	0.003	-0.006	0.002	-0.001	0.003	-0.006	0.003	-0.001	0.003	-0.006
	IDN	0.001	*	0.003	-0.002	0.001	*	0.002	-0.003	*	*	0.003	-0.002
	MYS	0.011	*	0.002	-0.011	0.011	*	0.002	-0.011	0.011	*	0.002	-0.011
	PHL	0.012	*	0.019	0.007	0.008	*	0.019	0.007	0.016	*	0.019	0.007
	SGP	*	*	0.001	N/A	*	*	0.001	N/A	*	*	0.001	N/A
	THA	0.004	*	-0.006	-0.007	0.004	*	-0.006	-0.007	0.004	*	-0.006	-0.006
	VNM	0.057	-0.009	0.295	0.102	0.030	-0.010	0.296	0.100	0.087	-0.009	0.294	0.103
	XSE	0.010	-0.001	0.028	0.015	0.006	-0.001	0.027	0.013	0.015	-0.001	0.030	0.016
SIM2	AUS	-1.786	-0.006	0.042	0.043	-1.646	*	0.013	0.013	-1.646	*	0.013	0.013
	CHN	-0.643	-0.016	0.085	0.089	-0.621	-0.026	0.073	0.083	-0.616	-0.026	0.073	0.083
	JPN	-0.125	*	-0.029	-0.023	-0.225	*	0.001	0.001	-0.225	*	0.001	0.001
	IND	-0.588	0.015	0.151	0.201	-0.595	*	0.001	0.001	-0.596	*	0.001	0.001
	KOR	-0.133	-0.005	0.006	0.006	-0.172	*	0.005	0.006	-0.172	*	0.005	0.006
	IDN	-0.253	-0.015	0.376	0.346	-0.180	0.038	0.048	0.271	-0.180	0.038	0.048	0.271
	MYS	-0.461	*	0.032	0.029	-0.395	*	0.002	0.002	-0.395	*	0.002	0.002
	PHL	-0.137	*	0.012	0.007	-0.150	*	0.006	0.005	-0.150	*	0.006	0.005
	SGP	-0.014	*	0.008	N/A	0.002	*	-0.009	N/A	0.002	*	-0.009	N/A
	THA	-0.133	*	0.010	0.011	-0.141	*	-0.003	-0.003	-0.141	*	-0.003	-0.003
	VNM	-0.249	-0.018	0.033	-0.029	-0.423	*	-0.001	-0.001	-0.423	*	-0.001	-0.001

	XSE	-1.536	-0.030	1.178	1.077	0.001	*	0.001	0.001	0.001	*	0.001	0.001

		Baseline				High				Low			
		CO_2	GDP	HH. Exp.		CO_2	GDP	HH. Exp.		CO_2	GDP	HH. Exp.	
				Urban	Rural			Urban	Rural			Urban	Rural
SIM3	AUS	-0.105	-0.005	-0.039	-0.039	-0.109	-0.005	-0.039	-0.039	-0.100	-0.005	-0.039	-0.039
	CHN	-0.491	-0.025	-0.117	-0.121	-0.492	-0.025	-0.117	-0.121	-0.491	-0.025	-0.117	-0.121
	JPN	-0.159	-0.012	-0.028	-0.027	-0.162	-0.012	-0.028	-0.027	-0.155	-0.012	-0.028	-0.026
	IND	-0.119	-0.009	-0.036	-0.036	-0.127	-0.009	-0.035	-0.036	-0.109	-0.009	-0.036	-0.037
	KOR	-0.077	-0.005	-0.017	-0.019	-0.080	-0.005	-0.017	-0.018	-0.074	-0.005	-0.017	-0.019
	IDN	-0.055	-0.002	-0.024	-0.020	-0.055	-0.002	-0.023	-0.020	-0.055	-0.002	-0.024	-0.020
	MYS	-0.342	-0.019	-0.077	-0.077	-0.347	-0.019	-0.077	-0.077	-0.337	-0.019	-0.077	-0.077
	PHL	-0.113	-0.007	-0.030	-0.021	-0.118	-0.007	-0.030	-0.021	-0.107	-0.007	-0.030	-0.021
	SGP	-0.012	*	-0.005	N/A	-0.012	*	-0.005	N/A	-0.011	*	-0.005	N/A
	THA	-0.090	-0.011	-0.028	-0.040	-0.089	-0.011	-0.028	-0.039	-0.090	-0.011	-0.028	-0.040
	VNM	-0.832	-0.061	-0.320	-0.255	-0.869	-0.061	-0.320	-0.256	-0.792	-0.060	-0.320	-0.254
	XSE	-0.235	-0.009	-0.054	-0.049	-0.234	-0.009	-0.053	-0.048	-0.236	-0.009	-0.055	-0.050

Notes: Baseline: simulations use initial parameter values, High: simulations use parameter values 50 per cent higher than initial values, and Low: simulations use parameter values 50 per cent lower than initial values; * = negligible value; GDP is in constant 2011 prices; AUS=Australia, CHN=China, JPN=Japan, IND=India, KOR=South Korea, IDN=Indonesia, MYS=Malaysia, PHL=the Philippines, SGP=Singapore, THA=Thailand, VNM=Vietnam, XSE=rest of ASEAN covers Cambodia, Myanmar, Brunei Darussalam, Lao PDR, and Timor-Leste; All prices are in constant 2011 price