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SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS OF INTENDED DECARBONISATION POLICIES IN THE EAST ASIA REGION

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Abstract

Even though there has been strong evidence that global warming has negative impacts on an economy, global carbon emissions have been increasing. Carbon emissions in the East Asia region has also shown a similar trend. The governments in East Asia have not implemented effective decarbonisation policies, presumably because so far limited analysis of the socio-economic and environmental impacts of these policies has been undertaken. This paper analyses the socio-economic and environmental implications of intended decarbonisation in the East Asian region using a computable general equilibrium model that captures closed-linkages between the economy and climate change. The results show that the intended decarbonisation policy does not always reduce carbon emissions. Incorporating CCS technology into existing coal power plants and carbon tax implementation could reduce carbon emissions significantly in all countries in the region. However, supplementary fiscal policies might be needed to mitigate the possible negative economic impacts of these intended decarbonisation policies.

Keywords: decarbonisation, climate change, East Asia, Computable General Equilibrium

JEL Classifications: D58, H23, Q54.

[1] 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

The establishment of the United Nations Framework Convention on Climate Change (UNFCCC) in the early 1990s was aimed to stabilise the Green-House Gasses (GHG) concentration to prevent anthropogenic interference with the climate system. Since then, there has been a continuous global effort to implement decarbonisation policies to reduce carbon emissions. One significant initiative was the Kyoto Protocol, which entered into force in 2005, aiming to limit and reduce GHG emissions from industrialised countries by allowing emissions trading, clean development mechanism, and joint implementation of the policy. The next significant initiative was the 2015 Paris Agreement that intended to bind all nations to reduce their GHG emissions according to their nationally determined contributions (NDCs) (United Nations, 2015).

One important component of GHG emissions is carbon emissions. Several studies have indicated that increasing carbon emissions affect an economy through global warming. In turn, the latter could harm agricultural output, water supply, economic growth, and income per capita (Dell, Jones, and Olken, 2009; Garnaut, 2011; Stern, 2007). However, despite growing evidence of the negative impacts of carbon emissions, up to recently, sufficient decarbonisation policies have not been implemented (Watson et al., 2019). Global carbon emissions increased by around 1.35 per cent in 2017 and were slightly higher again in 2018 at approximately 2.03 per cent (Global Carbon Project, 2020).

Carbon emissions in the East Asia region[2] showed a similar trend. Figure 1 reveals a significant increase in carbon emissions in the East Asia region between 1990 and 2016. During this period, East Asia's proportion of carbon emissions in global emissions has doubled, from around 21 per cent in 1990 to 45 per cent in 2016. The majority of these carbon emissions came from fossil fuel combustion.

<< Figure 1 here>>

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

Rapid economic and population growths leading to rising electricity demand have been argued as the main drivers of the increase in carbon emissions in the East Asia region (Chang et al., 2019; Lean and Smyth, 2010). Literature, nevertheless, also mentions three other factors explaining the increase in carbon emissions from fossil fuel combustions in the East Asia region. First, fossil fuel subsidies implemented by countries in East Asia have led to a fall in fossil fuel prices, a rise in demand for fossil fuels, and a rise in carbon emissions. Governments in countries in the East Asian region provided approximately USD100 billion per year in the 2010s for fossil fuel subsidies or around 20 per cent of global fossil fuel subsidies (IEA, 2021). Other implications of fossil fuel subsidies are less incentive to develop renewable energy and a reduction in government budget (Plante, 2014; UNEP, 2008).

Second, there has so far been insufficient commitments to reduce carbon emissions in the East Asia region, outsides their global commitments at the UNFCCC, the Kyoto Protocol, and the Paris Agreement. Meanwhile, several studies have argued that these global agreements have no significant carbon emission reduction impact so far (Nordhaus, 2019; Watson et al., 2019). A report by Watson et al. (2019) claims that among countries in the East Asian region, only Australia, Japan, and South Korea have partially sufficient decarbonisation targets, while other countries in the East Asian region have insufficient carbon emissions reduction targets.[3]

Finally, there is a limited solid analysis of the socio-economic and environmental impacts of the intended decarbonisation policy. Leaders and the public in the East Asian region hence are uncertain on what would the impacts of such policies on their economic, social, and environmental conditions (Nurdianto and Resosudarmo, 2016). Previous studies are either do not cover general equilibrium impacts of an intended decarbonisation policy or do not fully model the links from economic changes due to a policy to carbon emissions and the feedback links from global warming due to carbon emissions to the economy (Dejuán et al., 2020; Oyewo et al., 2020; Fujimori, Masui, and Matsuoka, 2014; Zhang, Guo, and Hewings, 2014).

This paper aims to provide a solid analysis of the socio-economic and environmental impacts of the intended decarbonisation policy in the East Asia region. First, the paper utilises a Computable General Equilibrium (CGE) model that includes a closed-loop model between the economy and global warming due to carbon emissions. Note that there is a relatively limited

[3] Sufficient decarbonisation targets are defined as having a commitment to reduce carbon emissions between 20–40 per cent in a country. 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).

CGE model with a closed-loop model between the economy and the environment. Among these few is that a paper by Resosudarmo (2002) models a closed link between Indonesia's economy and ambient air pollutants. Indicators on the socio-economic and environmental impacts observed in this paper are Gross Domestic Products (GDPs), sectoral outputs, household incomes, poverty incidents, income distributions and carbon emissions. Second, this paper shows results from simulating three specific policies intended to reduce carbon emissions on socio-economic conditions and levels of carbon emissions among East Asian region countries. The three intended decarbonisation policies are 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.

This paper shows that the intended decarbonisation policy does not always reduce carbon emissions. For most countries in the East Asian region, subsidising renewable electricity sectors leads to a slight rise in carbon emissions due to the positive spillover of renewable electricity sectors' development to other sectors. Meanwhile, incorporating CCS technology into existing coal power plants could reduce carbon emissions significantly for all countries in the East Asian region. Similarly, carbon tax implementation also could lead to carbon emissions reductions across countries in the East Asian region.

Regarding socio-economic impacts, this paper argues that most East Asian economies would contract due to implementing an intended decarbonisation policy; particularly since governments would need to reallocate some of their spendings to subsidise renewable electricity sectors or provide CCS technology. In terms of carbon tax implementation, the economy would contract due to a rise in commodity prices. Finally, poverty incidence could reduce if governments subsidise renewable electricity sectors and provide CCS technology for the existing coal electricity sector. However, carbon tax implementation leads to a rise in poverty incidence due to a rise in commodity prices, leading to a reduction in household expenditures.

The rest of this paper is organised as follows. The next section provides a literature review on the socio-economic and environmental impacts of the intended decarbonisation policy. The literature review section is followed by a section describing the method to construct a CGE model that includes a closed-loop model between the economy and climate change and a section on the datasets utilised in this paper. The next sections describe the intended decarbonisation policy simulations conducted, which are then followed by a discussion on the socio-economic and environmental impacts of the intended decarbonisation policies in each East Asian country. Finally, the last section concludes with some policy implications.

2. Literature Review

There has been growing empirical evidence on the impacts of global warming on an economy. For example, at a country level, studies by Tol (2009), Dell, Jones, and Olken (2012), and Burke, Hsiang, and Miguel (2015) find that there are adverse economic effects of climate change. Similarly, increasing temperatures have implications at the household level, notably reduced income (Dell, Jones, and Olken, 2009) and agricultural output (Aragón, Oteiza, and Pablo, 2021).

Despite the growing literature on the impacts of global warming, there is a gap in the current literature on solid models and analysis examining the socio-economic and environmental impacts of intended decarbonisation policy. There is a partial equilibrium approach estimating the impacts of an intended decarbonisation policy on economic outcomes. In the case of West Africa, Oyewo et al. (2020) find that an intended decarbonisation policy through a transition from fossil fuel to solar power electricity leads to a significant increase in job creation. However, this was a partial paper that did not cover the economy-wide impacts of the decarbonisation policy.

General equilibrium literature analysing economy-wide impacts of intended decarbonisation policy are available, though not many, utilising input-output analysis models, computable general equilibrium (CGE) models, or integrated assessment models (IAMs). For example, using a hybrid multi-regional input-output model, Dejuán et al. (2020) find that an intended decarbonisation policy 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 shows that climate change mitigation constraining carbon emissions would require carbon taxes and higher energy prices.

The majority of general equilibrium literature related to this topic have been on analysing the impacts of climate change on the economy rather than discussing the impacts of an intended decarbonisation policy. For example, Bosello, Roson, and Tol (2007) using a CGE model evaluate the impacts of rising sea levels as an exogenous shock through potential losses of land and coastal protection cost. Similarly, a study by Kompas and Van Ha (2019) incorporates climate change shock into four categories—i.e., 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.

Most of these general equilibrium models include the links from economic activities to the level of carbon emissions. Almost none, however, also included models simulating the feedback links from global warming due to carbon emissions to economic activities. This feedback from global warming (or climate change) to the economy is essential since it allows a complete cycle from climate change (increasing carbon emissions and temperature) into productivity and then back to climate change again—a closed-loop between the economy and climate change model—within a CGE model. Several studies on climate change have been arguing that a rapid increase in carbon emissions and accumulated stock of carbon in the atmosphere leads to climate change through global warming. And, in turn, this global warming affects many aspects of human life, such as falling crop yields, decreasing water supply, species extinction, and rising intensity of storms, forest fires, droughts, flooding, and heatwaves (Garnaut, 2011; Stern, 2007).

In the general equilibrium literature, few CGE models include a closed-loop between the economy and the environment. Among the few is a CGE model developed by Resosudarmo (2002), which includes links between the economy and ambient air pollutant levels in Indonesia. The finding of such a model is that increasing economic production activities would lead to an increase in ambient levels of air pollutants. As a result, there is an increase in health problems associated with air pollutants that affect the productivities of production sectors in urban areas and the spending related to air pollution-related health. Another example is also a CGE model constructed by Resosudarmo (2008), which includes links between agricultural production activities and levels of pesticides in agricultural sectors. In this model, levels of pesticides induce pesticide-health related issues among farmers, which then affects farmer productivities and results in declining agricultural production accordingly.

Climate change models having the closed-loop between the economy and global warming (or climate change) are mostly in the category of integrated assessment models (IAMs), which quantify relationships between carbon emissions, carbon concentration, and temperature in a carbon cycle[4] (Pindyck, 2013). Gillingham et al. (2018) argue that there are

[4] The carbon cycle process is a sequence of higher carbon emissions that leads to higher carbon accumulation in the atmosphere that later on will trap heat and results in climate change through global warming (Ikefuji, Masui, and Matsuoka, 2020; Nordhaus and Sztorc, 2013; Stern, 2008).

three IAMs that have a closed-link from climate change to the economy—i.e., DICE (Dynamic Integrated Climate–Economy) by Nordhaus and Sztorc (2013), FUND (Climate Framework for Uncertainty, Negotiation and Distribution) by Tol (2002), and WITCH (A World Induced Technical Change Hybrid Model) by Bosetti et al. (2006).

The main issue with the IAMs is that they assume there is only one composite commodity in the economy, following a neoclassical growth model (Solow, 1956; Swan, 1956), which is at a worldwide level. Hence, these models are too aggregated and do not allow for a specific sectoral policy in a particular country. There is, however, a regional IAM constructed by Nordhaus and Yang (1996), namely the Regional Integrated model of Climate and the Economy (RICE). Yet, like DICE, RICE assumes there is only one composite commodity in the economy.

This paper fills the gap in the current literature by constructing a CGE model that includes closed links between economic activities and climate changes represented by changes in global temperature. The model in this paper 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 Asian region. The new model developed in this paper is called a closed-loop Inter-Regional System of Analysis for East Asia (IRSA-EA) model. Using this closed-loop IRSA-EA model, this paper observes the socio-economic and environmental impacts of several different intended decarbonisation policies in countries in the East Asian region.

3. Methodology

The CGE model in this paper—i.e., the closed-loop IRSA-EA model—is a direct derivative of the inter-regional system of analysis for ASEAN (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), which are static, multi-sector, and multi-country CGE models. All these CGE models are built based on CGE models by Dervis, de Melo and Robinson (1982), Adelman and Robinson (1988), and Thorbecke (1991).

In the closed-loop IRSA-EA model, following IRSA-ASEAN and IRSA-Indonesia5 models, producer and consumer optimisations are modelled at the country level. These optimisation behaviours at a country level allow prices and quantities in each country to vary, which is important in carrying out simulations in this paper. Each country in the closed-loop

IRSA-EA model is connected through trades of goods and services. Also, each country is allowed to trade within the region and with countries outside the regions. Furthermore, among countries, there are flows of transfers in terms of foreign savings investments.

Similar to its precursors—i.e., IRSA-ASEAN and IRSA-Indonesia5 models—the closed-loop IRSA-EA model also includes a household income microsimulation model, disaggregating the total expenditures of urban and rural households in expenditures of 100 households in urban areas and of 100 households in rural areas in each country. The division of these 100 households in rural or urban areas is based on percentile distribution of household expenditures in the area (Nurdianto and Resosudarmo, 2016). Poverty incidents in rural and urban areas are calculated based on these expenditures (Yusuf and Resosudarmo, 2015).

The two main distinctions between the closed-loop IRSA-EA model and its precursors (IRSA-ASEAN and IRSA-Indonesia5) are as follows. First, while the closed-loop IRSA-EA includes a closed-loop model between the economy and climate change by incorporating a typical model available in DICE or RICE, its precursors do not cover it. Figure describes the closed-loop between the economy and climate change model in the closed-loop IRSA-EA model. Carbon emissions come from industrial sectors through consumption of energy commodities as their intermediate inputs, households through energy commodities consumption, and the forestry sector through deforestation. Total carbon emissions that are released into the atmosphere accumulate and become concentrated carbon in the atmosphere. Higher carbon concentration leads to a relatively higher temperature which then affects sectoral productivities. As sectoral productivities change, sectoral outputs and final demands of industries and households change as well.

<< Figure 2 here>>

Several additional equations are needed to construct a closed-loop IRSA-EA model, such as total emissions, carbon concentration in the atmosphere, temperature, and an abatement-damage function. Following works by Ikefuji et al. (2020) and Nordhaus and Sztorc (2013), those equations are defined as follows:

Total emissions (XCO) in Equation (1) are defined as a total of carbon emissions from industry ($XCOI$) by using fossil fuel type e in an industry i at country d, households ($XCOH$)

by using fossil fuel type e in household h at country d, and forestry ($XFOR$) as a fraction of forestry sector output. The emissions from industry sectors in Equation (2) come from the usage of energy commodities as intermediate inputs ($XINT\_S$) in the production. Similarly, carbon emissions from households in Equation (3) are generated through the consumption of energy commodities. For the forestry sector, Equation (4) implies that the carbon emissions come from land use that is assumed to be a proportion of the total output produced by the forestry sector, represented by parameter τ.

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

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

$$\mathrm{XCOH}_{e,h,d} = (1 - \mu 2_{h,d}).\, \mathrm{cch}_{e,h,d}.XHOU\_S_{e,h,d} \tag{3}$$

$$XFOR_d = \tau.XTOT_{'frs',d} \tag{4}$$

Terms $\mu 1_{i,d}$ and $\mu 2_{h,d}$ 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).

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

Regarding temperature, this paper assumes that current temperature comes from initial temperature ($TEMP0$) and concentration of carbon in the atmosphere (CDC) in logarithm values as presented in Equation (6). The current temperature ($TEMP$) is the difference between the average yearly temperature from 2002 till 2011 to the average yearly temperature from 1891 till 1900. Then, $TEMP$ is used to calibrate the initial temperature ($TEMP0$) in the model.

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

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

$$DAM_{i,d} = \frac{1}{1 + \xi_d .\ TEMP_d^2} \quad (7)$$

Finally, the closed-loop in the IRSA-EA model is applied by incorporating the productivity damage coefficient into the top nest of the production function, as presented in Equation (8).

$$\mathrm{XTOT}_{\mathrm{i,d}} = DAM_{i,d} \ . \ \alpha_{\mathrm{i,d}}^{\mathrm{tot}} . \left(\delta_{\mathrm{i,d}}^{\mathrm{tot}} . \mathrm{XINT\_SC1}_{\mathrm{i,d}}{}^{-\rho^{tot}} + \left(1 - \delta_{\mathrm{i,d}}^{\mathrm{tot}}\right) . \mathrm{XPRIMEN}_{\mathrm{i,d}}{}^{-\rho^{tot}}\right)^{-\frac{1}{\rho^{tot}}}$$
(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., 2020). 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 of analysis, i.e., a change between one to five years.

Additional closures are needed to ensure that the closed-loop IRSA-EA model is square in terms of the number of variables equalling the number of equations and could represent a short to medium term of analysis. The default closures for the closed-loop IRSA-EA model are as follows:

- 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.

The closures of non-labour inputs are set as immobile such that they cannot move across industries with average rents set as fixed. In contrast, labour is set as mobile to move into other sectors while keeping sectoral specific wages fixed (Löfgren, Robinson, and Harris, 2002).

The second distinction of the closed-loop IRSA-EA model from its precursors is that it allows industries to substitute using different types of energy sources and different sources of electricity—i.e., those generated from renewable energies and those generated from non-renewable energies. Nested constant elasticity of substitution (CES) production functions is utilised to model these substitutions in energy and electricity used.

4. Data

This paper analyses the socio-economic and environmental impacts of carbon emissions reduction (decarbonisation) in the East Asia region based on five datasets. The first dataset is mainly the inter-regional social accounting matrix for East Asia (EA-IRSAM), which is constructed from the Global Trade Analysis Project (GTAP) Power version 9 database with a common reference year of 2011 and currency of United States billion dollars using procedures developed by McDonald and Thierfelder (2004) and McDonald and Thierfelder (2013). This set of data includes several modifications. First, the regional household account extracted from GTAP is disaggregated into urban and rural households, firm, and government accounts. Second, subsidies for fossil fuels in each country are recalculated using the percentage of government spending for fossil fuel subsidies to calibrate EA-IRSAM. The EA-IRSAM covers 12 countries in the East Asian region, each of which has 33 production sectors (Table 1). Table 2 presents selected socio-economic indicators of the EA-IRSAM.

<< Table 1 here>>

<< Table 2 here>>

The second set of data covers several household surveys across countries in the East Asian region. These datasets are needed to estimate income distribution across urban and rural households and transfers from governments to households. These datasets are also used to calculate expenditure shares of both urban and rural households on various commodities. For Indonesia, data utilised are taken from the 2011 socio-economic survey (SUSENAS). The 2011 Annual Poverty Indicators Survey (APIS) is used 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. For South Korea, due to a lack of data, the share of urban and rural expenditure by commodity is assumed similar to Indonesia.

The third dataset is parameters of the elasticity of substitution that come from various studies. At the top level, the elasticity of substitution parameters between the composite of non-electricity and non-energy intermediate inputs and composite of primary, energy, and electricity intermediate inputs are taken from Resosudarmo (2002). At the lower level, the parameter for the elasticity of substitution between the composite of intermediate energy inputs and primary inputs and parameters of elasticity of substitution between energy and electricity intermediate inputs are following Yusuf and Resosudarmo (2015). Finally, parameters of elasticity of substitution for value-added and Armington are taken from GTAP Power 9 database.

The fourth dataset is carbon emissions by sector and country. This paper extracts data on carbon emissions from the GTAP Power 9 database. The data covers carbon emissions due to electricity consumption, coal, oil, gas, petroleum products, and gas manufactured distribution by each sector in each country.

The fifth dataset deals with the climate change. First, carbon concentration in the atmosphere is extracted from the NASA dataset.[5] In particular, this paper uses an AIRS/Aqua monthly CO_2 in the free troposphere dataset. It is monthly gridded data at 2.5 times 2-degree grid cell size. There is a possibility that carbon concentration is mixing globally in the atmosphere. However, based on the NASA dataset, there is a difference of carbon concentration in each country. Therefore, to extract a country level of carbon concentration in the atmosphere, this paper overlaps the carbon concentration dataset with country boundaries to extract the carbon concentration dataset at the country level. To do so, the paper reduces the grid to 0.25 times 0.2 degrees grid cell size, such that the overlap could fit in the country boundary. Then the paper takes an average value of the monthly dataset for each country in the

[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. Therefore, this paper converts the unit into part per millions (ppm) unit of carbon concentration.

East Asia region.[6] Second, the temperature is defined as the temperature difference between 10 years average of 2011 to 10 years average of 1900 in degrees Celsius. The dataset is extracted from Berkeley Earth analysis.[7]

5. Policy Simulations

Using a closed-loop interregional computable general equilibrium model analysis, this paper simulates three selected intended decarbonisation policies as follows:

Supporting the development of renewable electricity (SIM1): Government provides an additional five per cent subsidy rate to each renewable electricity sector. There are three renewable electricity sectors in the model: wind, hydro, and solar electricity powerplant sectors. By providing subsidies, prices of electricity from renewable electricity powerplant sectors decrease and demands of electricity from renewable electricity powerplant sectors will increase. In this scenario, to provide subsidies to renewable electricity, each government has to reduce their spendings on other goods and services.

Supporting instalment of CCS technology in the coal electricity sector (SIM2): Some coal electricity powerplant sectors receive a full subsidy from the government to install new technologies of CCS obtained from China. Hence, there is a flow of funding from governments in all countries in the East Asian region to manufacturing sectors in China. The total funding for the technology from each country in this scenario is set to be equal with the total subsidy for renewable development in SIM1 in each country. Incorporating CCS technology into the existing coal electricity sector should reduce carbon emissions from the coal electricity sector. Due to limited fund, however, not all coal power plants will be installed with the CCS technologies. Table 3 provides information on how much carbon emission could be reduced under SIM2. Column (1) shows the total available funds equivalent with the total subsidies renewable electricity sectors in SIM1. Column (2) presents the size of coal electricity sectors in each country. The percentage of coal electricity powerplants that could be installed with CCS technologies is shown in Column (3). Based on the size of coal electricity sector installed with CCS technologies, the size of carbon emission reduction could be calculated.

[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/.

<< Table 3 here>>

Carbon tax implementation on fossil fuel commodities (SIM3): Government collects carbon tax from energy sectors that generate carbon emissions. Enforcing the carbon tax on coal, petroleum products, and distributed gas is one way to reduce carbon emissions while conserving fossil fuels. As fossil fuel prices increase due to the carbon tax, fossil fuel consumption will fall, which is then followed by lower carbon emissions generated by industries and households. In this scenario, this paper assumes that each government collects carbon tax from energy commodities used by industries and households. The total value of carbon tax that each government collects is similar to the amount of renewable electricity subsidies in SIM2.

One important assumption of this paper is that the government savings are hold constant. Therefore, any additional spending to renewable electricity development comes from reallocation of government spending. Similarly, if there is an additional revenue, the government will reallocate all the additional revenue proportionally to the current spending.

6. Results

6.1 Sectoral Output Changes

Table 4 reveals the aggregated sectoral output changes due to the intended decarbonisation policy. In SIM1, the government introduces an additional subsidy for the renewable electricity sector. Providing subsidies for the renewable electricity sector implies that producers have a relatively lower cost to generate renewable electricity. As a response, the producers generate more renewable electricity outputs. For instance, in SIM1, the output of renewable electricity in Japan, India, Vietnam, and the rest of ASEAN increases by more than 1 per cent.

<< Table 4 here>>

Besides expanding renewable electricity output, this scenario has two main other implications: positive spillover impacts on other sectors in the economy and reduction in government spending. The first implication depends on the economic structure of each country, particularly on the linkages from renewable electricity sectors to other sectors in the economy. Based on this spillover impacts, the countries can be grouped into three classifications. Included in the first category are countries having positive spillover impacts on their agriculture sectors, such as India, Malaysia, the Philippines, Thailand, and the rest of ASEAN. The second category covers countries experiencing positive trade spillover impacts on their manufacturing sectors. This paper finds that all countries in the East Asian region expand their manufacturing outputs. The third category includes countries having a positive spillover impact on their energy or fossils fuel electricity sectors, such as Australia, China, Japan, India, South Korea, Malaysia, the Philippines, Singapore, Thailand, Vietnam, and the rest of ASEAN. These rising outputs of the energy and fossil fuel sectors are mostly a response to the rise in their manufacturing outputs.

As with reduction in government spending, this causes the outputs of services sectors in all countries in the East Asian region to decrease. The lower outputs in the services sector is mainly because, in this scenario, governments reallocate some of their spending to subsidise the renewable electricity sector and reduce their spending on other sectors proportionally.

In SIM2, the government primarily focuses on reducing carbon emissions by deploying CCS technology for the coal electricity sector. There are two implications in this scenario. First, expansion in manufacturing, energy, and electricity sectors in China has a positive trade spillover to other countries in the East Asian region. The positive trade spillover depends on trade linkages between China and other countries in the East Asian region. In Japan, the Philippines, and Vietnam, the spillovers are channelled to manufacturing, energy, and fossil fuel electricity sectors. For South Korea and Singapore, the spillovers are sent to manufacturing and fossil fuel electricity sectors, while for Malaysia and Thailand, they are concentrated in the manufacturing sector only.

The second implication is reducing the services sector outputs in China, Japan, Malaysia, the Philippines, Singapore, and Thailand. In SIM2, governments buy CCS technologies from China manufacturing sectors, hence the governments spend less on other goods and services. As a result, the injection into the domestic economy is less compared to the base situation or SIM1, resulting reduction in sectoral outputs in the services sector particularly. Meanwhile, the manufacturing sectors in China produce more outputs. For example, the manufacturing output in China increases by 0.18 per cent. The manufacturing sector demands more inputs, including energy and electricity commodities. Then, there is an increase in these two sectors in China by more than 0.03 per cent.

In SIM3, the government collects carbon tax from coal, petroleum products, and manufactured gas. Imposing a carbon tax on fossil fuel commodities results in an immediate rise in fossil fuel prices and an increase in production costs. The producer responds to this production cost increase by reducing their output. This paper finds that there is a reduction in most sectors in each country, and particularly in the manufacturing, energy, and fossil fuel electricity sectors, all of which largely require fossil fuels.

6.2 Macroeconomics and Carbon Emissions Changes

Table 5 provides the aggregate impacts of intended decarbonisation policy on macroeconomic and carbon emissions changes for each simulation in each East Asian country. In SIM1, providing subsidies for renewable electricity results in two situations. First, countries experiencing a rise in carbon emissions ("rebound effect")[8] while their economies shrink. Except Japan, all countries in the East Asian 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. Carbon emissions rise due to an expansion in their manufacturing sectors, while their economies shrink due to a reduction in their services sectors. In Japan, the spillover impact of renewable electricity sectors on other sectors is relatively small. Therefore, the economy is relatively unchanged, while carbon emissions get lower due to the decrease in the energy sector's outputs.

In SIM2, there is a considerable reduction in carbon emissions. In this simulation, a significant reduction in carbon emissions occurs because of the CCS technology installed in the coal power sectors for all countries in the East Asian region. The largest reduction in carbon intensity occurs in Australia and the rest of ASEAN by more than one per cent. These results indicate that providing CCS technology to a dominant carbon emitter sector is more effective than providing subsidies for renewable electricity.

Even though there is an environmental benefit, most countries in the East Asian 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

[8] Discussion on what a rebound effect can be seen in the work by Nurdianto and Resosudarmo (2016), for example.

dividend effect where carbon emission decreases and the economy expands. In India, the economy expands mainly due to the expansion of services sector.

<< Table 5 here>>

In SIM3, there is a reduction in carbon emissions from all countries in the East Asian region. The reduction in carbon emissions is mainly caused by a contraction in sectoral output due to the carbon tax implementation. In Japan and Vietnam, this carbon emission reduction 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

This section analyses changes in real household expenditure and poverty incidence for urban and rural households. Table 6 shows the changes in the real household expenditure of urban and rural households by percentile. There are two drivers of change in real household expenditure in Table 6, namely changes in commodity prices and changes in household income. In SIM1, all renewable electricity prices decrease as a direct impact of reducing the indirect tax. Therefore, as the price of renewable electricity decreases, there should be an increase in renewable electricity consumption by households. The second driver—i.e., changes in household income—consists of changes in income factor and those in government transfers.

<< Table 6 here>>

This paper finds that in SIM1, almost all countries in the East Asian 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. As a result, households cannot afford to consume more renewable electricity.

In SIM2 simulation, most households in countries in the East Asian region could increase their expenditure except for rural households in Vietnam. 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, as indicated in SIM3, implementing a carbon tax reduces real household expenditure for all countries in the East Asian 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 disaggregates total real household expenditure changes into changes in real 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 progressive, regressive, or neutral changes in the household expenditure in each percentile depend on the share of the household demand for each commodity. The progressive pattern implies that the intended decarbonisation policy leads to more positive changes in the expenditure of the poor than the rich households. On the other hand, the regressive pattern indicates that rich households gain more benefits from the policy than poor households. Finally, a neutral pattern indicates a relatively similar impact on poor and rich households' expenditure. In other words, the share of consumption for each commodity is relatively similar between the poor and the rich households.

<< Figure 3 here>>

This paper finds that the impacts of intended decarbonisation policy through providing subsidies for renewable electricity sectors (SIM1 in Figure 3) can be categorised into three situations. There is a progressive pattern of changes in household expenditure in China and Singapore. On the other hand, India and Thailand exhibit a regressive pattern of changes in household expenditure. Other countries in the East Asian region, such as Indonesia, Malaysia, the Philippines, Vietnam, and the rest of ASEAN have relatively neutral changes in household expenditure.

SIM2 in Figure 4 reveals that there are two categories of countries. The first group of countries experiences a progressive pattern of changes in their household expenditure, such as India, Indonesia, Thailand, and the rest of ASEAN. However, there are countries facing a regressive pattern in their household expenditure, such as China, Malaysia, and Vietnam. In the Philippines, there is a slightly regressive pattern in urban households, while rural households exhibit a progressive pattern of expenditure changes.

<< 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, it shows a U-shaped pattern. While in the Philippines' rural households it is relatively neutral, the U-shape pattern in urban households in the Philippines and Indonesia indicates that poor and rich households are affected less than middle-income households in both countries.

<< Figure 5 here>>

Furthermore, changes in real urban and rural household expenditure by percentile lead to changes in poverty incidence, as presented in Table 6. In SIM1, subsidising renewable electricity sectors leads to a rise in poverty incidence in China, Thailand, and rural households in Indonesia and Malaysia. In contrast, households in other countries in the East Asian region experience a decline in poverty incidence. In SIM2, the impacts of providing CCS technology for the coal electricity sector reduce poverty incidence for almost all countries, except for rural households in Vietnam. Ultimately, in SIM3, all households reduce their consumption, which leads to an increase in their poverty due to rising commodity prices.

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 has analysed the socio-economic and environmental impact of intended decarbonisation policies in the East Asia region. The aim of analysing it is to determine the best approach in reducing carbon emissions in the region. The novelty of this paper is that it utilises one of the very few multi-country CGE models that take into account links between economic activities and climate changes, represented by changes in global temperature, and vice versa, i.e., closed-links between the economy and climate change. The three intended decarbonisation analyses in this paper are as follows: (1) government spending more on subsidising renewable electricity powerplant sectors; (2) government installing CCS technology into existing coal powerplant boilers; and (3) government collecting carbon taxes from fossil-based fuel commodities. These analyses show that the total funding for installing CCS technology and the total value of carbon tax collected are similar to the amount of subsidies spent for renewable electricity sectors.

This paper's main finding is that the intended decarbonisation policy does not necessarily lead to lower carbon emissions. Subsidising the renewable electricity sector even increases carbon emissions slightly, as it creates a rebound effect, in most countries in the East Asian region except for Japan. An increase in manufacturing sectors and a decline in services sectors cause this increase in carbon emission. The increase in manufacturing sectors is due to the positive spillover impacts of the expansion of renewable electricity powerplant sectors. The decline in services sectors is due to the decline in government spending on goods and services.

Installing CCS technology in the existing coal-based electricity powerplants or enforcing carbon tax on fossil-based fuel commodities does reduce carbon emissions effectively. In general, reduction of carbon emission by installing CCS technology on the coal-based electricity powerplants is higher than by implementing carbon tax.

The socio-economic impact of intended decarbonisation policies tends to be varied across countries in the East Asia region. In terms of the economy, some generalisation would be as follows. In most countries, the three intended decarbonisation policies analysed in this paper would reduce the economy. The main driver of this reduction is less government spending on goods and services in the cases of government subsidising renewable electricity powerplant sectors and retrofitting CCS technology in the coal-based electricity powerplants. In the case of carbon tax implementation, the tax collection results in increased prices of commodities, which contracts the outputs accordingly.

In terms of regressivity or progressivity of the intended decarbonisation policies on household expenditures, a generalisation is difficult to obtain. A case by case and country by country observation is, therefore, needed. However, it is probably safe to generalise that the impact on income distribution would likely to be small. With regard to the changes in poverty incidence, this paper finds that it is likely to decline as governments spend funding to either subsidise their renewable electricity powerplant sectors or retrofit CCS technology in their coal-based electricity powerplants. Enforcing carbon tax, however, could lead to a higher poverty incident.

Finally, this paper would like to argue that the findings of this paper are relatively robust toward possible variations of elasticity parameter for substitution among different intermediate electricity inputs and for substitution between energy and composite electricity intermediate inputs. Several policies recommendations that can be drawn from the findings in this paper might be as follows. First, should some countries in East Asia be willing to put a priority in implementating a carbon tax policy, this policy would most likely reduce carbon emissions from the region. The issue with carbon tax is, however, on how best recycle the revenue from carbon tax to compensate the potential output contraction due to this tax.[9]

Second, for countries in East Asia region with coal-based electricity as a significant part of its electricity sector, installing CCS technology on its coal-based electricity powerplants should be a priority. This strategy might effectively result in lower carbon emission. Yet, without appropriate recycling strategies, the economic impact of retrofitting CCS technology is most likely not as strong as implementing carbon tax policy. Third, for these countries, directly boosting renewable electricity development without controlling carbon emission from coal-based electricity is not recommended as it could induce a rebound effect. Development of renewable electricity should be conducted at the same time as controlling emission from non-renewable energy.

[9] For discussions on how best recycle carbon tax revenues, please see, for example, Yusuf and Resosudarmo (2015) and Nurdianto and Resosudarmo (2016).

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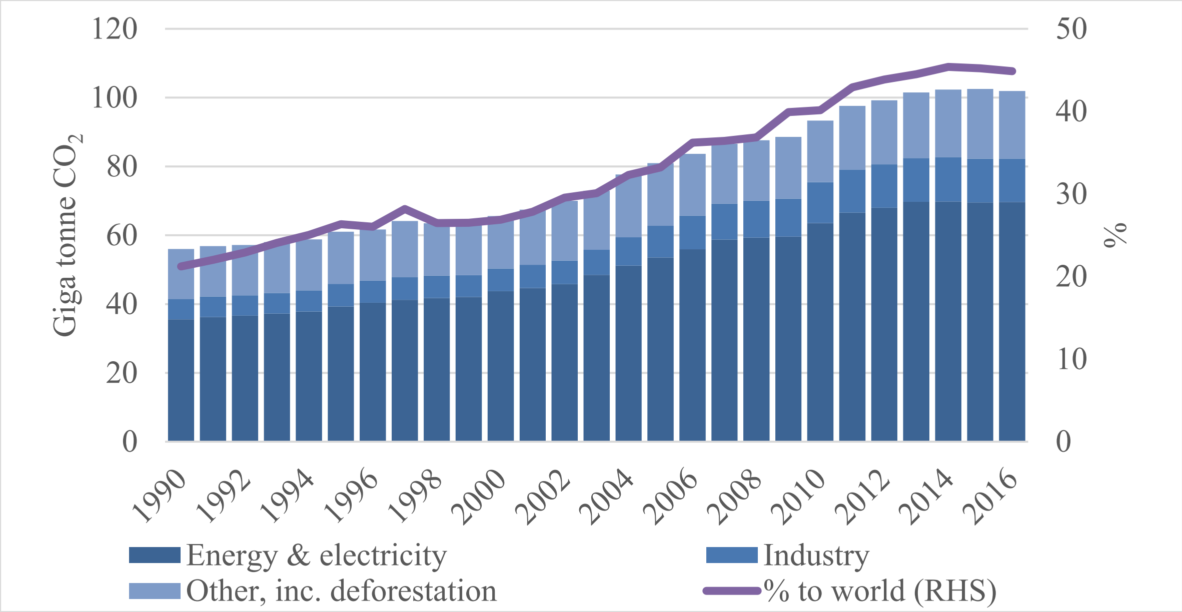

Source: WRI (2020).

Figure 1. Carbon Emissions in the East Asia Region

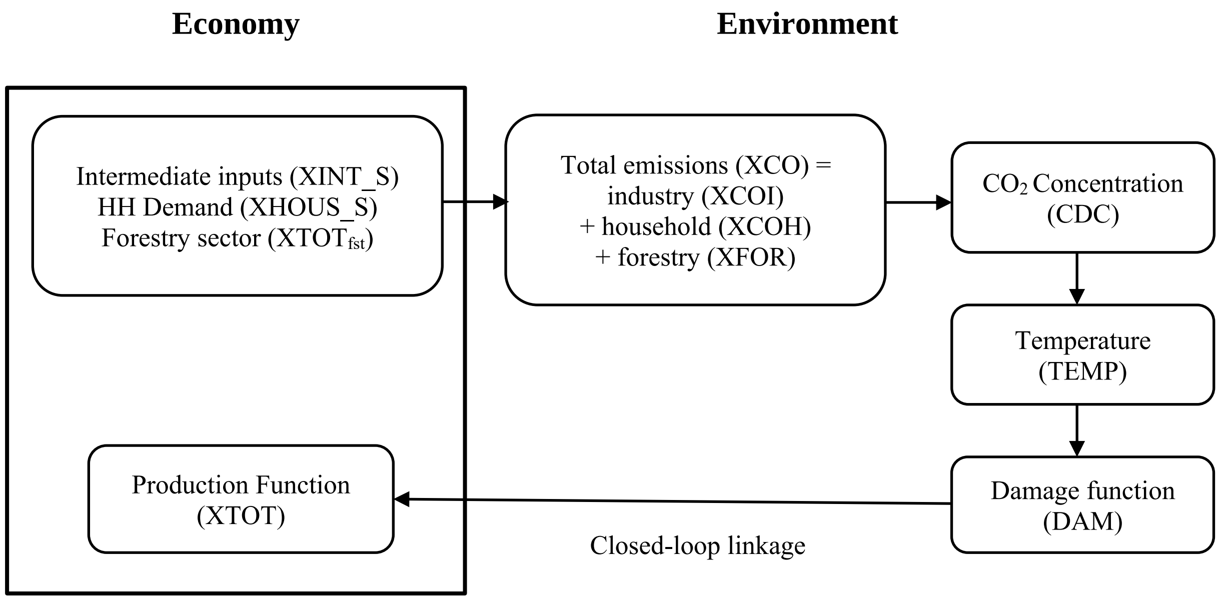

Figure 2. A Simplified Closed-Loop IRSA-EA Model in Each Country

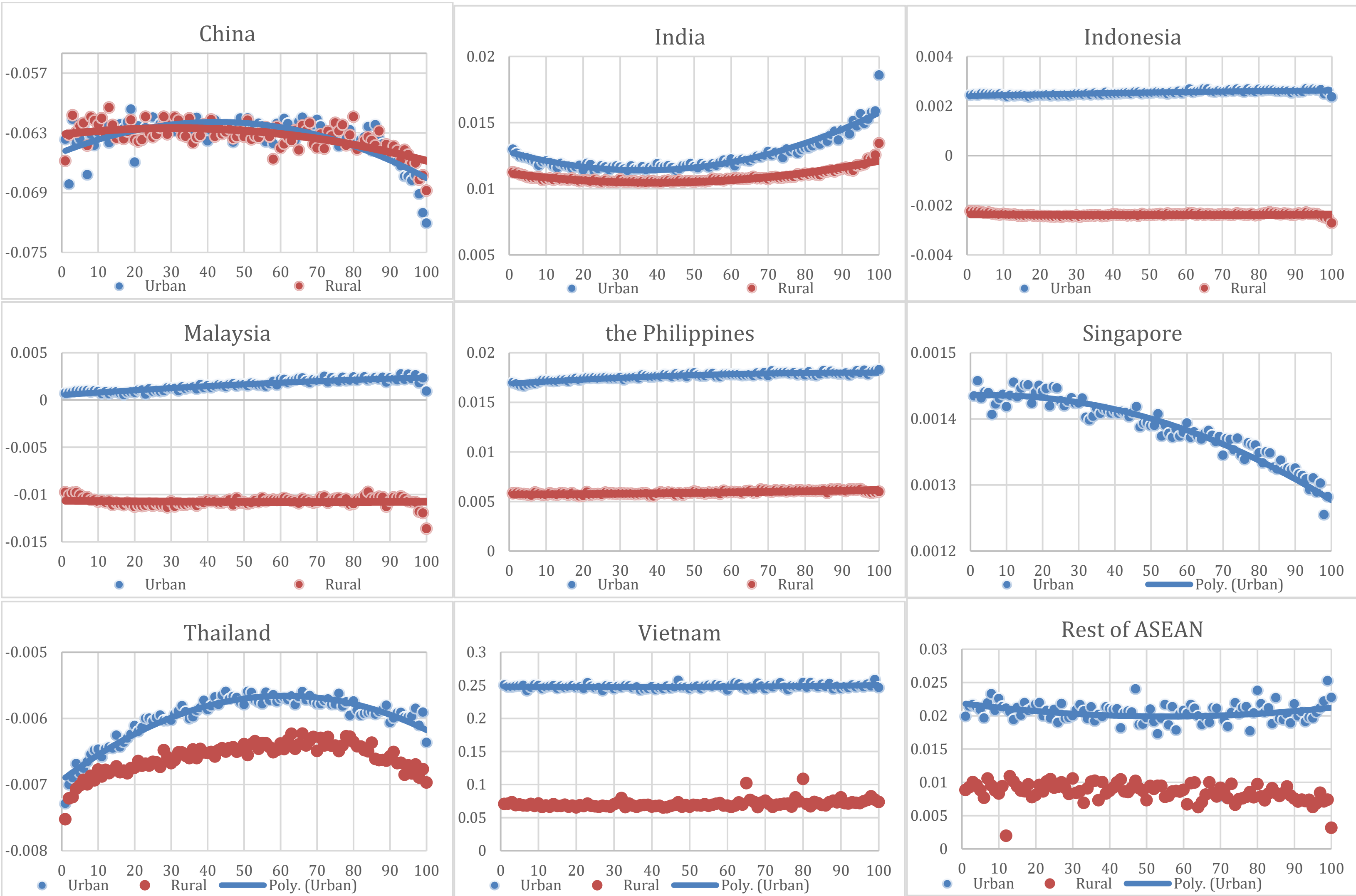

Figure 3. Real Household Expenditure Changes in SIM1 (in percentage)

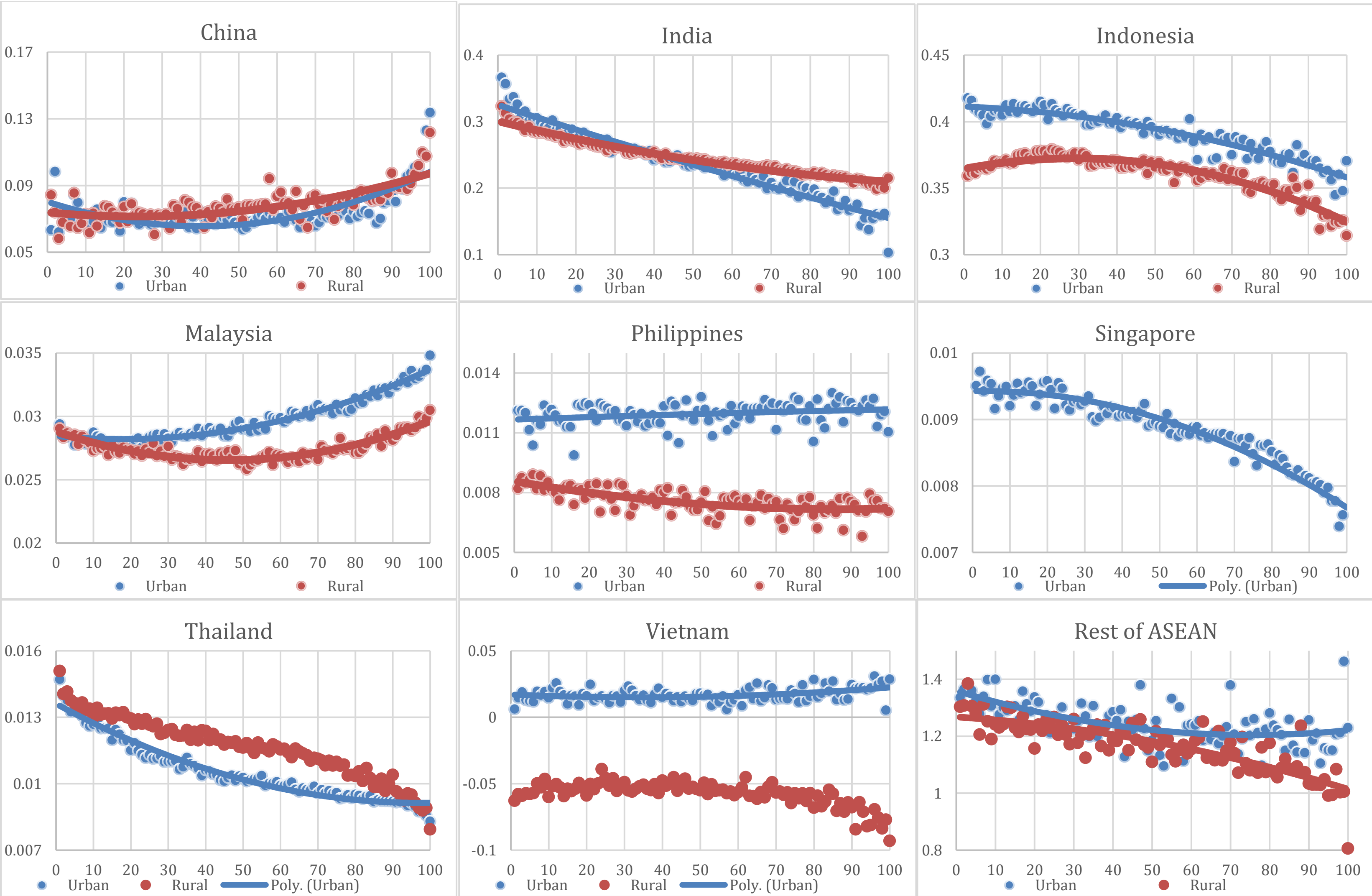

Figure 4. Real Household Expenditure Changes in SIM2 (in percentage)

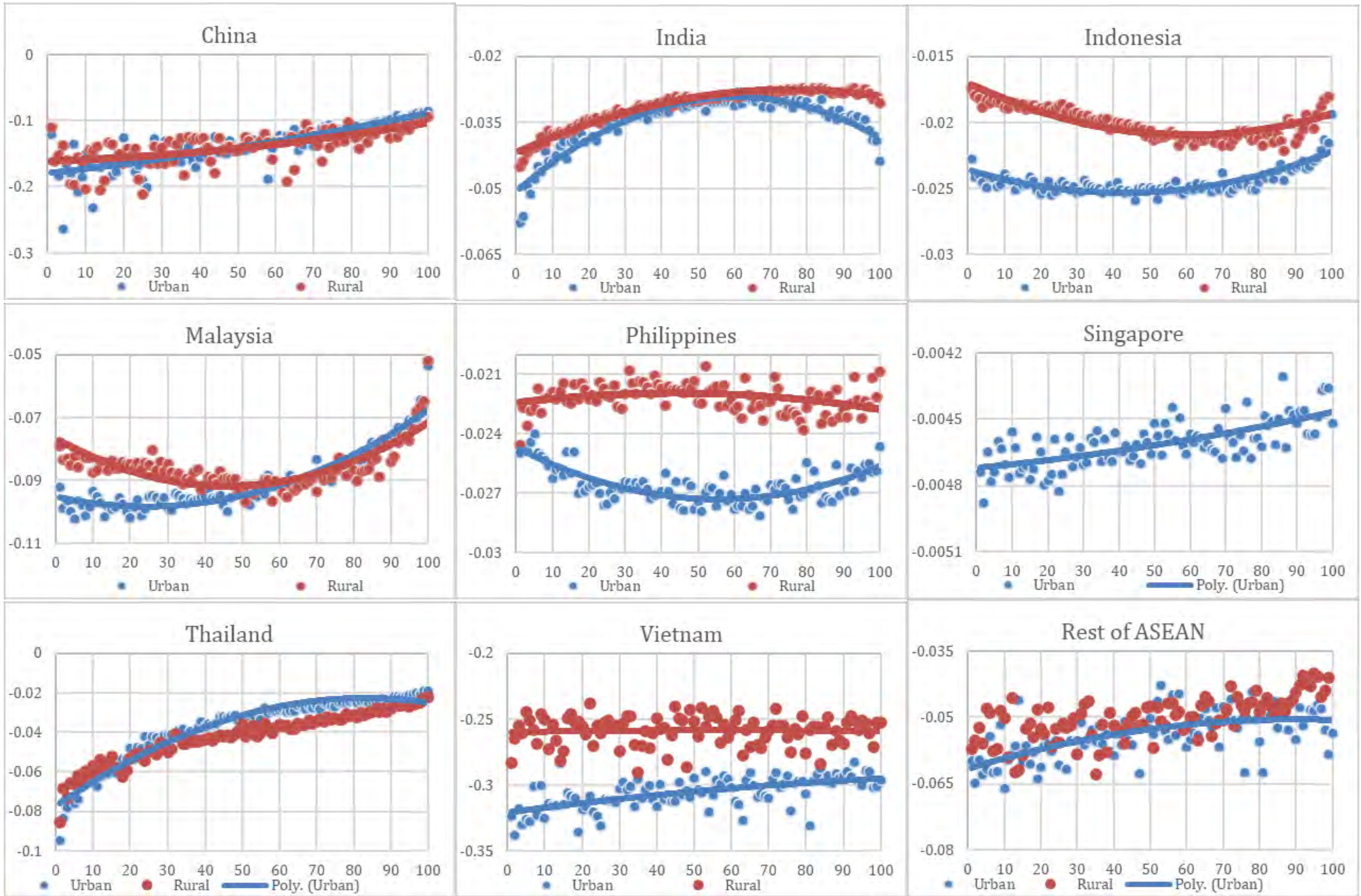

Figure 5. Real Household Expenditure Changes in SIM3 (in percentage)

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.

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

	SIM1			**SIM2**			**SIM3**		
	CO_2	**Real GDP**	**Carbon Intensity**	**CO_2**	**Real GDP**	**Carbon Intensity**	**CO_2**	**Real 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.

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

	SIM1				SIM2				SIM3			
	Real HH Exp.		Poverty		Real HH Exp.		Poverty		Real HH Exp.		Poverty	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
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
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
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; CHN=China, IND=India, IDN=Indonesia, MYS=Malaysia, PHL=the Philippines, THA=Thailand, VNM=Vietnam, XSE=rest of ASEAN covers Cambodia, Myanmar, Brunei Darussalam, Lao PDR, and Timor-Leste

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

		Baseline				High				Low			
		CO_2	Real GDP	Real HH. Exp.		CO_2	Real GDP	Real HH. Exp.		CO_2	Real GDP	Real 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	Real GDP	Real HH. Exp.		CO_2	Real GDP	Real HH. Exp.		CO_2	Real GDP	Real 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. N/A: Not available. * = 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