Developing renewable electricity with carbon tax recycling mechanisms in the East Asia region

Yuventus Effendi [1,2,3] and Budy P Resosudarmo [1]

[1] Arndt-Corden Department of Economics

Crawford School of Public Policy

Australian National University

Canberra, Australia

[2] Indonesian Ministry of Finance, Jakarta, Indonesia

[3] Corresponding author email: yuventus.effendi@anu.edu.au.

Abstracts

This paper analyses the socio-economic and environmental impacts of recycling carbon tax to develop renewable electricity in the East Asia region. There are two recycling mechanisms through indirect tax reduction for renewable electricity sectors and subsidies for renewable electricity consumption by households. Using a multi-country computable general equilibrium for East Asian countries, this paper finds that in terms of the economic impact, providing indirect tax reduction is only economically beneficial for Indonesia. Further, subsidising renewable electricity prices for households would primarily benefit India economy only. Regarding environmental impact, this paper finds that providing indirect subsidies for renewable electricity is beneficial for all East Asian countries while subsidising renewable electricity prices for households would not benefit Australia, Indonesia, and the rest of ASEAN. This paper also finds that recycling mechanisms could alter the distribution pattern of household expenditures across countries in the East Asia region that leads to poverty incidences reduction in some countries. Providing subsidies to renewable electricity reduces poverty incidence in Indonesia and the rest of ASEAN. On the other hand, China, India, Malaysia, the Philippines, and Vietnam have poverty incidence reduction by subsidising renewable electricity prices.

Keywords: energy economics, computable general equilibrium model, East Asia economics, regional economics.

JEL Classification: Q43, Q48, O21, O53

1. Introduction

In recent years, the East Asia region (ASEAN member countries, China, Japan, South Korea, India, and Australia)[1] has become more important in terms of economy and population. Figure 1 reveals that in 2018, the region contributed more than 30 per cent of the world's economy (World Bank, 2019a) and constituted more than 60 per cent of working-age cohorts aged between 15 and 64 globally (United Nations, 2019). Nonetheless, the region has increased carbon emissions significantly. Figure 1 indicates that in 2016 the East Asia region contributed more than 40 per cent to total global carbon emissions[2] (World Resources Institute, 2020).

One factor contributing to significant increasing carbon emissions in the East Asia region is a dominant role of electricity generated from fossil fuels. In 2018, for instance, the East Asia region's contributed up to almost half of global fossil-fuel electricity. Nonetheless, the development of renewable electricity in the East Asia region was relatively sluggish. In 2018, the share of electricity produced from renewables in the East Asia region compared to the world was relatively low at around 30 per cent.

<<Figure 1 here>>

There are at least two barriers to renewable electricity deployment in developing countries. First, low fossil fuel prices and subsidised on-grid electricity lead to less incentive to develop renewable electricity. Second, fluctuating investment in renewable electricity leads to fluctuating renewable electricity capacity. In the end, these barriers hinder the deployment of renewable electricity in the region (ERIA, 2020; IEA, 2019b; REN21, 2019; Burke et al., 2019).

Carbon taxes on the consumption of fossil fuel commodities could overcome these barriers in renewable electricity deployment for several reasons. First, carbon tax implementation raises fossil fuel prices, reduces demand for fossil fuels, and reduces energy-related carbon emissions. Second, the implementation of carbon tax provides an additional revenue that can be recycled

[1] East Asia region in this paper covers ASEAN member countries, China, Japan, South Korea, India, and Australia. These countries signed an initiative for East Asia Energy Market Integration (EMI) in 2005 during the East Asia Summit.

[2] The top emitters in the East Asia region were China (57.29 per cent), India (13.92 per cent), and Indonesia (11.10 per cent). Together, these three countries contribute by more than 80 per cent of total emissions in East Asia region (World Resources Institute, 2020).

back into the economy. There are four recycling mechanisms through providing an additional budget for a government, promoting fiscal reform, carbon tax earmarking, and compensating those most affected by the carbon tax (Baranzini, Goldenberg, and Spech, 2000; Parry, van der Ploeg, and Williams, 2012; Marten and van Dender, 2019; World Bank, 2019b).

Despite a growing literature on the recycling mechanism of the carbon tax revenue, many policymakers are unsure about adopting carbon tax due to limited literature on specific recycling mechanism of carbon tax revenue for renewable electricity development. In India, there is a study by Ojha, Pohit, and Ghosh (2020) that examines the impacts of recycling carbon tax revenue for renewable electricity development. However, there is a limited study in other East Asian countries such as Australia, China, Japan, South Korea, and ASEAN countries.

Besides limited literature on the impact of recycling carbon tax revenue for renewable electricity development, many policymakers are unsure about adopting carbon tax due to progressive or regressive distributive impacts on the household expenditure. The distributive impacts of the carbon tax on the household income tend to be regressive such that the cost of the carbon tax will have more impacts on the poor household than the rich household (Baranzini, Goldenberg, and Spech, 2000). However, several studies point out that carbon tax could have progressive impacts on the households expenditure if there is a uniform lump-sum transfer to the urban households (Yusuf and Resosudarmo 2015); the rich households consume more energy commodities than the poor households (Brenner, Riddle, and Boyce, 2007); and burden of carbon tax falls into capital owner than the final consumers (Shah and Larsen, 1992).

Limited study on the impacts of recycling carbon tax revenue to develop more renewable electricity and ambiguous distributive impacts of this recycling mechanism lead the policymakers into uncertainty. Therefore, this paper aims to fill the gap in the literature on the impacts of renewable electricity development using a specific recycling mechanism of the carbon tax in the East Asia region. The first recycling mechanism is that the government provides subsidies for the production of renewable electricity. The second recycling mechanism is that the government subsidises households on renewable electricity consumption. The observed indicators are broadly categorised as macroeconomic impacts, in terms of carbon emissions and gross domestic product (GDP) changes; sectoral impacts, such as sectoral output changes; and microeconomics impacts, such as household expenditure and poverty incidence changes.

This paper finds that recycling carbon tax revenue for an indirect tax reduction of renewable electricity leads to environmental benefit only, except for Indonesia. In this scenario, Indonesia has a reduction in carbon emissions and expansion of the economy. Subsidising renewable electricity for households lead to three different impacts: rebound effect in Australia, Indonesia, and the rest of ASEAN; double dividend in India; and reduction in carbon emissions for other East Asian countries. In this scenario, most East Asian countries have positive changes in the real household expenditure, except for Indonesia and the rest of ASEAN. This paper argues that the types of recycling mechanism and structure of the economy significantly affect each simulation's socio-economic and environmental results.

This paper contributes to the current literature in two ways. Firstly, this paper develops a flexible electricity input production structure using nested constant elasticity substitution (CES). With a flexible production structure, changes in the price of renewable electricity induce changes in demand for renewable electricity as intermediate inputs in industries and final consumption by the households. Secondly, this paper is one of a few studies that incorporate specific carbon tax recycling mechanisms on developing renewable electricity, namely indirect tax reduction for specific renewable electricity sectors and subsidies for a household to consume more renewable electricity.

The rest of this paper is organised as follows. Section 2 provides a current literature review on the socio-economic and environmental impacts of recycling carbon tax revenue for renewable electricity development. Section 3 explains the methodology to measure the socio-economic and environmental impacts of renewable electricity development. Section 4 describes the data that is used in this paper. Section 5 presents the policy simulations that are used in this paper. Section 6 presents and discusses the socio-economic and environmental impacts of renewable electricity development in each East Asian country. Finally, the last section concludes with some policy implications.

2. Literature review

This paper tries to fill two main literature gap. First, there is a limited study on the impacts of recycling carbon tax revenue to develop renewable electricity sectors. Second, the distributive impacts of this recycling mechanism are unclear, whether it is progressive or regressive on the household expenditure, particularly in the East Asia region.

A carbon tax is a charge that should be paid when fossil fuel commodities are used, proportional to the quantity of carbon emitted. There are several implications of the carbon tax implementation. Firstly, the immediate effects of the carbon tax are an increase in the fossil fuel commodity prices and reduce the demand for fossil fuel commodities (Baranzini, Goldenberg, and Spech 2000; Parry, van der Ploeg, and Williams, 2012).

The second implication of carbon tax implementation is that there is additional revenue that the government can collect. For example, across European countries, the actual revenue from the carbon tax is estimated at around more than one per cent of GDP (Marten and van Dender, 2019).

This additional revenue can be recycled or reallocate back into the economy through at least four options: providing an additional budget for a government, promoting fiscal reform, carbon tax earmarking, and compensating those most affected by the carbon tax. First, regarding the additional budget for the government, carbon tax revenue can be used as the additional fiscal capacity of the government budget. Second, in terms of fiscal reform, carbon tax revenue can be used to deduct other taxes, i.e., labour taxes, household income taxes, and corporate income taxes. Third, the earmarking of the carbon tax allocates additional revenue from the carbon tax into a specific environmental program or research and development. Finally, carbon tax revenue can be recycled to subsidise households and corporates affected most by implementing the carbon tax (Baranzini, Goldenberg, and Spech, 2000; Parry, van der Ploeg, and Williams, 2012; Marten and van Dender, 2019; World Bank, 2019b).

Despite a growing literature on the mechanism of recycling carbon tax revenue, there is a limited study on the recycling carbon tax revenue into the development of renewable electricity sectors. In India, there is a study by Ojha, Pohit and Ghosh (2020). The authors of that study analyse recycling mechanisms such as transfer to the household and investment in clean energy sectors, namely wind, hydro, solar, and nuclear. They find that allocating the carbon tax into clean energy investment results in relatively no gain in terms of the economy because the capital cost of clean energy is relatively higher than conventional energy. Hence, it is more costly for the economy. In other words, investment in clean energy benefits for carbon emissions reduction only, but not for the economy (Ojha, Pohit, and Ghosh, 2020).

Besides limited studies on the impacts of renewable electricity development through carbon tax recycling, there are also ambiguous distributive impacts on household income and expenditure. Baranzini, Goldenberg, and Spech (2000) claim that the carbon tax is regressive in developed countries because low-income households spend more on energy commodities than high-income households. Several studies, however, claim that there is a progressive distributive impact of the carbon tax in developing countries. In China, a recycling carbon tax into lump-sum redistribution based on an equal amount per capita to all household leads to progressive distributional effects on the households as long as rich households use more carbon products than poor households (Brenner, Riddle, and Boyce, 2007). In Indonesia, Yusuf and Resosudarmo (2015) find that carbon tax implementation leads to a solid progressive pattern across rural households and a slightly progressive across urban households. In Pakistan, Shah and Larsen (1992) find that carbon tax implementation could be progressive if the burden of carbon tax majority distributed to the capital owner or a small amount of carbon tax burden fall into final consumption.

This paper aims to fill these two gaps in the literature. In particular, this paper establishes a specific recycling mechanism for the development of the renewable electricity sector and observes the distributive impacts of these recycling mechanisms in the East Asia region.

3. Methodology

This paper uses an inter-regional system of analysis for the East Asia (IRSA-EA) model. IRSA-EA is a static and multi-country computable general equilibrium (CGE) model. In particular, IRSA-EA covers Australia, China, Japan, South Korea, India, and ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore, Thailand, Vietnam, and the rest of ASEAN).

Several features of IRSA-EA come from developments in CGE modelling that have been made over many years. For example, the features of IRSA-EA are build based on studies by Dervis, de Melo and Robinson (1982), Adelman and Robinson (1988), Thorbecke (1991), and Resosudarmo (2002). In addition, IRSA-EA is a direct descendant of the inter-regional system of analysis for ASEAN (IRSA-ASEAN) model by Nurdianto (2011) and inter-regional system of analysis for Indonesia five regions (IRSA-Indonesia5) developed by Resosudarmo et al. (2011). Therefore, IRSA-EA has similarities in terms of notational use and purposes with IRSA-ASEAN and IRSA-Indonesia5.

There are two significant expansions of the IRSAM-EA that make it distinguishable from both IRSA-Indonesia5 and IRSA-ASEAN. Firstly, IRSA-EA has a flexible production structure. A flexible production structure of IRSA-EA allows for substitutions between primary and intermediate energy and electricity inputs. Allowing a flexible substitution among energy and electricity intermediate inputs enables the model to simulate the impacts of the lower price of particular commodities such as renewable electricity to the whole economy (Yusuf and Resosudarmo, 2015). Secondly, IRSA-EA has a specific recycling mechanism for simulating renewable electricity development, i.e., indirect tax reduction of renewable electricity sectors and subsidies for households to consume more renewable electricity.

<<Figure 2 here>>

The first expansion of IRSA-EA is a flexible production structure. Figure 2 describes the nested production structure of IRSA-EA as a flow of supply and demand of industry i in country d. On the demand side, $XTOT(i,d)$ denotes output produced by sector i in region d through four levels of aggregation of constant elasticity substitution (CES) functions:

- At the bottom level, demand for intermediate energy $XINT\_S(c2,i,d)$ and intermediate electricity inputs $XINT\_S(c3,i,d)$ are CES aggregated into composite energy intermediate inputs $XINT\_SC2(i,d)$ and composite electricity intermediate inputs $XINT\_SC3(i,d)$.
- At the third level, both $XINT\_SC2(i,d)$ and $XINT\_SC3(i,d)$ are CES aggregated into a composite of energy and electricity intermediate inputs $XEN(i,d)$. At the same production level, production factors $XFAC(f,i,d)$ are CES aggregated into a composite of primary inputs $XPRIM(i,d)$.
- At the second level, $XEN(i,d)$ and $XPRIM(i,d)$ are CES aggregated into a composite of primary-energy-electricity inputs $XPRIMEN(i,d)$. At the same level, non-energy and non-electricity intermediate inputs $XINT\_S(c1,i,d)$ are Leontief aggregated into a composite of non-energy and non-electricity intermediate inputs $XINT\_SC1(i,d)$.
- Finally, on the top nest level, both $XPRIMEN(i,d)$ and $XINT\_SC1(i,d)$ are CES aggregated into $XTOT(i,d)$.

The output of $XTOT(i,d)$ is then supplied into the domestic market $XTRAD(c,r,d)$ and export market $XEXP(c,r)$. Country of destination d of commodity c chooses optimal demand from different origin countries r in aggregated CES function. Similarly, country d also chooses the optimal condition between domestic $XD(c,'dom',d)$ and import $XD(c,'imp',d)$ goods using the Armington assumption. Finally, the optimal $XD\_S(c,d)$ supplies the final demand in country d that comes from households $XHOU\_S(c,h,d)$, government $XGOR\_S(c,d)$, investment $XINV\_S(c,d)$, and intermediate inputs $XINT\_S(c,i,d)$. The optimisation of the final demand of household and government is done with a constant budget share.

The second model expansion of IRSA-EA is specific recycling mechanisms to develop renewable electricity. This paper develops two specific carbon tax recycling mechanisms: indirect tax reduction for renewable electricity sectors and subsidies for renewable electricity consumption by households. This paper assumes that the government in each country d collects additional revenue from carbon tax ($TCTR_d$) in Equation 1. Then, the additional revenue due to carbon taxation is reallocated into a different mechanism, namely additional spending by the government (TCG_d), indirect tax reduction for renewable electricity sectors (TCI_d), and subsidies for renewable electricity consumption by households (TCH_d).

$$TCTR_d = TCG_d + TCI_d + TCH_d \tag{1}$$

The first term on the right-hand side of Equation 1, additional government spending (TCG_d), implies that there is no specific recycling mechanism for renewable electricity development. In this reallocation process, the government expands its budget proportionally based on constant share allocation across sectors in an economy.

The second term on the right-hand side of Equation 1 is a recycling mechanism through reducing the indirect tax rate of the renewable electricity sector. The recycling mechanism is presented in Equation 2 and Equation 3. In Equation 2, the reduction of the indirect tax rate ($ritxr_{ren,d}$) is a ratio of reallocated carbon tax revenue to total values of renewable electricity sectors output. The reallocated carbon tax revenue (TCI_d) is redistributed into each renewable electricity sector proportionally to the total output of each sector ($shxtot_{ren,d}$). Equation 3 shows that reducing the indirect tax rate for the renewable electricity sector at each industry i occurs at the market-clearing condition of industry i.

$$ritxr_{ren,d} = \frac{shxtot_{ren,d} \cdot TCI_d}{PDOM_{ren,d} \cdot XTOT_{ren,d}} \; \forall \, ren \in c = \{wnd, hyd, slr\} \tag{2}$$

$$\left(1 - itxr_{i,d} + ritxr_{i,d}\right) PDOM_{i,d}.XTOT_{i,d} = PPRIMEN_{i,d}.XPRIMEN_{i,d} + PQ\_SC1_{i,d}.XINT\_SC1_{i,d} \tag{3}$$

The last term on the right-hand side of Equation 1 is a recycling mechanism through a direct subsidy on renewable electricity consumption for urban and rural households. Equation 4 defines the subsidy rate for renewable electricity consumption ($tren_{ren,h,d}$) as a ratio of reallocated carbon tax revenue to total consumption values of renewable electricity by each type of household. The reallocation of carbon tax revenue (TCH_d) to the household into urban and rural households is based on the share of household demand on renewable electricity sectors ($shxhous_{ren,h,d}$). Equation 5 implies that the subsidy rate reduces the commodity price.

$$tren_{ren,h,d} = \frac{shxhous_{ren,h,d} \cdot TCH_d}{PQ\_S_{ren,d} \cdot XHOUS\_S_{ren,h,d}} \qquad \forall\, ren \in c = \{wnd, hyd, slr\} \qquad (4)$$

$$XHOU\_S_{c,h,d} = \frac{\beta_{c,h,d}}{(1+stx_{c,d}) \cdot (1-tren_{c,h,d}) \cdot PQ\_S_{c,d}} \cdot EH_{h,d} \qquad (5)$$

Additional closures are needed to ensure that the IRSA-EA model is square in terms of the number of variables is precisely equal to the number of equations. The default closures for the IRSA-EA as follows:

- The output price index is the numeraire
- World export and import prices are exogenous
- Household and firm savings rate 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
- Labour is mobile and fully employed[3].

The closures of non-labour inputs are set immobile such that they cannot move across industries with average rents are set to be fixed. In contrast, labour is set to be mobile to move into other sectors while keeping sectoral specific wage is set to be fixed[4]**.** Hence, the analysis in this paper is a short term analysis (Löfgren et al., 2002). The sets of variables are presented in Table 1.

[3] The paper assumes that there is a full employment in the economy. In many of East Asia, the size of informal sector is significant; in such is reasonable to assume that those who want to work can actually find a job, if they are willing to work in the informal sector. In this situation, a full employment situation is reasonable to apply. Also, the carbon tax shock simulated is relatively small. Therefore the impacts on employment is relatively small.

[4] The implications of immobile capital and mobile labour across sector assumptions are the changes in GDP mainly comes from changes in the indirect tax revenue and changes in exchange rates.

<<Table 1 here>>

Further, in IRSA-EA, the carbon emissions and household income analyses are kept separate from the primary model. Nonetheless, the analyses use the results from IRSA-EA directly. For example, assuming that carbon content parameters constant, this paper computes the changes in carbon emissions due to fossil fuel consumption changes by industries and households.

Regarding household income analysis, this paper computes changes in income-expenditure across household percentile as follows. First, changes in household expenditures $XHOU\_S(c, h, d)$ from the IRSA-EA lead to changes in expenditure across urban and rural household percentiles. After that, this paper computes real consumption per capita for each percentile by dividing the household expenditure by percentile to the population by percentile in urban and rural areas.

Finally, this paper computes changes in the poverty incidence. Poverty incidence is defined as the percentage of the poor household to total household in a country. A poor household is defined as those whose income per capita is lower than the poverty line in a country. Then, the poverty incidence is computed using an interpolation technique adopted by Yusuf and Resosudarmo (2015).

4. Data

This paper uses four sets of data. First, the main dataset is the inter-regional social accounting matrix for East Asia (EA-IRSAM). The EA-IRSAM is constructed from the Global Trade Analysis Project (GTAP) Power version 9 database with a common reference year of 2011 and currency of the United States trillion dollars (USD trillion). This paper extracts and converts the GTAP 9 Power database into EA-IRSAM by using General Algebraic Modelling System (GAMS) software, following McDonald and Thierfelder (2004) and McDonald and Thierfelder (2013). Then, the next step is to reconstruct the structure of each SAM for each country from the GTAP 9 Power database. In this stage, this paper disaggregates the regional household account extracted from GTAP into household, firm, and government accounts. Also, at the same step, this paper computes subsidies for fossil fuels in each country using the percentage of government spending for fossil fuel subsidies to calibrate EA-IRSAM. The final step combines all submatrices of individual SAM into EA-IRSAM. In the end, there are 33 sectors in the EA-IRSAM with 12 East Asian countries. Table 2 exhibits the sectoral aggregation from

GTAP 9 Power database into the EA-IRSAM, while Table 3 presents selected socio-economic indicators of the EA-IRSAM.

<<Table 2 here>>

<<Table 3 here>>

The second dataset covers several household surveys across East Asian countries. The GTAP Power 9 database had to be modified such that IRSA-EA can mimic various country-specific datasets, i.e., income distribution across urban and rural households and transfer from the government to the households. In particular, this paper extracts the share of both urban and rural household expenditures on each commodity from the following surveys and studies. For Indonesia, this paper uses the 2011 socio-economic survey (SUSENAS). The 2011 Annual Poverty Indicators Survey (APIS) is used for the Philippines. For Thailand, this paper extracts the 2011 Household Socio-Economic Survey (SES). The 2014 Vietnam Household Living Standards Survey (VHLSS) is used for Vietnam. For China, this paper uses the 2012 China Family Panel Survey (CFPS). The 2009-2010 Household Expenditure Survey is extracted for Australia. For Japan, this paper uses the 2009 Family Income and Expenditure Survey. Finally, for India, this paper extracts the 2011-2012 Household Consumer Expenditure NSS-68th Round. For South Korea, due to 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 substitutions that come from various studies. At the top level, the elasticity of substitutions 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 substitutions between the composite of energy intermediate inputs and primary inputs and parameters of elasticity of substitutions between energy and electricity intermediate inputs are following Yusuf and Resosudarmo (2015). Finally, parameters of elasticity of substitutions for value-added and Armington are taken from GTAP Power 9 database.

The last 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 consumption of electricity, coal, oil, gas, petroleum products, and gas manufactured distribution by each sector in each country.

5. Policy simulations

This section provides details on each policy simulation in this paper based on several assumptions. First, this paper assumes that the government in each East Asian country charges a relatively low carbon tax at one USD per tonne of carbon emissions from fossil fuel sectors, namely coal, petroleum product, and distributed gas sectors. As the carbon tax is relatively small, it is expected that there is less resistance in each East Asian country to apply the carbon tax. Second, this paper assumes only one recycling mechanism in each simulation for simplicity in interpreting the results.

The simulations in this paper are as follows:

SIM1: Each government retains 100 per cent of the carbon tax revenue to increase government spending proportionally. In this scenario, the government reallocates all additional revenue from carbon tax as additional government spending. As a result, there will be an expansion in government spending proportionally. Therefore, in this scenario, there is no specific recycling mechanism for developing renewable electricity.

SIM2: Each government redistributes 100 per cent for the subsidies for the renewable electricity sectors in the form of indirect tax reduction for renewable electricity sectors. The first recycling mechanism for renewable electricity development is that the government recycles all the additional revenue from the carbon tax to the renewable electricity industries as indirect taxes reduction. With these subsidies, the renewable electricity industries could produce more renewable electricity's outputs with lower domestic prices. Also, the total reduction in indirect tax of renewable electricity industries should be equal to the total carbon tax revenue received by the government.

SIM3: Each government redistributes 100 per cent to provide subsidies for the households to consume renewable electricity. The last mechanism for renewable electricity development is that the government subsidises renewable electricity prices consumed by urban and rural households. The subsidies allow the households to consume renewable electricity at a lower price than the baseline and expand their demand for renewable electricity. As a result, the households' demand will rise proportionally to the households' share of renewable electricity consumption in each country. Like SIM2, total subsidies to the households should be equal to the total carbon tax revenue received by the government.

The results in this paper are in real changes as all changes are computed at the original price. Also, this paper compares the results of each simulation relative to the baseline. Further, results from SIM2 and SIM3 could indicate whether the intervention by providing specific incentives for renewable electricity sectors can compensate negative impacts of introducing a carbon tax in a country.

6. Results

6.1 Sectoral impacts

Table 4 reveals the changes in sectoral outputs due to renewable electricity development. In SIM1, introducing carbon taxation increases fossil fuel prices (coal, petroleum products, and distributed gas) across East Asian countries immediately. In the next round, sectors that use fossil fuels as primary inputs experience relatively higher prices, particularly the fossil-fuel electricity and manufacturing sectors.

As the intermediate input prices of fossil fuels and other sectors increase due to carbon taxes, producers have increased production costs. As a response, the producers reduce their outputs to minimise costs and maintain optimum profits. Hence, almost all sectoral outputs fall in each East Asian country. For instance, energy and fossil fuels' electricity sector outputs reduce relatively more extensive than any sectors. A similar pattern also can be found across sectors in SIM1. For example, the agriculture and manufacturing sectors' outputs fall mainly due to the increasing price of fossil fuel commodities.

In SIM2, recycling carbon tax revenue for indirect tax reduction in the renewable electricity sectors leads to two impacts: expansions of renewable electricity sectors and positive spillover to other sectors. The first impact is an immediate expansion of renewable electricity outputs. The outputs of renewable electricity sectors expand mainly due to a reduction in the producer price of renewable electricity output. Because now it is relatively cheaper to produce renewable electricity, the producer produces more renewable electricity outputs.

The second impact is positive spillovers to other sectors. There is positive spillover because expansions of renewable electricity sectors' output lead to the increasing demand for inputs from other sectors. The positive spillover impact to other sectors in an economy depends on the sectoral linkages in an economy. For example, in some countries, such as Australia, South Korea, Indonesia, Singapore, and the rest of ASEAN, expanding the renewable electricity sector leads to higher output of the services sector. In Japan, India, South Korea, and Vietnam, as renewable electricity output expands, the manufacturing sector's output expands by 0.13, 0.72, 0.03, and 0.004 per cent. For the Philippines and the rest of ASEAN, increasing the output of renewable electricity leads to an expansion in the agriculture sector's output by 0.003 and 0.15 per cent.

<<Table 4 here>>

Finally, in SIM3, providing subsidies for households leads to increasing demand for renewable electricity commodities. Similar to SIM2, there are two implications for expanding renewable electricity sectors and positive spillover to other sectors. First, the subsidies on the renewable electricity sectors reduce consumer price. As consumer price falls, there is demand expansion for renewable electricity output. As a response, the producer produces more renewable electricity output to satisfy the rise in demand and hence, the outputs of renewable electricity expands. This paper finds that the renewable electricity sectors in SIM3 expand more than SIM2 for Australia, Japan, India, the Philippines, Vietnam, and the rest of ASEAN.

The main reason for the renewable electricity expansion in these countries is that the share of household spending on renewable electricity is relatively higher than other East Asian countries. On the other hand, in China, South Korea, Indonesia, Malaysia, and Thailand, the household consumption of the renewable electricity sector is relatively low. It hence leads to relatively lower expansion of renewable electricity sectors.

The second implication is positive spillover to other sectors. The positive spillover occurs because the producers produce more renewable electricity outputs due to the enlargement of renewable electricity demand. As a consequence, the producers demand more inputs from other sectors. This paper finds that positive spillover occurs in different sectors. In Australia, China, Indonesia, Malaysia, and Thailand, the spillover of renewable electricity sectors expansion leads to expansion of agriculture and manufacturing sectors. In Vietnam, the agriculture sector is the one that gets the positive spillover, while the rest of ASEAN has a spillover on the manufacturing sector only. There is a spillover on the fossil-fuel electricity sector as well in Australia and the rest of ASEAN. The main reason for expanding the output of the fossil-fuel electricity sector is that as other sectors produce outputs, they demand more energy inputs, including from the fossil-fuel electricity sector.

6.2 Macroeconomics and emissions results

Table 5 exhibits macroeconomics and emissions results. In general, carbon taxation on fossil fuel commodities in SIM1 has immediate impacts on carbon emissions reduction across East Asian countries. Considerable reduction in carbon emissions occurs in Indonesia, Malaysia, and Vietnam by more than 0.2 per cent. The reduction of carbon emissions comes from output contraction across all sectors in an economy due to relatively higher fossil fuel prices in a country. In the end, the aggregate outputs reduce and lead to a reduction in the real GDP.

The subsequent important implication is carbon intensity changes. Carbon intensity is the ratio between carbon emissions and GDP in each country in gram CO2 per USD. Enacting carbon tax reduces carbon intensity mainly because there is a significant reduction in carbon emissions. Therefore, in countries where fossil fuel commodities are consumed heavily, such as Indonesia, Malaysia, and Vietnam, carbon intensity reduces by more than 0.2 per cent.

<<Table 5 here>>

In SIM2, the government redistributes additional carbon tax revenue to the renewable electricity sectors as an indirect tax reduction. In this scenario, most East Asian countries experience environmental benefits only while the economy contracts except for Indonesia. Carbon emissions in SIM2 reduce slightly larger than SIM1 indicates that providing indirect tax cuts can shift the electricity demand from fossil fuel-based to renewable electricity. However, substituting fossil fuels with renewables does not compensate negative impacts of the carbon tax on the whole economy. For example, in SIM2, GDP falls more significant for Australia, India, South Korea, the Philippines, Singapore, Thailand, Vietnam, and the rest of ASEAN. For Indonesia, on the other hand, there is a slight contraction in the economy. This contraction mainly due to increasing renewable electricity output leads to increasing services sector output.

In terms of carbon intensity changes, in SIM2, there is a relatively more considerable carbon intensity reduction than those in SIM1 for Australia, China, Indonesia, Malaysia, Singapore, and the rest of ASEAN. This considerable reduction in carbon intensity is mainly due to the combination of a reduction in carbon emissions and a slight reduction in GDP. For example, the rest of ASEAN has carbon intensity reduction by more than 1 per cent because carbon emissions reduce significantly by more than 1 per cent, and at the same time, GDP slightly falls.

Finally, in SIM3, the government redistributes the carbon tax revenue to the households in renewable electricity subsidies. Introducing renewable electricity subsidies for households will boost demand for renewable electricity as the consumer prices of renewable electricity are relatively lower than fossil fuel-generated electricity. As a response to the increasing demand for renewable electricity from households, the producers will produce more renewable electricity.

Table 5 reveals that there are three groups of countries in SIM3. First, a country with a rebound effect such as Australia, Indonesia, and the rest of ASEAN. The rebound effect occurs mainly due to the manufacturing and energy sectors' expansion. For instance, in Australia, the spillover of expansion of renewable electricity output leads to the expanded output of agriculture, manufacturing, and fossil fuel electricity sectors. Similarly, there is an enlargement in the agriculture, manufacturing, and energy sectors in Indonesia. While for the rest of ASEAN, expansion of renewable electricity sectors lead to enlargement in manufacture and energy sectors outputs. Together, expansion in manufacturing, energy, and fossil fuel electricity sectors lead to more carbon emissions emitted in these countries.

Second, a country with environmental benefits only includes China, Japan, South Korea, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. In these countries, there is a reduction in energy, fossil-fuel electricity, and services sectors. Therefore, in aggregate, the economy shrinks and lead to fewer carbon emissions.

The last group is a country where there is a double dividend, such as India. Double dividend occurs when there is a carbon emissions reduction and economic expansion. This double dividend occurs because increasing in renewable electricity leads to increasing services sectors output. In India, increasing the services sector alone leads to a slight expansion in the economy with relatively low carbon emissions. Hence, in India, there is a positive change in the GDP with lower carbon emissions.

Regarding changes in carbon intensity, there is an increase in carbon intensity in a country where the rebound effect occurs, such as Australia, Indonesia, and the rest of ASEAN. This increase in carbon intensity is mainly due to increasing carbon emissions while the economy shrinks.

6.3 Household expenditure and poverty changes

This section provides analyses on the changes of aggregate real household expenditure (Table 6), changes of the real household expenditure across percentile household (Figure 3), and changes in poverty incidence for urban and rural households (Table 6).

There are two effects of implementing the carbon tax on the changes of real household expenditure in SIM1: increasing fossil fuel price effect and increasing government transfer to the effect of the household. First, the carbon tax on fossil fuel commodities increases fossil fuel prices and increases other commodities' prices. Because fossil fuel and other fossil fuel-related product prices increase, urban and rural households reduce their expenditures. Second, there is an increase in the government transfer to the households in SIM1. This increase in the government transfer is mainly due to each government use additional revenue from the carbon tax to increase their spending proportionally, including transfer to the households. In aggregate, the real household expenditures in SIM1 fall because increasing commodity price is more considerable than the effect of increasing government transfer.

Similar to SIM1, changes in commodity prices and changes in government transfer determine the changes in household expenditure in SIM2. First, carbon taxation leads to relatively increasing fossil-fuel commodity prices and other commodity prices, similar to SIM1. However, in SIM2, the government cannot transfer more to the households because in this scenario, each government reallocates all carbon tax revenue into indirect tax reduction of renewable electricity sectors.

This paper, however, finds that there is an increase in the government transfer to the households in China, Indonesia, Malaysia, and the rest of ASEAN. This increasing government transfer is mainly because there is an increase in the government revenue from indirect taxes and imports taxes in these countries. However, for China and Malaysia, increasing government transfer is not significant enough to compensate increasing in commodity price due to carbon tax. On the other hand, for Indonesia and the rest of ASEAN, the effect of increasing government transfer is more significant than the effect of increasing commodity prices. Hence, this paper finds that the households in Indonesia and the rest of ASEAN can increase their spending.

In SIM3, the changes in total household income are mainly driven by increasing household subsidies due to the recycling mechanism of carbon tax revenue. As a result, almost all East Asian countries increase their real household expenditure, except for Indonesia and the rest of

ASEAN. For Indonesia and the rest of ASEAN, there is a decreasing real household expenditure due to reducing the households' income. In these two countries, the income of the households falls because of a significant reduction in government transfer. One main reason for the reduction in government transfer is that there is a reduction in government revenue due to the reduction of indirect tax revenue from the services sectors.

The next step is to decompose total real household expenditure changes into changes of real household expenditure by percentile in both rural and urban areas, as presented in Figure 3. This paper finds that the impacts of the carbon tax in SIM1 are relatively different across East Asian countries. For example, there is a progressive pattern of expenditure distribution in Indonesia. The progressiveness of the real household expenditure pattern implies that carbon tax affects the richer households' consumption more, as the richer household consumes more fossil fuel-related products.

In contrast, there is a regressive pattern of expenditure distribution in China. The regressiveness of the real household expenditure pattern implies that poor households are affected most by carbon tax implementation.

In Vietnam, on the other hand, the distribution of expenditure is relatively flat. Relatively neutral changes in changes in the household expenditure pattern in Vietnam indicate that the budget share of renewable electricity for poor and rich households is relatively similar.

In SIM2, a regressive pattern in China and a flat pattern in Vietnam still exist. However, the households in Indonesia have a positive and progressive pattern in the household expenditure changes for two reasons. First, there is an increase in the transfer from the government to the households. Second, the poor households receive more share of government transfer than the rich households. Therefore, poor household can increase their spending more than urban households.

<<Figure 3 here>>

After introducing renewable electricity subsidies in SIM3, the pattern of income distribution changes significantly. The directions change from progressive pattern to regressive pattern, vice versa. The changes depend on whether the subsidies compensations for the households are large enough to counteract the negative impacts of carbon taxation. Figure 3 reveals that if the compensations are large enough, such as in China, the regressive pattern transformed into the progressive pattern. However, in Indonesia, the compensation values by providing renewable electricity consumption subsidies are insufficient, and only rich households enjoy more benefits from the subsidies.

Finally, changes in real urban and rural household expenditure by percentile lead to changes in the poverty incidence, as presented in Table 6. In SIM1, all East Asian countries experience increasing poverty incidences due to decreasing aggregate household expenditure. Also, the rural households have a relatively more considerable increase in poverty incidences, except for Indonesia. In Indonesia, the rich households have more reduction in consumption than the poor households implies that urban households use more fossil fuel commodities than rural households.

<<Table 6 here>>

In SIM2, only Indonesia and the rest of ASEAN experience a reduction in poverty incidences. The main reason for this is that there is an increase in the real household expenditure in these two regions due to increased government transfer to the households.

Finally, in SIM3, there are three groups of the country. First, a country with reductions in urban and rural poverty incidence is China, India, Malaysia, the Philippines, and Vietnam. Second, a country where there is an increase in poverty incidences such as Indonesia and the rest of ASEAN. Third, a country with a reduction in urban poverty incidence only, such as in Thailand.

Changes in the poverty incidence in these three groups of countries correlate to the changes in expenditure distribution across percentile households. For China, India, Malaysia, the Philippines, and Vietnam, positive changes in all percentile lead to poverty incidence reduction. On the other hand, for Indonesia and the rest of ASEAN, there are negative changes in the real household expenditure across percentile and hence increase poverty incidence in these two countries. The last group is Thailand, where only urban household experience a reduction in poverty incidence. The reduction in urban poverty incidence in Thailand mainly because the expenditure distribution has an inverted U shape. This inverted U shape implies that the poor and rich households affected more than the middle-income households.

6.4 Sensitivity Analysis

A sensitivity analysis is necessary to examine the reliability of the results as the IRSA-EA model uses parameters from other studies. This study has two main parameters that need to be examined: the elasticity of substitution and carbon tax value. In terms of elasticity of substitution, this paper conducts the sensitivity analysis for the elasticity of substitution among electricity intermediate inputs ($\sigma_{i,d}^{ely}$) and elasticity of substitution between energy and electricity intermediate inputs ($\sigma_{i,d}^{en}$). These two parameters are essential in determining substitution among energy and electricity sectors.

The sensitivity analysis is done by randomly choosing parameters values in a range of 50 per cent higher and lower than the baseline parameters values. Similarly, a sensitivity analysis for the carbon tax value allows for a lower and higher carbon tax per tonne of carbon emissions by increasing or decreasing the carbon tax value randomly by 50 per cent of 1USD per tonne CO_2 emissions. Then, this paper runs each simulation 100 times for both random values of elasticities of substitutions and carbon tax. Finally, for each simulation, the mean and standard deviation are computed.

The results of sensitivity analysis are presented in Table 7 for randomly assigned $\sigma_{i,d}^{ely}$ and $\sigma_{i,d}^{en}$. In general, the sensitivity analysis results in Table 9 indicate that the main results in Table 5 (changes in carbon emissions and changes in real GDP) and Table 6 (changes in real household expenditure) are less sensitive to different values of elasticities of substitution. Two indications can be inferred from Table 7. First, the signs of the sensitivity analysis results are all consistent with the leading results in Table 5 and Table 6. Second, the sensitivity analysis results have relatively lower standard deviation values for each outcome.

Similarly, the sensitivity analysis results in Table 8 for randomly assigned carbon tax value have a consistent sign with the main results in Table 5 and Table 6 and a relatively low standard deviation. Therefore, the results in this study are robust to different values of elasticity of substitutions and the carbon tax value per tonne CO_2 emissions.

<<Table 7 here>>

<<Table 8 here>>

7. Conclusions

This paper has analysed the impacts of a different method of developing renewable electricity in the East Asia region. Further, this paper has observed the best policy to develop renewable electricity in a country. To do so, this paper used the IRSAM-EA model, a comparative static multi-region CGE that covers all ASEAN member countries with the addition of Australia, China, Japan, South Korea, and India. There are three main simulations in this paper. The first simulation is that there is no recycling mechanism for renewable electricity development. In this case, the government expands its budget in all sectors proportionally. Second, all carbon tax revenue is redistributed as the indirect tax reduction of renewable electricity sectors. Finally, the government redistributes the carbon tax revenue to the households, both in urban and rural areas, by subsidising renewable electricity consumption.

Regarding the best policy to develop renewable electricity, this paper finds that in terms of the economic objective, providing indirect tax reduction is only economically beneficial for Indonesia. Further, subsidising renewable electricity prices for households would primarily benefit India only.

Regarding environment objectives, this paper finds that providing indirect subsidies for renewable electricity is beneficial for all East Asian countries while subsidising renewable electricity prices for households would not benefit Australia, Indonesia, and the rest of ASEAN.

Finally, in terms of the equity objective, only a few countries reduce poverty incidence. For example, providing indirect subsidies to renewable electricity reduces poverty incidence in Indonesia and the rest of ASEAN. On the other hand, China, India, Malaysia, the Philippines, and Vietnam could reduce poverty incidence by subsidising renewable electricity prices for households.

The main caveat of this paper is that the paper assumes there is only one mechanism that could occur at one time. In reality, there are many combinations of the recycling mechanism of carbon tax revenue. Further, this paper assumes that the rate of household subsidy for renewable electricity consumption is similar across different type of households. In practice, the government could only target the most impoverished households, and hence the subsidy rate could be more extensive than that simulated in this paper. Therefore, in the end, the poverty incidence reduction could be more considerable as well.

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Table 1. Set of variables

Production Sectors		**Regions**
Agriculture	Gas manufacture distribution	Indonesia
Farming	Water	Malaysia
Forestry	Construction	Philippines
Fishing	Trade	Singapore
Coal	Transportation	Thailand
Oil	Communication	Vietnam
Gas	Financial services	Rest of ASEAN
Minerals *nec*	Public administration, defence, health, and education	Australia
Food and beverages		China
Textile and leather products		Japan
Wood and paper products	Dwellings and other services	South Korea
Petroleum products		India
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. Sectoral Aggregation

Aggregated sector	Original Sector
Agriculture (AGR)	Agriculture (PDR)
	Farming (CTL)
	Forestry (FRS)
	Fishing (FSH)
Manufacturing (MNF)	Minerals nec (OMN)
	Food and Beverages (CMT)
	Textiles (TEX)
	Wood Products (LUM)
	Chemical rubber plastic prods (CRP)
	Mineral products nec (NMM)
	Metal products (I_S)
	Manufacturing (MVH)
Energy (ENR)	Coal (COA)
	Crude oil (OIL)
	Gas (GAS)
	Petroleum products (P_C)
	Gas manufacture distribution (GDT)
Fossil-fuel electricity (FFE)	Coal power electricity (COA_ELY)
	Oil power electricity (OIL_ELY)
	Gas power electricity (GAS_ELY)
	Other electricity (O_ELY)
Renewable electricity (REE)	Wind power electricity (WND)
	Hydropower electricity (HYD)
	Solar power electricity (SLR)
Services (SRV)	Transmission and distribution of electricity (TND)
	Water (WTR)
	Construction (CNS)
	Trade (TRD)
	Transport (TSP)
	Communication (CMN)
	Financial services (OFI)
	Dwellings and Other Services (ROS)
	Public Admin Defence Health (OSG)

Table 3. Selected Socio-Economic Indicators from the 2011 East Asia-IRSAM

	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	0.00	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		37.34	61.25	52.20
Poverty Incidence (in percentage)												
Urban		0.54		13.39		10.75	1.00	4.10		8.80	5.10	7.15
Rural		15.44		24.83		15.96	3.40	20.50		15.95	15.90	38.02
Carbon Emissions (in kilo tonne CO_2)												
Total emissions	269.00	5943.00	863.00	1200.00	373.00	259.00	95.00	35.00	24.00	149.00	77.00	14.00
Carbon intensity (in gram CO2 per USD)	0.19	0.81	0.15	0.64	0.31	0.38	0.39	0.20	0.09	0.49	0.70	0.18

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. Poverty incidences for Australia, Japan, South Korea, and Singapore are not available.

Table 4. Total sectoral output changes (in per cent)

	SIM1						SIM2						SIM3					
	AGR	MNF	ENR	FFE	REE	SRV	AGR	MNF	ENR	FFE	REE	SRV	AGR	MNF	ENR	FFE	REE	SRV
AUS	-0.009	-0.012	-0.068	-0.167	-0.001	-0.011	-0.033	-0.087	-0.115	-0.464	0.172	0.015	0.022	0.055	-0.028	0.129	0.499	-0.038
CHN	-0.019	-0.076	-0.620	-0.079	0.003	0.005	-0.037	-0.118	-0.652	-0.084	0.472	-0.013	0.020	0.051	-0.573	-0.071	0.276	-0.050
JPN	-0.011	-0.028	-0.208	-0.094	-0.001	-0.003	-0.018	0.133	-0.177	-0.014	0.714	-0.008	-0.005	-0.183	-0.239	-0.190	1.345	-0.006
IND	-0.011	-0.084	-0.301	-0.319	-0.017	-0.007	-0.001	0.719	-0.271	-0.021	0.638	-0.255	-0.013	-1.049	-0.309	-0.669	1.425	0.268
KOR	-0.014	-0.038	-0.230	-0.178	**	-0.004	-0.013	0.026	-0.243	0.036	0.028	0.015	-0.004	-0.058	-0.196	-0.343	0.024	-0.039
IDN	-0.005	-0.043	-0.110	-0.458	**	-0.008	-0.058	-0.766	-0.533	-0.525	0.113	0.210	0.052	0.621	0.280	-0.286	0.026	-0.224
MYS	-0.010	-0.030	-0.089	-0.284	**	-0.010	-0.008	-0.034	-0.126	-0.284	0.003	-0.023	0.008	0.024	-0.034	-0.283	0.001	-0.031
PHL	-0.006	-0.019	-0.090	-0.181	-0.006	-0.008	0.003	-0.001	-0.081	-0.155	0.539	-0.013	0.004	-0.017	-0.069	-0.256	0.983	-0.029
SGP	-0.009	-0.016	-0.224	-0.082	*	-0.003	-0.008	-0.015	-0.356	-0.088	*	0.005	-0.010	0.003	-0.073	-0.080	*	**
THA	-0.026	-0.050	-0.129	-0.099	**	-0.029	-0.025	-0.049	-0.151	-0.105	0.042	-0.038	0.005	0.033	-0.076	-0.070	0.005	-0.046
VNM	-0.008	-0.075	-0.119	-0.244	-0.022	-0.025	-0.010	0.004	-0.120	-0.170	0.696	-0.065	0.012	-0.135	-0.104	-0.271	0.884	-0.158
XSE	-0.003	-0.010	-0.025	-0.141	-0.001	-0.008	0.154	-0.631	0.749	-4.058	0.714	0.231	-0.101	0.445	-1.026	3.365	1.015	-0.219

Notes: AGR= agriculture, MNF=manufacturing, ENR= energy, FFE= fossil fuels electricity, REE = renewable electricity, SRV=services. Sectoral aggregation can be found in Table 2A. * = a country without any renewable sector; ** =negligible value

Table 5. Macroeconomic and emissions results (in per cent)

	SIM1			SIM2			SIM3		
	CO2 changes	**Real GDP changes**	**Carbon Intensity changes**	**CO2 changes**	**Real GDP changes**	**Carbon Intensity changes**	**CO2 changes**	**Real GDP changes**	**Carbon Intensity changes**
AUS	-0.120	-0.006	-0.114	-0.236	-0.011	-0.225	0.010	-0.005	0.015
CHN	-0.194	-0.009	-0.185	-0.227	**	-0.227	-0.142	-0.032	-0.110
JPN	-0.110	-0.008	-0.101	-0.044	-0.008	-0.036	-0.172	-0.010	-0.162
IND	-0.193	-0.012	-0.181	-0.137	-0.046	-0.092	-0.199	0.007	-0.206
KOR	-0.141	-0.010	-0.132	-0.054	-0.023	-0.031	-0.198	-0.004	-0.193
IDN	-0.207	-0.003	-0.205	-0.386	0.001	-0.386	0.039	-0.072	0.111
MYS	-0.217	-0.006	-0.210	-0.273	**	-0.273	-0.129	-0.015	-0.114
PHL	-0.142	-0.008	-0.134	-0.115	-0.009	-0.107	-0.133	-0.009	-0.124
SGP	-0.076	-0.007	-0.069	-0.089	-0.008	-0.081	-0.060	-0.008	-0.052
THA	-0.162	-0.020	-0.142	-0.162	-0.021	-0.142	-0.121	-0.019	-0.103
VNM	-0.291	-0.022	-0.268	-0.199	-0.032	-0.167	-0.342	-0.030	-0.312
XSE	-0.143	-0.006	-0.137	-1.532	-0.025	-1.507	1.030	-0.045	1.076

Notes: ** = negligible value

Table 6. Changes in the Real Household Expenditure and Changes in Poverty Incidence

	SIM1				SIM2				SIM3			
	Real HH Exp. Changes		Poverty Changes		Real HH Exp. Changes		Poverty Changes		Real HH Exp. Changes		Poverty Changes	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
CHN	-0.073	-0.080	**	0.035	-0.112	-0.127	**	0.049	0.212	0.135	**	-0.130
IND	-0.063	-0.065	0.015	0.195	-0.285	-0.389	0.101	0.443	0.407	0.527	-0.122	-1.570
IDN	-0.063	-0.065	0.122	0.025	0.452	0.490	-0.780	-0.309	-0.369	-0.368	1.323	0.390
MYS	-0.044	-0.044	0.003	0.005	-0.008	-0.016	0.001	0.002	0.105	0.028	**	-0.008
PHL	-0.037	-0.026	0.004	0.014	-0.009	-0.018	0.001	0.010	0.026	-0.001	-0.003	**
THA	-0.047	-0.068	0.267	0.118	-0.052	-0.073	0.274	0.123	0.108	0.015	-0.586	0.020
VNM	-0.117	-0.093	0.013	0.294	0.002	-0.060	0.001	0.077	0.096	0.038	-0.011	-0.032
XSE	-0.029	-0.033	0.005	0.113	1.016	0.923	-0.142	-0.685	-0.700	-0.656	0.099	1.793

Notes: ** = negligible value

Table 7. Sensitivity Analysis for changes in elasticity of substitution (in per cent)

			AUS	CHN	JPN	IND	KOR	IDN	MYS	PHL	SGP	THA	VNM	XSE
SIM1	CO2 changes	Mean	-0.120	-0.195	-0.110	-0.194	-0.141	-0.206	-0.216	-0.141	-0.076	-0.162	-0.290	-0.142
		Std Dev	0.002	0.014	0.001	0.006	0.001	0.001	0.000	0.003	0.000	0.001	0.003	0.001
	Real GDP changes	Mean	-0.006	-0.009	-0.008	-0.012	-0.010	-0.003	-0.006	-0.008	-0.007	-0.020	-0.022	-0.006
		Std Dev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Real HH Exp. Urban changes	Mean	-0.038	-0.073	-0.019	-0.061	-0.025	-0.041	-0.043	-0.031	-0.018	-0.047	-0.096	-0.031
		Std Dev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Real HH Exp. Rural changes	Mean	-0.038	-0.080	-0.018	-0.065	-0.033	-0.047	-0.044	-0.027	-	-0.068	-0.091	-0.032
		Std Dev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-	0.000	0.000	0.000
SIM2	CO2 changes	Mean	-0.236	-0.228	-0.044	-0.141	-0.056	-0.386	-0.273	-0.116	-0.090	-0.162	-0.202	-1.549
		Std Dev	0.004	0.015	0.002	0.010	0.001	0.002	0.000	0.004	0.000	0.001	0.006	0.015
	Real GDP changes	Mean	-0.011	-0.000	-0.008	-0.046	-0.023	0.001	0.000	-0.009	-0.008	-0.021	-0.033	-0.025
		Std Dev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Real HH Exp. Urban changes	Mean	-0.026	-0.112	-0.049	-0.303	-0.043	0.447	-0.014	-0.018	-0.024	-0.052	-0.059	0.874
		Std Dev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
	Real HH Exp. Rural changes	Mean	-0.025	-0.127	-0.045	-0.387	-0.043	0.491	-0.016	-0.017	-	-0.073	-0.066	0.928
		Std Dev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-	0.000	0.000	0.001
SIM3	CO2 changes	Mean	0.009	-0.143	-0.172	-0.197	-0.196	0.040	-0.129	-0.134	-0.060	-0.122	-0.339	1.044
		Std Dev	0.007	0.009	0.003	0.009	0.000	0.003	0.001	0.007	0.000	0.001	0.002	0.017
	Real GDP changes	Mean	-0.005	-0.032	-0.010	0.007	-0.004	-0.072	-0.015	-0.009	-0.008	-0.019	-0.029	-0.045
		Std Dev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Real HH Exp. Urban changes	Mean	-0.010	0.212	0.030	0.425	0.059	-0.361	0.111	0.029	-0.014	0.108	0.155	-0.593
		Std Dev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
	Real HH Exp. Rural changes	Mean	-0.018	0.135	0.023	0.525	0.075	-0.370	0.028	-0.001	-	0.015	0.037	-0.660
		Std Dev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-	0.000	0.000	0.001

Table 8. Sensitivity Analysis for changes in carbon tax value (in per cent)

			AUS	**CHN**	**JPN**	**IND**	**KOR**	**IDN**	**MYS**	**PHL**	**SGP**	**THA**	**VNM**	**XSE**
SIM1	CO2 changes	Mean	-0.117	-0.189	-0.107	-0.188	-0.138	-0.202	-0.211	-0.139	-0.075	-0.158	-0.283	-0.139
		Std Dev	0.036	0.058	0.033	0.057	0.042	0.062	0.064	0.042	0.023	0.048	0.086	0.042
	Real GDP changes	Mean	-0.006	-0.009	-0.008	-0.012	-0.01	-0.003	-0.006	-0.008	-0.007	-0.019	-0.022	-0.005
		Std Dev	0.002	0.003	0.002	0.004	0.0029	0.001	0.002	0.002	0.002	0.006	0.007	0.002
	Real HH Exp. Urban changes	Mean	-0.037	-0.071	-0.019	-0.061	-0.029	-0.050	-0.043	-0.036	-0.018	-0.046	-0.114	-0.034
		Std Dev	0.011	0.022	0.006	0.019	0.0088	0.015	0.013	0.011	0.005	0.014	0.035	0.010
	Real HH Exp. Rural changes	Mean	-0.037	-0.078	-0.018	-0.063	-0.032	-0.044	-0.043	-0.025	-	-0.066	-0.091	-0.031
		Std Dev	0.011	0.024	0.006	0.019	0.0097	0.013	0.013	0.008	-	0.020	0.028	0.009
SIM2	CO2 changes	Mean	-0.236	-0.229	-0.044	-0.137	-0.053	-0.387	-0.275	-0.116	-0.090	-0.164	-0.201	-1.504
		Std Dev	0.059	0.064	0.012	0.033	0.0122	0.088	0.075	0.032	0.023	0.045	0.056	0.347
	Real GDP changes	Mean	-0.011	-0.000	-0.008	-0.046	-0.023	-0.002	-0.000	-0.009	-0.008	-0.021	-0.032	-0.028
		Std Dev	0.003	0.000	0.002	0.012	0.0067	0.014	0.001	0.002	0.002	0.006	0.009	0.018
	Real HH Exp. Urban changes	Mean	-0.026	-0.113	-0.049	-0.285	-0.022	0.453	-0.008	-0.009	-0.024	-0.052	0.002	1.009
		Std Dev	0.008	0.031	0.013	0.070	0.0055	0.075	0.001	0.003	0.007	0.015	0.000	0.268
	Real HH Exp. Rural changes	Mean	-0.026	-0.128	-0.045	-0.388	-0.045	0.494	-0.016	-0.018	-	-0.073	-0.060	0.917
		Std Dev	0.007	0.035	0.012	0.096	0.0114	0.096	0.003	0.005	-	0.021	0.017	0.245
SIM3	CO2 changes	Mean	0.009	-0.136	-0.164	-0.191	-0.189	0.038	-0.124	-0.127	-0.057	-0.116	-0.327	0.977
		Std Dev	0.002	0.042	0.051	0.063	0.0583	0.013	0.039	0.039	0.020	0.035	0.100	0.254
	Real GDP changes	Mean	-0.005	-0.030	-0.010	0.007	-0.004	-0.069	-0.014	-0.009	-0.008	-0.018	-0.028	-0.044
		Std Dev	0.002	0.009	0.003	0.001	0.0017	0.015	0.004	0.003	0.002	0.006	0.009	0.018
	Real HH Exp. Urban changes	Mean	-0.010	0.203	0.028	0.392	0.0428	-0.355	0.100	0.025	-0.013	0.103	0.092	-0.664
		Std Dev	0.003	0.061	0.009	0.135	0.0136	0.049	0.032	0.007	0.004	0.032	0.028	0.165
	Real HH Exp. Rural changes	Mean	-0.017	0.129	0.022	0.508	0.0732	-0.354	0.027	-0.001	-	0.014	0.037	-0.622
		Std Dev	0.005	0.039	0.007	0.174	0.0226	0.053	0.009	0.000	-	0.004	0.011	0.155

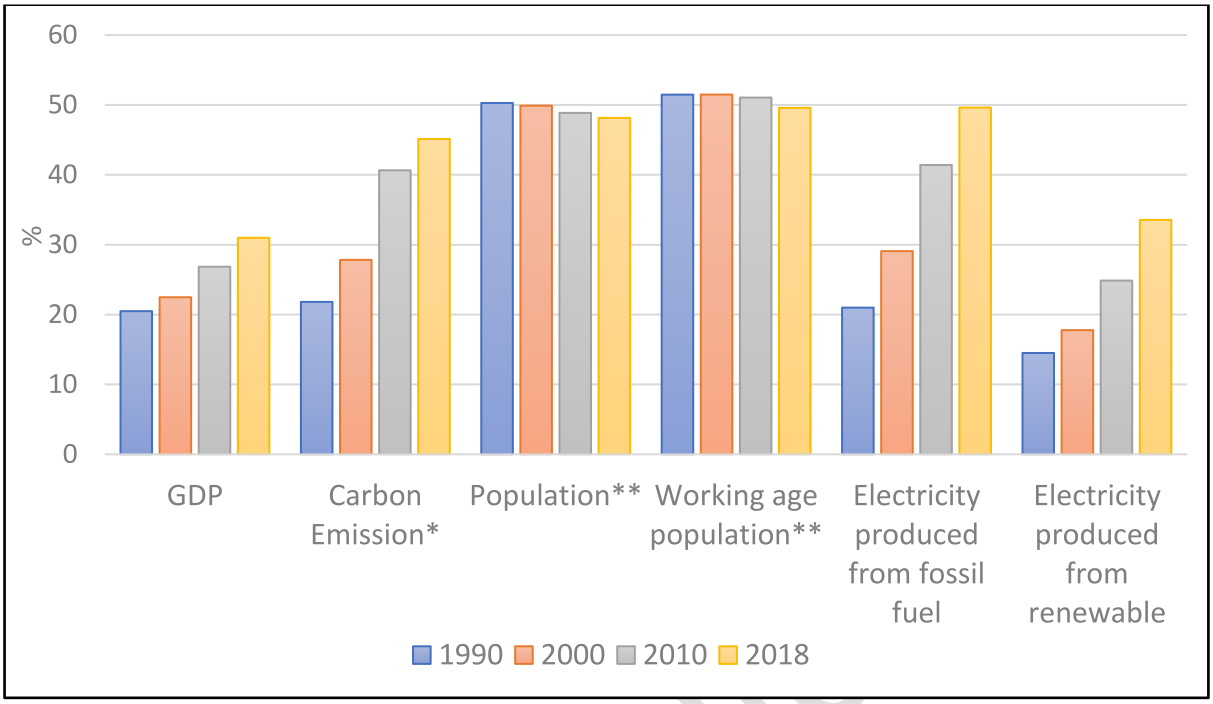

Figure 1. Share of selected indicators in the East Asia region (per cent to the world)

Source: World Bank (2019a), United Nations (2019), IEA (2020a), IEA (2020b), World Resources Institute (2020).
Notes: * The latest carbon emissions data by region only available for 2016; ** Population data available for 2020.

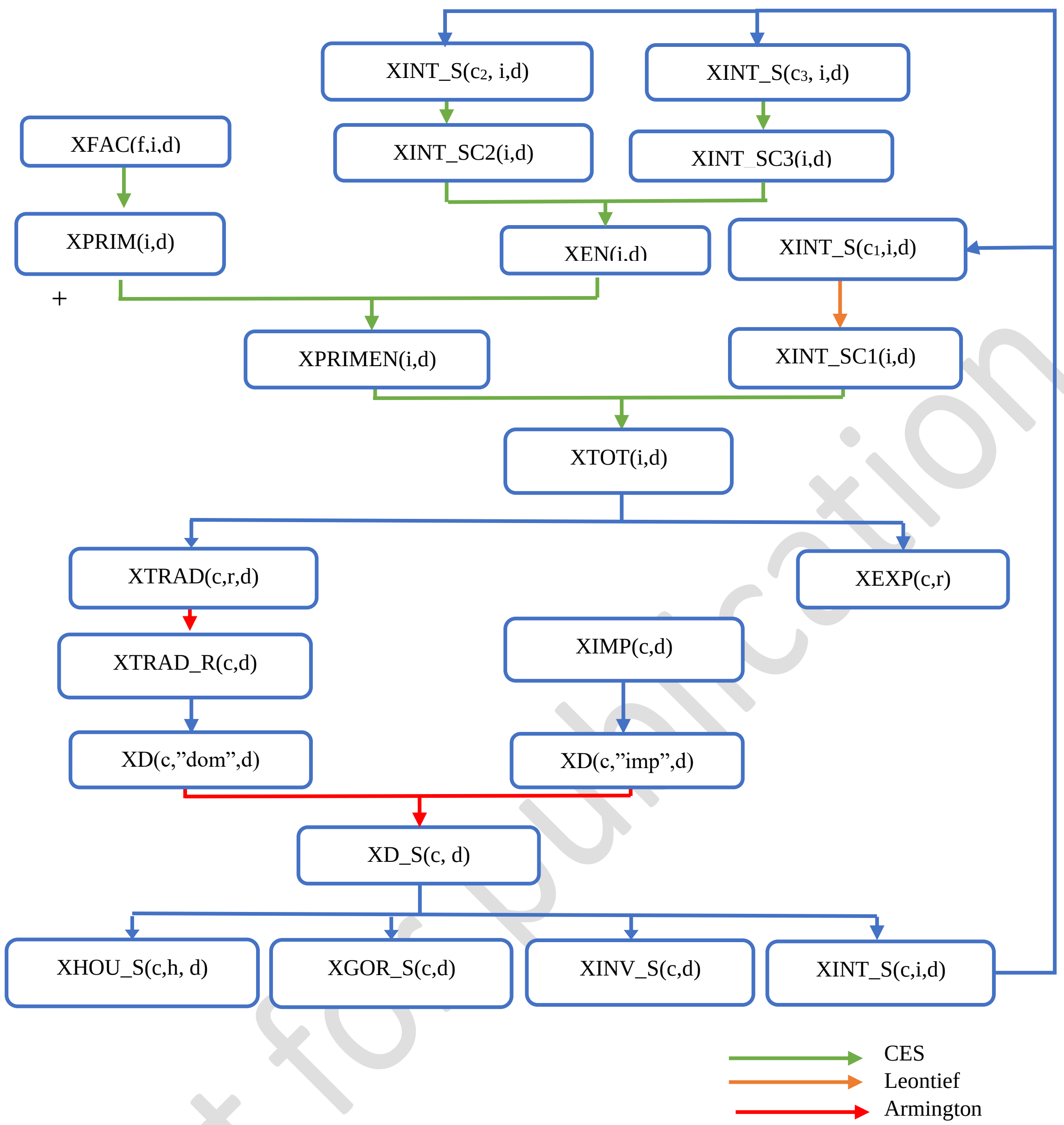

Figure 2. Production structure of IRSA-EA Model

Subscript notations in Figure 2 are defined as follows
c commodity;
c_1 non-energy and non-electricity intermediate inputs;
c_2 energy intermediate inputs (coal, gas, petroleum products, gas manufacture distribution) ;
c_3 electricity intermediate inputs (wind, hydro, solar, coal electricity, oil electricity, gas electricity, other electricity);
d country destination of commodity;
f production factor;
h household;
i industry;
r country source of commodity;
s source of commodity, composite between domestic ("dom") and import ("imp").

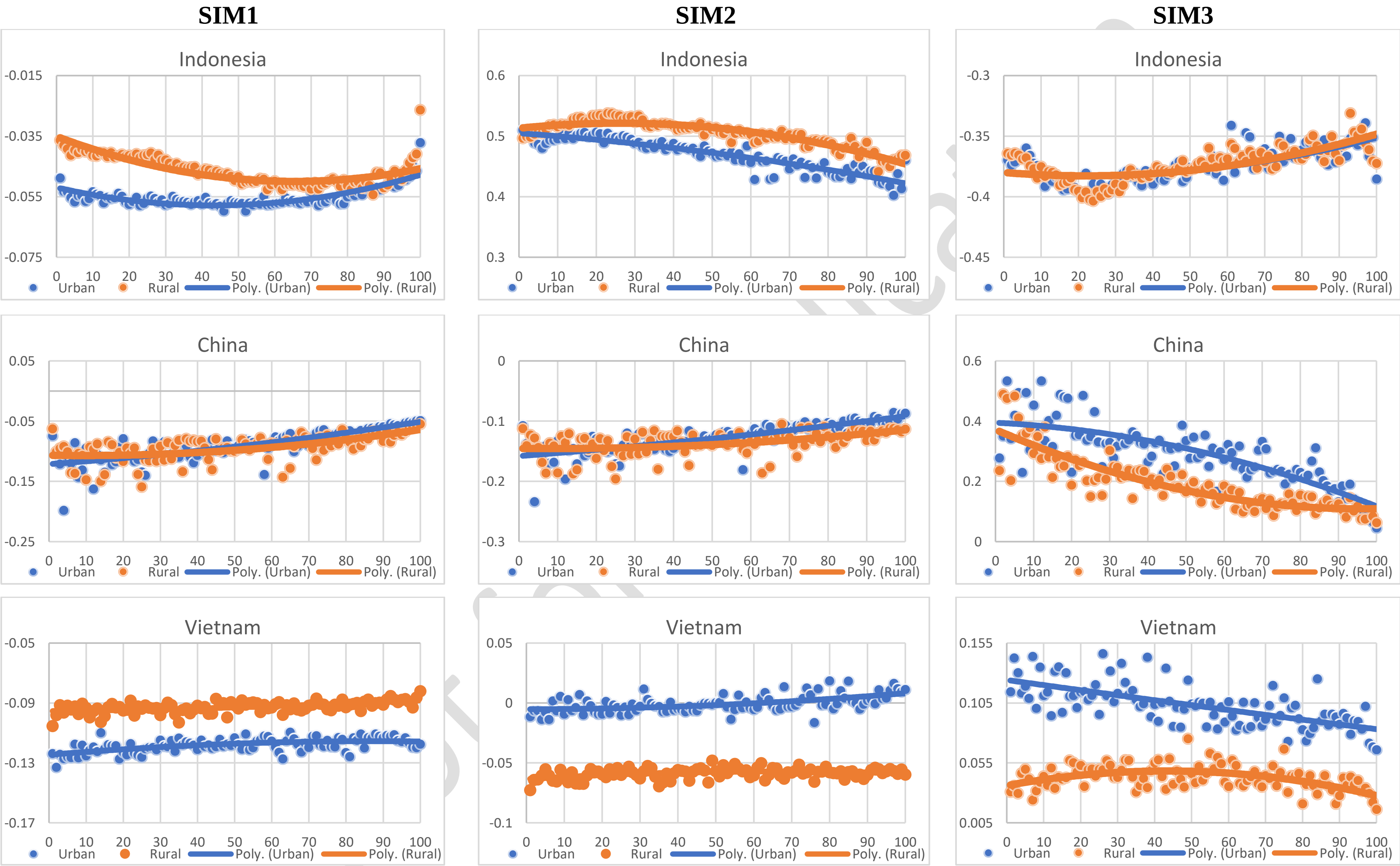

Figure 3. Real Household Expenditure Changes (in per cent)