# Economic Impacts of a Carbon Tax in an Integrated ASEAN

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The Economy and Environment Program for Southeast Asia (EEPSEA) was established in May 1993 to support research and training in environmental and resource economics. Its objective is to enhance local capacity to undertake the economic analysis of environmental problems and policies. It uses a networking approach, involving courses, meetings, technical support, access to literature and opportunities for comparative research. Member countries are Thailand, Malaysia, Indonesia, the Philippines, Vietnam, Cambodia, Lao PDR, China, and Papua New Guinea.

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## EXECUTIVE SUMMARY

The establishment of an ASEAN Economic Community in 2015 has been on the agenda for quite some time. One issue that recently emerged is the climate change issue in which each member of ASEAN needs to respond. The main goal of this study is to analyze the benefits and losses of cooperation among ASEAN members in mitigating their carbon dioxide ($CO_2$) emission, particularly by implementing a uniform carbon tax across ASEAN.

To achieve this goal, this study develops a multi-country computable general equilibrium (CGE) for ASEAN, known as the Inter-Regional System of Analysis for ASEAN (IRSA-ASEAN) model. An ASEAN Social Accounting Matrix (ASEAN-SAM) consisting of Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam is constructed as the main database for this CGE.

This study finds that the implementation of a carbon tax scenario is an effective means of reducing carbon emissions in the region. However, this environmental gain could come at a cost in terms of gross domestic product (GDP) contraction and reduction in social welfare, i.e. household income. Nevertheless, Indonesia and Vietnam can still gain from the implementation of a carbon tax depending on how revenues generated from the carbon tax are redistributed.

## 1.0 INTRODUCTION

The world has now moved beyond the conventional view that economic growth objectives are incompatible with environmental objectives. Left unaddressed, climate change represents a serious threat to economic wellbeing. Central to such principles is the appropriate pricing of carbon and ensuring that climate change mitigation policies across the board are both effective and economically efficient (Ministry of Finance, 2009).

As such, this studyanalyzes the impact of implementing a carbon tax, or a levy on carbon dioxide ($CO_2$) emission[1], in Southeast Asia, namely Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam. As of 2010, these are the six of the ten member countries of the regional cooperation known as the Association of Southeast Asian Nations (ASEAN).[2] This study utilizes the Inter-Regional System Analysis for ASEAN (IRSA-ASEAN) multi-country computable general equilibrium (CGE) model to look at the economy-wide impact of implementing such a tax in terms of environmental improvement, economic growth, and income equity.

The first part of this study provides a brief overview of current environmental issues at the global, regional, and national level with a particular emphasis on Indonesia. The second part of this study provides a detailed step-by-step procedure on the construction of a social accounting matrix for ASEAN (ASEAN-SAM). The third part of this study provides a detailed review of the IRSA-ASEAN model, including its construction method. The fourth part the study presents the results and analysis of using the IRSA-ASEAN model to simulate various policy scenarios with regard to the implementation of a carbon tax in the region. Lastly, the final section provides a summary and conclusion for this study.

## 2.0 ENVIRONMENT AS PART OF THE WORLD

According to the United Nations Framework Convention on Climate Change (UNFCCC) in 2007, rising fossil fuel burning and land use changes have emitted, and are continuing to emit, increasing quantities of greenhouse gases into the Earth's atmosphere. These greenhouse gases include carbon dioxide ($CO_2$), methane ($CH_4$), and nitrogen dioxide ($N_2O$), and a rise in these gases has caused a rise in the amount of heat from the sun withheld in the Earth's atmosphere, heat that would normally be radiated back into space. This

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[1] In this study, the definition of a carbon tax is limited to a levy on the emission of carbon dioxide only; and thus, the term carbon tax refers to $CO_2$ tax and these terms are used interchangeably.

[2] Other members of ASEAN, namely Brunei Darussalam, Cambodia, Lao PDR, and Myanmar, are not included in the model due to severe lack of data.

increase in heat has led to the greenhouse effect, resulting in climate change. The main characteristics of climate change are increases in average global temperature (global warming); changes in cloud cover and precipitation particularly over land; melting of ice caps and glaciers and reduced snow cover; and increases in ocean temperatures and ocean acidity due to seawater absorbing heat and carbon dioxide from the atmosphere (UNFCCC, 2007).

Moreover, the Intergovernmental Panel on Climate Change(IPCC) Fourth Assessment Report in 2007 states that emissions of Greenhouse Gases (GHG's) have increased since the mid-19th century and are causing significant and harmful changes in the global climate. Higher emission levels are producing sea level and climate that will dramatically affect billions of coastal people, the quality of the global environment, and the capacity of countries to sustain future economic expansion (IPCC, 2007).

The much cited, albeit surrounded by many controversies, Stern Report (2006) states that average temperatures could rise by 5 degrees Celsius from pre-industrial levels if climate change goes unchecked. Warming of 2 degrees Celsius could leave 15 to 40 percent of species facing extinction; while a warming of 3 or 4 degrees Celsius will result in many millions more people being flooded. Warming of 4 degrees Celsius or more is likely to seriously affect global food production. By the middle of the century 200 million may be permanently displaced due to rising sea levels, heavier floods and drought.

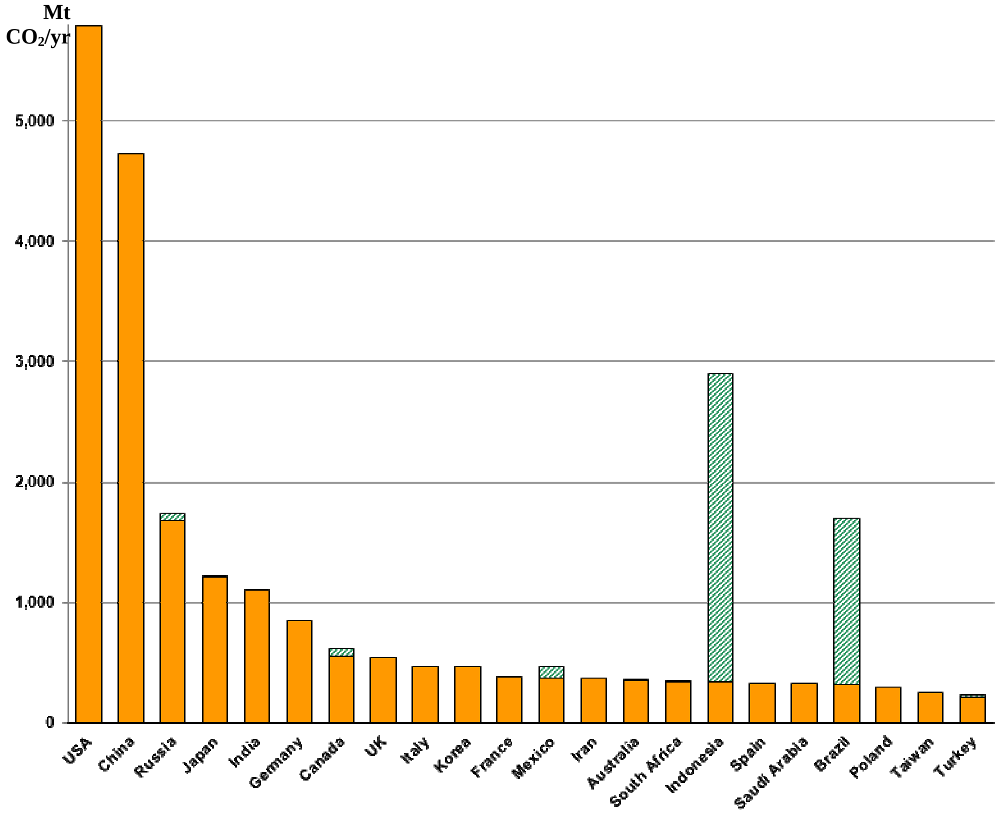


**Figure 1. Top 25 global $CO_2$emission in 2004**

Source: Resosudarmo *et al.* (2009)[3]

Figure 1 shows that the largest emitters of $CO_2$ in the world *was* the United States, followed China, Indonesia, Brazil, Russia, and Japan in 2004.According to the United Nations (UN) Millennium Development Goals Indicators, China has replaced the United States as the largest emitters of $CO_2$, while India has replaced Russia by 2007 (UN, 2010). More interestingly, however, is the sectoral source of emission. In the case of the United States, China, Russia, and Japan, the energy sector contributes the largest share of $CO_2$ emission. In contrast, despite existing concerns with the reliability of such data, $CO_2$ emission in Indonesia and Brazil mainly comes from the forestry sector.

Since the pre-industrial era, the concentration of atmospheric carbon dioxide (CO2) has expanded by 35 percent, approximately 18 percent of which is due to deforestation and the degradation of forests. About 75 percent of this has been from the developing countries of Brazil, Indonesia, Malaysia, Papua New Guinea, Gabon, Costa Rica, Cameroon, Republic of Congo and Democratic Republic of Congo, which have large areas of tropical forest. The

[3] Data are taken from International Energy Agency (2007) for fossil fuel emission and World Resource Institute (2007) for deforestation emission. See Resosudarmo *et al*. (2009) for more details.

Food and Agricultural Organization (FAO) Global Forest Resource Assessment 2005 stated that an alarming 13 million hectares of tropical forest are lost per year, while a further 7.3 million hectares per year suffer various degrees of degradation. Global emissions from land use, land use change, and forestry have reached 1.65 gigaton of carbon per year (FAO, 2006).

Unabated climate change could cost the world at least 5 percent of Gross Domestic Product (GDP) each year; if more dramatic predictions come to pass, the cost could be more than 20 percent of GDP. Each ton of $CO_2$ emitted causes damages worth of at least US$85 but emissions can be cut at a cost of less than US$ 25 a ton.Shifting the world onto a low-carbon path could eventually benefit the economy by US$2.5 trillion a year. The investments made in the next 10 to 20 years could lock in very high emissions for the next half-century, or present an opportunity to move the world onto a more sustainable path (Stern, 2006). As such, while developed countries grapple with the challenge of reducing their high emissions through new technologies and clean development, tropical countries find their challenge lies in finding pathways less dependent on the conversion of forests (Ministry of Forestry, 2008).

## 2.1 International Environmental Cooperation

In 2003, the first legally binding international agreement on climate protection entered into force. This agreement goes back to the 3rd Conference of Parties (COP3) to the Climate Convention in 1997 in Kyoto, where industrialized nations committed themselves to reducing their emissions of GHG by roughly 5 percent on average, compared with their 1990 emission levels, during the commitment period from 2008 to 2012. The so-called Kyoto Protocol was celebrated as a breakthrough in international climate policy, because it implied substantial emission reductions for industrialized countries *vis-à-vis* business-as-usual emissions (Böhringer and Vogt, 2003).

The driving force behind the Kyoto Protocol lies in the idea that a global externality requires global cooperation, international emissions trading lowers costs for all nations, and emission pricing is the key to the development of new climate-friendly technologies. Yet, there are some clear indications that this architecture has not worked so well. Most obviously, the United States was originally out of the system and developing countries have successfully avoided any discussion of commitments under the Protocol. There is also the reality that most Kyoto participants are well above their targets, with the exception of transition countries such as Russia and Poland, and countries that underwent unrelated structural changes such as the United Kingdom and Germany.Among countries that have implemented or are on the way to implementing mandatory programs, only the European Union (EU) Emissions Trading Scheme (ETS) is designed to parallel Kyoto's cap-and-trade architecture. Other countries have pursued a combination of standards, voluntary programs, and technology incentives that seemingly hinge more on domestic political agendas and less on incentives created by the Protocol (Pizer, 2006).

In the latest string of meetings to address environmental issues globally, the 15th session of the Conference of Parties (COP15) was held in Copenhagen on 7-19 December 2009. After weeks of negotiating and uncertainty on who would be on board, an 11th hour agreement dubbed the Copenhagen Accord was finally drawn up on 18 December by a limited group of leading countries. In the next day, the Conference of Parties to the UN Framework Convention on Climate Change “took note” of the accord (Clarke, 2009),a non-binding accord.

The Copenhagen Accord itself, nevertheless,recognized the scientific view that the increase in global temperature should be below 2 degrees Celsius. It also promised money up to US$100 billion annually by the year 2020 for mitigation and adaptation activities in developing countries. Another positive outcome of the accord include the recognition of two new classes of countries as opposed to the developed and developing countries, namely countries that will be major emitters of GHG in the future and countries that are most vulnerable to the impacts of climate change.What was perhaps most striking about the dynamics of Copenhagen, however, was the unavoidable evidence of the shifting centers of geo-political power. No longer was it the EU or the Anglophone nations that carried the day, nor even the nations of the OECD. It was China, India, Brazil, and South Africa that became the makers and breakers of deals (Hulme, 2010).

Copenhagen has shown the limitationsof what can be achieved on climatechange through centralization andmultilateralism, in particular, with the top-down approach adopted by the UN. Meanwhile, sub-global fora, such as the G20, the Major Economies Forum, ASEAN Plus 3, Asia-Pacific Economic Cooperation (APEC), Organization of Petroleum Exporting Countries (OPEC), the Forest 11, OECD, and the BASIC Group countries (Brazil, South Africa, India, and China), provide a promising venue for pursuing diplomatic agreement. If an agreement is not yet possible at a global level, the need for strong and effective international coordination becomes even more important, especially to progress technical issues and to enable comparison of outcomes (Ashton, 2010).

### 2.2 The Southeast Asian Perspective

Focusing on the Southeast Asian region, the region contributed 12 percent of the world's GHG emissions in 2000, amounting to 5,187 megaton of $CO_2$-equivalent, up 27 percent from 1990. The land use change and forestry sector was the biggest source, contributing 75 percent of the region's total, the energy sector 15 percent, and the agriculture sector 8 percent. According to the Asian Development Bank (ADB) 2009 Review, the region is especially vulnerable to climate change The review identifies a number of factors that explain why the region is particularly vulnerable as 563 million people are concentrated along coastlines measuring 173,251 kilometers long, which ranks third behind North America and Western Europe, leaving them exposed to rising sea levels. At the same time, the region's heavy reliance on agriculture for livelihoods with the sector accounting for 43 percent of total employment in 2004 and contributed about 11 percent of GDP in 2006, make it vulnerable to droughts, floods, and tropical cyclones associated with warming. Southeast Asia's high economic dependence on natural resources and forestry as one of the world's biggest providers of forest products also puts it at risk. Increase in extreme weather events and forest fires arising from climate change jeopardizes vital export industries.

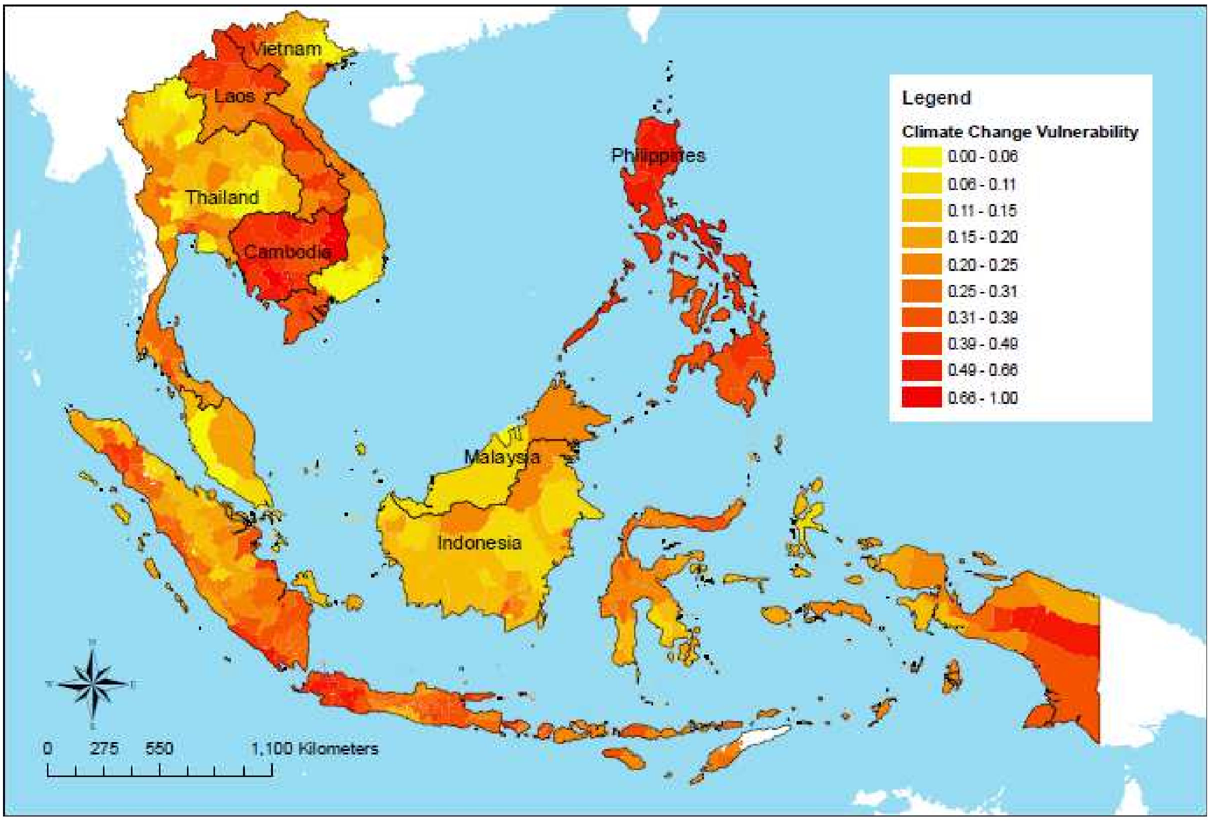


**Figure 2. Climate change vulnerability map of Southeast Asia in 2005**

Source: Yusuf and Francisco (2009)

Figure 2 shows the map of climate change vulnerability in Southeast Asia. Overall, most vulnerable areas include: all the regions of the Philippines; the Mekong River Delta region of Vietnam; almost all the regions of Cambodia; North and East Lao PDR; the Bangkok region of Thailand; and the west and south of Sumatra as well as western and eastern Java in Indonesia. The Philippines, unlike other countries in Southeast Asia, is not only exposed to tropical cyclones, especially in the northern and eastern parts of the country, but also to many other climate related hazards, especially: floods, such as in central Luzon and Southern Mindanao; landslides due to the terrain of the country; and droughts (Yusuf and Fancisco, 2009).

In terms of regional cooperation, environmental issues including climate change are mostly addressed through two of the most significant regional organizations, namely APEC[4] and ASEAN. Of the two, APEC extends its cooperation on selected sectors only (APEC, 2007a). According to Sydney APEC Leaders' Declaration on Climate Change, Energy Security, and Clean Development in 2007, key areas of cooperation, among others, are: improving energy efficiency through the reduction of energy intensity of at least 25 percent by 2030; increasing forest cover by at least 20 million hectares by 2020, which would store approximately 1.4 billion ton of carbon, equivalent to 11 percent of annual global emission in 2004; and working with industry to improve fuel efficiency and promote alternative fuel use in the transportation sector. Unfortunately, what little cooperation existed with regards to the environment, this has experienced a further setback with the advent of the Global Financial Crisis (GFC) in 2008 and has remained in the backseat in subsequent summits.

As for ASEAN, at the 13th ASEAN Summit in November 2007, its leaders reaffirmed the need to tackle climate change based on the principles set out by the UNFCCC through the Singapore Declaration on Climate Change, Energy, and Environment. The declaration aims, among other things, to deepen understanding of the region's vulnerability to climate change and to implement appropriate mitigation and adaptation measures. These include intensifying ongoing operations to improve energy efficiency and the use of cleaner energy, promoting cooperation in afforestation and reforestation, and continuing support and initiatives under the UNFCCC (ASEAN, 2007; ASEAN, 2009). Among concrete measures, the 41st ASEAN Ministerial Meeting in July 2008 delegated the responsibility of mainstreaming climate

[4] Only seven members of ASEAN are also members of APEC, namely Brunei, Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam.

change actions into ASEAN programs to the ASEAN sectoral bodies on energy efficiency, transportation, and forestry (ADB, 2009).

In the Roadmap for an ASEAN Community 2009-2015, cooperation has been extended to managing transboundary haze pollution and hazardous waste. Other areas of cooperation include operating the ASEAN Network on Environmentally Sound Technology (ASEAN-NEST) that will adopt region-wide environmental management/labeling schemes as well as intensify cooperation on joint research, development, deployment, and transfer of environmentally sound technology (EST). Promoting sustainable use of coastal and marine environment, e.g. joint efforts to maintain and protect marine parks in border areas, as well as promoting sustainable management of natural resources and biodiversity, e.g. control transboundary trade in wild fauna and flora (ASEAN, 2009).

Nevertheless, there is indeed a gap between intention and action (Elliott, 2003). It is worth bearing in mind the nature of the decision-making process in ASEAN, which is consensus-based. In cases where consensus cannot be achieved the “ASEAN Minus X” formula can be invoked although some countries’ lack of participation coupled with its non-binding nature might undermine these efforts. The “ASEAN Way”, characterized by consensus-based decision-making, strict principles of non-intervention, and the sanctity of state sovereignty, has helped maintained peace in the region; however, in the terms of implementing concrete projects, the Way presents itself as a challenge. Lastly, the diversity among ASEAN member countries in terms of economic development, geographical difference, population demography, and resource endowment poses a definite obstacle not only at the implementation level, but vision as well.

### 2.3 Indonesia’s Commitments: Pre-Emptive or Premature?

Indonesia is the largest archipelagic state, which comprises of 18,110 islands stretching 5,110 kilometers (km) from east to west and 1,888 km from north to south. It has a coastline length of about 108,000 km and situated at the confluence of four tectonic plates, namely Asian Plate, Australian Plate, Indian Plate, and Pacific Plate, making it susceptible to earthquakes. Due to its geological and geographical factors, the region suffers from a range of climatic and natural hazards, such as earthquakes, typhoons, floods, volcanic eruptions, droughts, fires, and tsunamis, which are becoming more frequent and severe. In addition, the geophysical and climatic conditions shared by the region have also led to common and transboundary environmental concerns such as air and water pollution, urban environmental degradation, and haze pollution (ADB 2009; ASEAN 2009).

Indonesia stands to experience significant impacts from climate change. These include sea-level rise and saltwater inundation, droughts, increased frequency of extreme weather events, heavier rainfall events and flooding, and the spread of diseases. In turn, these may harm the country's agricultural, fishery and forestry industries, threatening both food security and livelihoods. Indonesia's rich biodiversity is also at risk (Jotzo *et al.*, 2009). Nevertheless, Indonesia itself is a significant emitter of greenhouse gases. Indonesia has become one of the three largest emitters of greenhouse gases in the world. This is largely due to significant release of $CO_2$ from deforestation. Yearly emissions in Indonesia from energy, agriculture, and waste all together are around 451 million tons of $CO_2$ equivalent ($MtCO_2e$). Yet, land use change and forestry (LUCF) alone is estimated to release about 2,563 $MtCO_2e$, mostly from deforestation[5] (Sari *et al.*, 2007). However, although currently $CO_2$ emission from LUCF is much higher than that due to fossil fuel combustion, it is certain that in the future, the situation will be reversed as illustrated by Figure 3.

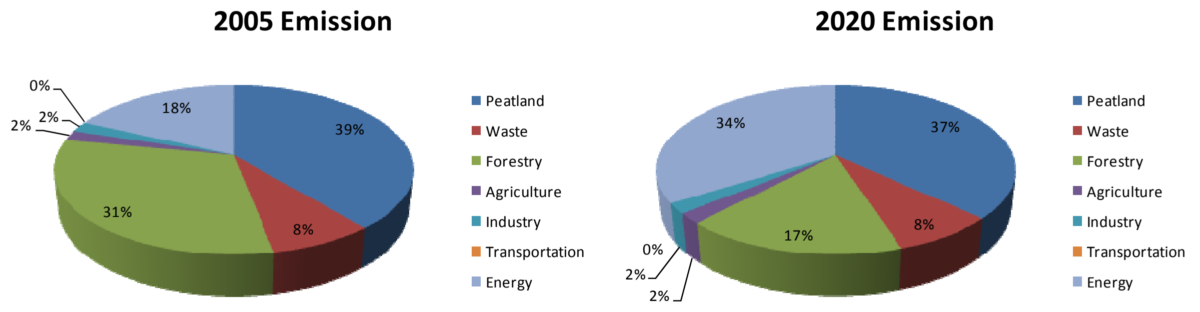


**Figure 3. Indonesia's $CO_2$ Sectoral Emission Shares**

Source: Ahmad (2010)

Figure 3 illustrates the composition for the sectoral emission share of $CO_2$. In 2005, peatland, forestry, and energy make up the largest sectoral emitters of $CO_2$ in Indonesia. By 2020, under the Business As Usual (BAU) scenario, not much will change except that forestry as the second largest emitter will be replaced by the energy sector. With continuing deforestation, forest area in Indonesia will naturally decline by 2020 such that $CO_2$ emission

[5] While data on the emissions from difference sources does vary between studies, the overall conclusion is the same. Indonesia is a major emitter of GHGs.

decline as well with less forest fire and land clearing. The energy sector, on the hand, is expected to continuously grow during this period, and thus, become the largest emitter of $CO_2$. The main drive behind the increasing $CO_2$ emission in Indonesia is the increase in carbon intensity due to the increased use of coal as a source of energy, particularly for electricity generation (Resosudarmo *et al.*, 2009).

Emissions from the energy sector through the use of coal, oil, and gas currently account for only one quarter of Indonesia's emissions. Energy use in Indonesia is still far below the per capita global average, and ever further below per capita energy consumption levels in developed countries. But Indonesia's fossil fuel emissions are catching up fast. Aggregate energy use is growing roughly in line with GDP, and a growing share of energy supplied by high-carbon coal, especially through the expansion of coal-fired power plants. If left unchecked, Indonesia's emission profile could be dominated by emission from fossil fuel within a few decades (Ahmad, 2010; Jotzo and Mazouz, 2010).

To its credit, at the Pittsburgh G20 Leaders' Meeting in September 2009, President Yudhoyono implored fellow leaders to act on climate change and made a remarkable commitment. Indonesia pledges to devise an energy mix policy including land use, land use change, and forestry that will reduce its emission by 26 percent by 2020 from Business As Usual. With international support, it pledges an emission reduction by as much as 41 percent (Yudhoyono, 2009). As such, Indonesia has committed to reigning in GHG emissions, in a bid to do its share in an emerging global effort to mitigate climate change.

And herein lies a conundrum, albeit one faced by many countries; Indonesia's energy supply needs to grow in order to facilitate economic growth and improve livelihoods, but it is also creating fast growth in carbon emissions that threaten those very goals. As such, possible options for curbing emissions growth are to improve energy efficiency and so use less energy so supply the same services, and to take the carbon out of the energy supply by shifting to lower-carbon energy sources. In the long run, climate change will require also not only sector specific policies and reform, but putting a price on carbon emissions (Resosudarmo *et al.*, 2009;Jotzo and Mazouz, 2010). However, this approach has to take into account the existing social and economic conditions as well as other relevant factors at the national levels (Situmeang 2010).

## 2.4 Carbon Pricing as a (Possible) Solution

There are many opportunities to achieve emissions abatement within the economy. The challenge is to achieve overall abatement at least cost. Carbon pricing takes advantage of the market mechanism in deciding whether emissions reductions occur. A price is put on carbon emissions, raising the prices of goods that have associated carbon emissions in their production. Goods and services that embody a lot of emissions will see higher increases in price than those that embody few emissions; and the price of low-emissions goods and services may fall. Consumers and producers will react to this price signal by switching toward lower-emissions alternatives. The economic reaction to the price signal automatically implements the lower-cost abatement options as opposed to, among others, promoting energy efficient technology, e.g. solar panel subsidy (Jotzo and Mazouz, 2010).

Market based responses to environmental externalities fall broadly into one of two categories: price or quantity instruments. An emission tax is a price based instrument while a “cap-and-trade” system is a quantity based instrument. In the absence of uncertainty either approach can be used to achieve a given environmental goal. If a tax is set on emissions, firms adjust emissions until the emission fee is set equal to the marginal cost of abatement on emissions. Conversely if a cap and trade system is utilized firms buy and sell permits. The price of the permits is set by demand and supply conditions. Demand follows from individual firms' marginal cost of abatement functions while supply is set by the aggregate cap. In equilibrium each firm sets its marginal cost of abatement equal to the price of permits. In a world of certainty, taxes and permits schemes should have equivalent results (Green, 2008; Metcalf, 2009).Kaplow and Shavell (2002) argue that the potential superiority of the quantity instrument over the price instrument only holds under the restriction of linear tax systems. If non-linear taxes are allowed then the tax is uniformly superior. The superiority of the non-linear taxis that firms' responses to the tax reveals information about their marginal abatement cost functions, information that is not revealed by quantity controls (Metcalf, 2009).Another work conducted by McKibbin *et al*. (2008) also shows that the international carbon tax is more economically efficient than the cap andtrade scheme of the Kyoto Protocol. Thus, most economic analyses of policy choice under uncertainty favor prices on efficiency grounds (Pizer, 2002; Strand, 2010).

### 2.4.1 Double the Pleasure, Double the Fun

Environmental tax reforms have indeed become increasingly popular in recent years. One reason is increasing concern about the quality of the natural environment; environmental taxes are generally an efficient instrument for protecting the environment. A second reason involves the revenues from environmental taxes. These revenues can be used to cut other distortionary taxes. In this way, the government may reap a “double dividend”, i.e. not only a cleaner environment but also a less distortionary tax system. If the double dividend hypothesis holds, an environmental tax reform is a so-called “no-regret” option; even if the environmental benefits are in doubt, an environmental tax reform may be desirable (Pearce, 1991; Goulder, 1995; Bovenberg, 1999; Glomm *et al*., 2007).

Empirical studies have suggested, however, that the double dividend theory in which a revenue-neutral tax shift may yield environmental gains at virtually no cost does not hold up. While there are significant environmental benefits associated with a tax shift, which may well exceed the costs for many policy choices, these gains are not generally costless. Nevertheless, despite the mixed signals, both theoretical developments and recent trends suggest some optimism for the future of environment-related taxes. It has been argued that the revenue-raising environmental policies are more efficient than the non-revenue-raising policies because of the revenue-recycling effect(Morgenstern, 1995; Lai, 2009). The tax type, “recycling policy”, and economic model significantly influence the chance that a double-dividend effect can be obtained.

The term “recycling policy” refers to revenue recycling, that is, using new revenues from environment-related taxes, e.g. carbon tax, to decrease pre-existing distortionary taxes. The mechanism consists of recycling revenues from environmental taxes on carbon products,energy consumption, or use of natural resources inorder to reduce taxes on other phases of theproduction process. Therevenues might then be employed to reduce other distortionarytaxes on the “good” part of the economicprocess, whichinclude regulatory measures and technological research, resulting in more efficient energy use. Other forms of financial recyclingare also possible, such as lump-sum transfers tohouseholds or industries, consisting of recycling therevenues to households or to the industries in theform of one-off payments, or interventions in corporateprofit taxes and value added tax. Alternatively, if the government were instead to keep the revenueswithout recycling them within thesystem, an economic depression would likely takeplace (Patuelli *et al*. 2005).There is also increasing evidence that the way in which tax revenues are recycled may be more important than the question whether the tax is introduced in a single country or jointly in several countries such that imposing a carbon tax, provided the revenues are recycled, is a sensible approach that could meet the country's economic, environmental and equity objectives (Welsch, 1996; Corong, 2008).

### 2.4.2 Regress and Rebound: The Limits

There are, of course, some *caveats* associated with the implementation of a carbon tax. Among such is regressive nature of a carbon tax in which it imposes the highest on the lower income groups. Policy targeting $CO_2$ emissions from energy consumption also tend to be more regressive than a price on all emissions (Grainger and Kolstad, 2009). The literature also suggests that carbon or energy taxes generally are, or are expected to be, regressive in developed economies and progressive in developing economies (Pearce, 1991; Verde and Tol, 2009). However, it should be noted that Devarajan *et al*. (2009) shows some evidence that the regressivity of a carbon tax also exists in developing countries, i.e. South Africa.

Another note caution deals with the so-called "rebound effect". To achieve reductions in carbon emissions, most governments are seeking ways to improve energy efficiency throughout the economy including, among others, through the implementation of a carbon tax. It is generally assumed that such improvements will reduce overall energy consumption, at least compared to a scenario in which such improvements are not made. The rebound effect results in part from an increased consumption of energy services following an improvement in the technical efficiency of delivering those services. This increased consumption offsets the energy savings that may otherwise be achieved. If the rebound effect is sufficiently large it may undermine the rationale for policy measures to encourage energy efficiency (Sorrell and Dimitropoulos, 2008; Sorrell 2009). Greening *et al.* (2000) differentiates the rebound effects into four categories: direct rebound effects; secondary fuel use effects; market-clearing price and quantity adjustments, or economy-wide effects; and transformational effects.

Indeed, various empirical studies and simulations have indicated that the rebound effect occurs in many countries. Brännlund *et al*. (2007) finds such evidence in Sweden in which the rebound effect can be considerable. That is, the initial emission reduction due to an increase in energy efficiency is more than counteracted by changes in consumption. Thus, an exogenous increase in energy efficiency may not lead to lower energy consumption, and hence lower emissions. Similarly, a study conducted by Otto *et al.* (2008) on the Netherlands finds that the most cost effective climate policy include a combination of research and development (R&D) subsidies and $CO_2$ emission constraints, although R&D subsidies raise the shadow value of the $CO_2$ constraint, i.e. $CO_2$ price, because of a strong rebound effect from stimulating innovation. Likewise, the rebound effect is also observed in other countries including the United Kingdom (Barker *et al.*, 2007); Japan (Mizobuchi, 2008); and the United States of America and Western Europe (Holm and Englund, 2009).Numerous empirical studies suggest that these rebound effects are real and can be significant. However, while their basic mechanisms are widely accepted, their magnitude and importance are still disputed (Sorrell and Dimitropoulos, 2008).

## 3.0 OVERVIEW OF A SOCIAL ACCOUNTING MATRIX

A social accounting matrix (SAM) is a traditional double accounting economic matrix in the form of a partition matrix that records all economic transactions between agents in the economy, especially between sectors in production blocks, sectors within institution blocks (including households), and sectors within production factors(Pyat *et al.*, 1977; Pyatt and Round, 1977; Pyatt *et al.*, 1984; Round, 2003). It is a solid database system, since it summarizes all transaction activities in an economy within a certain period of time, thus, giving a general picture of the socio-economic structure in an economy and illustrating the income distribution situation.

The basic framework of SAM is a 4x4 partition matrix. The accounts in SAM are grouped into endogenous and exogenous accounts. The use of SAM for modeling involves an important task of deciding which of the accounts in the SAM table are endogenous and exogenous. It is customary to consider the government, rest of the world, and capital accounts as exogenous. Meanwhile, factors of production, institutions, and production activities accounts are endogenous (Sadoulet and de Janvry, 1995). Endogenous accounts are normally those that depend on a country's economic activity, while exogenous accounts are independent of economic activity and payments, e.g. exports, investment, and government expenditure. These are normally referred to as injections into the economic system. Contrarily, exogenous expenditures are normally referred to as leakages.

In Figure 4, the main endogenous accounts are divided into three blocks: production factor, institutional, and production activity blocks. The row shows income, while the column shows expenditure. Sub-matrix $\boldsymbol{a}_{ij}$ (or $\boldsymbol{z}_i$) shows the income of the account in row *i* from the account of column *j*. Vector $y_i$ shows the total incomes of all accounts and vector $y_j'$ shows the total expenditure account of all accounts. In addition, SAM requires that the vector $y_i$ is the same as vector $y_j'$. In other words, $y_j'$ is a transpose of $y_i$, for every $i = j$(Defourny and Thorbecke, 1984). A balanced SAM is defined as such when this is fulfilled.

| | | | **EXPENDITURES** | | | | |
|---|---|---|---|---|---|---|---|
| | | | *Endogenous Accounts* | | | *Exogenous Account* | TOTAL |
| | | | Factors | Institutions | Production Activities | | |
| **RECEIPTS** | *Endogenous Accounts* | Factors | *0* | *0* | $a_{13}$ | $z_1$ | $y_1$ |
| | | Institutions | $a_{21}$ | $a_{22}$ | *0* | $z_2$ | $y_2$ |
| | | Production Activities | *0* | $a_{32}$ | $a_{33}$ | $z_3$ | $y_3$ |
| | *Exogenous Account* | | $v_1$ | $v_2$ | $v_3$ | $x$ | $z$ |
| | TOTAL | | $y_1'$ | $y_2'$ | $y_3'$ | $z'$ | |

**Figure 4. A social accounting matrix**

*Source: Defourney and Thorbecke (1984)*

As an illustration, sub-matrix $a_{13}$ in Figure 4 shows the amount of production factors used in production activities, which equates to the value added in the production sector, e.g. wages and salaries paid for the use of labor in production activities. Meanwhile, sub-matrix $a_{21}$shows the transfer payment from production factors to various institutions, namely households, firms, and governments. For example, some farmers in the agricultural sector belong to the small-farmer association; as such, a certain amount of fund will flow from farmers as a production factor to the association as an institution. Sub-matrix $a_{22}$ shows transfer payment between institutions, such as subsidy payments from the government to households or from firms to households as well as transfer payment from one household to another.

On the other hand, sub-matrix $a_{32}$ shows the demand for goods and services by institutions. In other words, this sub-matrix shows the amount of money paid by institutions to the production sector to buy the consumed goods and services. As for sub-matrix $a_{33}$, it shows the intra- and inter-industry demand for goods and services, specifically in the production sector. Lastly, aside from the sub-matrices aforementioned, SAM also records economic activities in the financial sector as well as economic transactions with foreign countries, which are captured in the exogenous accounts.

Figure 5 illustrates how economic activities/transactions occur within an economy in which the arrows represent monetary flows.

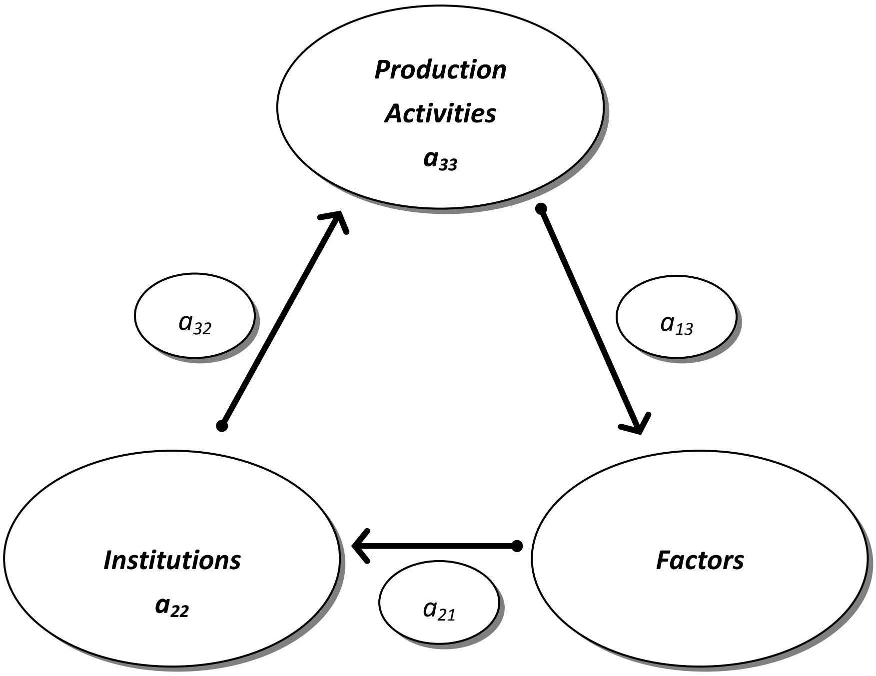


**Figure 5. Economic Transactions between Agents**

*Source: Defourney and Thorbecke (1984)*

In general, SAM provides information on the social structure within an economy, particularly information related to production structure, production factor condition, household income distribution, and expenditure pattern of institutions. It is an important tool for analyzing social concerns, e.g. welfare implications of an exogenous change in institutional income, because it emphasizes origins and distribution of income as well as of expenditure. It also emphasizes disaggregation of institutions depending on study objectives, e.g. disaggregation of households if the objective is to study income origins and distribution to different socio-economic groups of households (Matete, 2006). Accordingly, SAM is the best approach to generate a general equilibrium analysis (Thorbecke, 1985).

## 3.1 Inter-Regional/Multi-Country Social Accounting Matrix

Similarly, a social accounting matrix can also be constructed to include multiple regions or countries. In this type of SAMs, blocks within an economy may receive transfers from various blocks in other economies, and vice versa. In order to know how these economies are inter-connected, it is necessary to construct macroeconomic SAMs for each of the member economies. The individual macroeconomic SAMs must then be joined into a single macroeconomic SAM (Resosudarmo *et al.*, 1999; Jellema *et al.*, 2004; McDonald and Thierfelder, 2004; Matete, 2006; Yusuf, 2007, Resosudarmo *et al.*, 2009).

In the case of a multi-country SAM, this involves converting the macroeconomic SAMs into a single currency using exchange rates, including trade flows among the member countries, and subtracting these from the respective rest of the world (ROW) accounts. Also, factor-service flows and capital flows among the member countries might be added as well as inter-institutional transfers, with appropriate subtractions made from the respective ROW accounts (Reinert and Roland-Holst, 1997).

Figure 6 illustrates such a multi-country social accounting matrix. For the time being, transactions are limited to those conducted between two countries.

<table>
<tr><th colspan="3"></th><th colspan="8">EXPENDITURES</th><th></th><th></th></tr>
<tr><th colspan="3" rowspan="2">MC-SAM<br>Classifications</th><th colspan="4">Country 1</th><th colspan="4">Country 2</th><th rowspan="2">ROW</th><th rowspan="2">TOT<br>AL</th></tr>
<tr><th>Fact.</th><th>Inst.</th><th>Prod.</th><th>O. A.</th><th>Fact.</th><th>Inst.</th><th>Prod.</th><th>O. A.</th></tr>
<tr><td rowspan="9">RECEIPTS</td><td rowspan="4">Country 1</td><td>Factors</td><td colspan="4" rowspan="4">$A_{11}$</td><td colspan="4" rowspan="4">$A_{12}$</td><td rowspan="4">$Z_1$</td><td rowspan="4">$Y_1$</td></tr>
<tr><td>Institutions</td></tr>
<tr><td>Productions</td></tr>
<tr><td>Other Accounts</td></tr>
<tr><td rowspan="4">Country 2</td><td>Factors</td><td colspan="4" rowspan="4">$A_{21}$</td><td colspan="4" rowspan="4">$A_{22}$</td><td rowspan="4">$Z_2$</td><td rowspan="4">$Y_2$</td></tr>
<tr><td>Institutions</td></tr>
<tr><td>Productions</td></tr>
<tr><td>Other Accounts</td></tr>
<tr><td colspan="2">Rest of the World</td><td colspan="4">$V_1$</td><td colspan="4">$V_2$</td><td></td><td></td></tr>
<tr><td colspan="3">TOTAL</td><td colspan="4">$Y_1$’</td><td colspan="4">$Y_2$’</td><td></td><td></td></tr>
</table>

**Figure 6. Structure of a multi-country SAM**

Variables within the endogenous accounts matrix are written as follows:

$$a_{ij}^{rs} \quad \text{where } i,j = 1,\ldots,n;\ r,s = 1,2 \qquad [1]$$

If $a_{ij}^{11} \in A_{11}; a_{ij}^{22} \in A_{22}; a_{ij}^{12} \in A_{12};$ and $a_{ij}^{21} \in A_{21},$ then the endogenous accounts matrix can be illustrated in a block matrix form as follows:

$$A = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \qquad [2]$$

$A_{11}$ and $A_{22}$ are the inter-block flows within a country, while $A_{12}$ and $A_{21}$ are the inter-block flows between country 1 and country 2.

In this type of SAMs, international trade is the key inter-country link, even when trade issues are not the main focus. However, "current account" relations between countries overshadow their counterpart "capital account" relations partly because of the issues being studied, but also because the numerical modeling of financial and asset-related flows is less well-developed. Data on bilateral flows of merchandise trade are also easier to obtain than similar data for capital flows. Nevertheless, empirical studies show that multi-country model produces non-trivial differences in the estimated impacts of policy experiments compared to a single country, or even a less integrated multi-country, model (Hertel *et al.*, 1997; McDonald and Sonmez, 2004).

### 3.2 Structure of the ASEAN-SAM

The ASEAN-SAM to be constructed has a similar structure as shown by Figure 3. Table 1 provides a detailed list of sets that make up the components for the ASEAN-SAM. Factors of production consist of two types of labors, Unskilled and Skilled Labors, and three types of non-labor factors, namely Land, Natural Resources, and Capital. As for institutions, there are four types of households, which are Rural-Low, Rural-High, Urban-Low, and Urban High, with the addition of Corporate and Government. Note that the terms Low and High refer to households with income below and above the average respectively. Meanwhile, economic activities are divided into 57 production sectors. Lastly, other accounts consist of Indirect, Import, and Export Taxes as well as Saving-Investment.

The above-mentioned blocks is identical across all endogenous regions, i.e. all six ASEAN member countries, henceforth called ASEAN[6]. As for Rest of the World, it has a different set of classifications. For example, it lacks an institutional block and includes all other exogenous accounts. These differences are further explained in the following section.

[6] Although Brunei, Cambodia, Laos, and Myanmar are official members ASEAN, they have been excluded due to severe limitation of available data.

## Table 1. Detailed List of Sets

| Production Sectors[7] | | Other Accounts |
|---|---|---|
| Paddy rice | Motor vehicles and parts | Indirect Tax |
| Wheat | Transport equipment nec | Import Tax |
| Cereal grains nec | Electronic equipment | Saving-Investment |
| Vegetables, fruits, and nuts | Machinery and equipment nec | |
| Oil seeds | Manufactures nec | **Regions** |
| Sugar cane and sugar beet | Electricity | |
| Plant-based fibers | Gas manufacture distribution | Indonesia |
| Crops nec | Water | Malaysia |
| Cattle, sheep, goats, and horses | Construction | Philippines |
| Animal products nec | Trade | Singapore |
| Raw milk | Transport nec | Thailand |
| Wool silk-worm cocoons | Sea transport | Vietnam |
| Forestry | Air transport | Rest of the World[8] |
| Fishing | Communication | |
| Coal | Financial services nec | |
| Oil | Insurance | |
| Gas | Business services nec | |
| Minerals nec | Recreation and other services | |
| Meat: cattle, sheep, goats, and horse | Public administration, defense, health, and education | |
| Meat products nec | Dwellings | |
| Vegetable oils and fats | | |
| Dairy products | **Factors** | |
| Processed rice | | |
| Sugar | Unskilled Labor | |
| Food products nec | Skilled Labor | |
| Beverages and tobacco products | Land | |
| Textiles | Natural resources | |
| Wearing apparel | Capital | |
| Leather products | | |
| Wood products | **Institutions** | |
| Paper products and publishing | | |
| Petroleum and coal products | Rural-Low Household | |
| Chemical, rubber, and plastic products | Rural-High Household | |
| Mineral products nec | Urban-Low Household | |
| Ferrous metals | Urban-High Household | |
| Metals nec | Corporate | |
| Metal products | Government | |

[7] Due to technical limitations, Production Sectors will be aggregated into 26 sectors.
[8] Note that Rest of the World has a different set of classifications. It also includes all other exogenous accounts.

Meanwhile, Figure 7 provides a simplified schematic of the ASEAN-SAM with only two countries included. Note that inter-block flows within Country 1 and Country 2, i.e. $A_{11}$ and $A_{22}$, are structurally identical; while inter-block flows between countries, i.e. $A_{12}$ and $A_{21}$, are also are also analogous to one another. Although countries may have different economic structures, e.g. existence/absence of consumer sales tax; a common form can still be found by using the relatively simpler structure as a benchmark should additional data be unavailable, i.e. lowest common denominator form.

| | | **EXPENDITURES** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **MC-SAM Classifications** | | **Country 1** | | | | **Country 2** | | | | **ROW** | **TOTAL** |
| | | **Fact.** | **Inst.** | **Prod.** | **O. A.** | **Fact.** | **Inst.** | **Prod.** | **O. A.** | | |
| **RECEIPTS** — **Country 1** | **Factors** | | | $a_{13}^{11}$ | | | | | | | $y_1^1$ |
| | **Institutions** | $a_{21}^{11}$ | $a_{22}^{11}$ | | $a_{24}^{11}$ | | $a_{22}^{12}$ | | | | $y_2^1$ |
| | **Productions** | | $a_{32}^{11}$ | $a_{33}^{11}$ | $a_{34}^{11}$ | | $a_{32}^{12}$ | $a_{33}^{12}$ | $a_{34}^{12}$ | $z_3^1$ | $y_3^1$ |
| | **Other Accounts** | | $a_{42}^{11}$ | $a_{43}^{11}$ | | | | $a_{43}^{12}$ | $a_{44}^{12}$ | $z_4^1$ | $y_4^1$ |
| **Country 2** | **Factors** | | | | | | | $a_{13}^{22}$ | | | $y_1^2$ |
| | **Institutions** | | $a_{22}^{21}$ | | | $a_{21}^{22}$ | $a_{22}^{22}$ | | $a_{24}^{22}$ | | $y_2^2$ |
| | **Productions** | | $a_{32}^{21}$ | $a_{33}^{21}$ | $a_{34}^{21}$ | | $a_{32}^{22}$ | $a_{33}^{22}$ | $a_{34}^{22}$ | $z_3^2$ | $y_3^2$ |
| | **Other Accounts** | | | $a_{43}^{21}$ | $a_{44}^{21}$ | | $a_{42}^{22}$ | $a_{43}^{22}$ | | $z_4^2$ | $y_4^2$ |
| **Rest of the World** | | | $v_2^1$ | $v_3^1$ | | | $v_2^2$ | $v_3^2$ | | $x$ | $z$ |
| **TOTAL** | | $y_1^1{}'$ | $y_2^1{}'$ | $y_3^1{}'$ | $y_4^1{}'$ | $y_1^2{}'$ | $y_2^2{}'$ | $y_3^2{}'$ | $y_4^2{}'$ | $z'$ | |

**Figure 7. Simplified schematic of the ASEAN-SAM**

In Figure 7, $a_{21}^{11}$ represents household income payment, e.g. household's revenue from labor income and capital interest. $a_{21}^{11}$ represents inter-institutional payment, such as government subsidy and income tax; $a_{32}^{11}$ institutional payment for goods and services consumed; and $a_{42}^{11}$ represents institutional saving. Meanwhile, $a_{42}^{11}$ represents input factor payment for its use in production activities, e.g. labor wage and capital rent; $a_{33}^{11}$ represents intermediate input production activities; and $a_{43}^{11}$ represents indirect tax payment. $a_{24}^{11}$ basically represents government tax income, namely indirect and import taxes; while $a_{34}^{11}$ represents purchases of goods and services for investment purposes. Note that up to this point, these cells represent *within* country activities. For example, goods and services purchased in these cells represent *domestic* goods and services. As such, everything from $a_{21}^{22}$ to $a_{34}^{22}$ in country 2 is the same as everything from $a_{21}^{11}$ to $a_{34}^{11}$ in country 1 by analogy.

Furthermore, cross-country activities are represented by the *other* diagonal matrices. $a_{22}^{21}$ represents inter-institutional payment, i.e. household remittance from country 1 to country 2; and $a_{32}^{21}$ represents imported goods and services purchased by institutions in country 1 from country 2. $a_{33}^{21}$ also represents imported goods and services purchased from country 2, however, these are used as intermediate inputs by the production activities in country 1; and $a_{43}^{21}$ represents import tariff paid by country 1 to country 2 for goods and services exported from country 1 to country 2 represented by $a_{22}^{12}$ , $a_{32}^{12}$, $a_{33}^{12}$, and $a_{34}^{12}$. It is important to note that import tariff is paid by the exporting country to the importing country, such that tariff rate in country 2 is represented by $a_{43}^{21}$ divided by the summation of $a_{22}^{12}$ , $a_{32}^{12}$, $a_{33}^{12}$, and $a_{34}^{12}$; and not by $a_{43}^{12}$ divided by the summation of $a_{22}^{12}$ , $a_{32}^{12}$, $a_{33}^{12}$, and $a_{34}^{12}$ . Lastly, $a_{34}^{21}$ represents imported goods and services from country 2 by country 1 used for investment purposes; and $a_{44}^{21}$ represents net payment transfer. This payment is in the form of capital though this is different from the capital used in factor of production. This net payment transfer is needed for a *balanced* balance of payment due to, among others, bilateral trade deficit.

### 3.3 Data Sources

For the purpose of building the ASEAN-SAM in this study, the bulk of the database is derived from the Global Trade Analysis Project (GTAP) 7 Data Base. The GTAP 7 Data Base is the global database representing the world economy for a given reference year, i.e. 2004 for this latest version of the database. In the standard GTAP 7 Data Base, there are 57 commodities, 5 factors, and 113 regions. The commodities range from paddy to dwelling, while the factors are categorized into skilled labor, unskilled labor, capital, land, and natural resources. Meanwhile, the 113 regions are defined as aggregates of 226 countries using the GTAP standard country list (Narayanan G. *et al.*, 2008).

The GTAP 7 Data Base is the seventh major public release of the GTAP Data Base since the Project began in 1992 and uses 2004 as its reference year. The domestic databases or input-output (I-O) tables are combined with international datasets on macroeconomic aggregates, bilateral trade, energy, agricultural input-output, and protection for the new reference year (Narayanan G. and Dimaranan, 2008).

The primary data sources for the GTAP 7 Data Base are the regional input-output (I-O) tables, initially in national currency units, which are then scaled-up by the ratio of the gross domestic product (GDP) calculated from the I-O tables to external data, i.e. 2004 Real GDP in million US dollar. Then, data on GDP aggregates, i.e. private consumption, gross capital formation, and government consumption, are used to update the values of these aggregates in the regional I-O tables (Aguiar and Dimaranan, 2008).

One potential transformation of the GTAP Data Base is its conversion from a format based on a form of input-output table with additional sub-matrices for trade and other transactions that are presented as a series of multi-dimensional sub-matrices into a single three dimensional SAM format, henceforth known as the Global SAM. In other words, this SAM is basically an extension of the original input-output model with additional actors, e.g. households, government, and rest of the world, to the production sectors and presenting a complete flow of resources for the whole economy. In general terms, the Global SAM structure follows the conventions of the 1993 United Nations' System of National Accounts, albeit with adjustments in light of the limited data on intra-institutional accounts (McDonald and Thierfelder, 2004). The programs that carry out the transformation of the GTAP Data Base into the Global SAM format are freely available. Appendix 1 illustrates the Global SAM of a representative region.[9]

At this stage, the resultant SAMs are "incomplete". As such, there are two main reasons behind the modifications of these SAMs. The first reason has to do with the fact that the Global SAM is built from a country's input-output dataset such that it is bound to be less extensive than a "true" SAM. This is readily apparent where institutional transfers are concerned. Only Private Household and Government are listed under institutions in the Global SAM. Additionally, Regional Household is created to compensate the lack of

[9] In the newer GAMS program for GTAP version 7, there are two notable terminological changes from Appendix 1, namely Import Margins becomes Transport Margin and Rest of the World becomes Trade Margins.

information inherent in the GTAP 7 Data Base with regards to institutions. Although theoretically sound, empirically, it makes little sense.

The second reason for modifying the resultant SAMs lies in the inter-institutional international transfers. Each SAM basically represents an individual region which focuses heavily on the commodities sector, which is expected as it is built upon the input-output model of individual country. As such, inter-regional transactions are also focused on traded commodities while inter-institutional international transfers are lacking.

As such, although GTAP and Global SAM have their own models, this study utilizes only the database. This study develops its own model to be called the Inter-Regional System of Analysis for ASEAN (IRSA-ASEAN).[10] This study derives its own model simply because it is more relevant for economic-wide analytical purposes. Among others, highlights of the alternative model are the inclusions of income distributions among socio-economically disaggregated households and inter-institutional international transfers, i.e. remittance.[11]

Therefore, in order to ensure conformity between the Global SAM data and IRSA-ASEAN model, additional datasets have to be used. The following lists the additional datasets required to build the so-called ASEAN-SAM:

<u>Indonesia</u>

1. 2005 Social Accounting Matrix; and
2. 2005 Inter-Regional Social Accounting Matrix (Resosudarmo *et al.*, 2008).

<u>Malaysia</u>

1. 2004/2005 Household Expenditure Survey;
2. 2004 Distribution and Use of Income Accounts and Capital Account;
3. 2000 Population and Housing Census; and
4. 1970 Social Accounting Matrix (Pyatt *et al*., 1984).

<u>Philippines</u>

1. 2006 Family Income Expenditure Survey;
2. 2000 Social Accounting Matrix (Cororaton and Corong, 2009); and
3. 1997 Family Income Expenditure Survey.

<u>Singapore</u>

1. 2008 Yearbook of Statistics; and

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[10] The new model shares some similarities with the Inter-Regional System of Analysis for Indonesia in Five Regions (IRSA-Indonesia5). See Resosudarmo *et al*. (2008) for the latter model.

[11] The next section will discuss the IRSA-ASEAN model in greater details.

2. 2002/2003 Report on the Household Expenditure Survey.

Thailand

1. 2008 Key Statistics;
2. 2002 Household Socio-Economic Survey; and
3. 1998 Social Accounting Matrix (Li, 2002).

Vietnam

1. 2004 Living Standard Survey; and
2. 1997 Social Accounting Matrix (Nielsen, 2002).

Others

1. 2010 World Development Indicators;
2. 2008 ASEAN Statistical Yearbook;
3. 2005 ASEAN Statistical Yearbook;
4. 2005 Bilateral Remittance Estimates (Ratha and Shaw, 2007); and
5. 2004 Combustion-Based $CO_2$ Emissions Data for GTAP Version 7 (Lee, 2008).

It should be pointed out here the reasons for using GTAP as the main dataset instead of using official country-specific SAMs in the construction of the ASEAN-SAM. This is simply because an official SAM is not always available for every country, or even exists at all such as in the case of Singapore. Even for countries in which a SAM is constructed, both officially and unofficially, they are not available for every year, e.g. the latest publicly available SAM for Malaysia is 1970. As such, SAMs from different countries would most likely use different reference years; not to mention currencies and categorical definitions, e.g. different commodities and household disaggregation. In this regard, GTAP provides a common ground to which SAM of one country can be created relatively easily and compared to another. Nevertheless, country-specific SAMs are still used to enrich the database and ensure compatibility with the model.

Lastly, with regard to the final data source used, the combustion-based $CO_2$ emissions data, the data is kept as a separate matrix. Although this is not explicitly included in the ASEAN-SAM, it is still an integral part of the ASEAN-SAM for modeling purposes. This separate matrix is essential when conducting energy and environmental policy impact analysis.

## 3.4 Constructing the ASEAN-SAM

Constructing the ASEAN-SAM for modeling purposes in following sections is divided into three phases. The first phase involves the preparation of the GTAP Version 7 Data Base. Phase 2 lists the steps required to transform individual Global SAM into a standard form. Lastly, Phase 3 is when all individual SAMs are combined to form the ASEAN-SAM.

### 3.4.1 Phase 1: Pre-SAM

In the original GTAP 7 Data Base, there are 57 commodities, 5 factors, and 113 regions. For the purpose of this study, factors are not aggregated. They are left in their original categories in order to provide as much details as possible for analytical purpose. On the other hand, commodities are aggregated into 26 sectors due to technical difficulties with such a large number of commodities in the modeling. Also, countries are aggregated into seven regions, namely Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam, and Rest of the World. The first six countries are in this study defined as ASEAN.[12]

The transformation of a database to a SAM format does involve some complications, among others, resolving differences in the terminology used in the GTAP literature and SAM literature as well as addressing technical issues such as ensuring that all commodities are valued at a common price. Fortunately, McDonald and Thierfelder (2004) provides both the technical note and General Algebraic Modeling System (GAMS) program. What this program does is to create a balanced SAM for each region. For the purpose of this study, seven SAMs are created based on the aggregation of the regions. Note that for the Rest of the World region, the intra-regional transaction flows are not needed. Only accounts that deal with other regions are necessary for the construction of the ASEAN-SAM.

### 3.4.2 Phase 2: Global SAM

1. *Aggregating Taxes*

   There are seven blocks for taxes in the Global SAM with Trade Taxes actually consisting of Export and Import Taxes. Five other taxes can actually be "lumped" together as Indirect Tax, they are Import Sales Taxes, Domestic Sales Taxes, Factor

[12] Other ASEAN members, namely Brunei, Cambodia, Lao, and Myanmar, are not included in this study as their data are sorely lacking.

Taxes, Production Taxes, and Export Tax. This basically means aggregating five blocks into one block by row and column.

2. *Creating Production Activities*

Production Activities in the ASEAN-SAM consist of three blocks, namely Imported Commodities, Domestic Commodities, and Activities. Imported Commodities should be left alone for now, whereas Domestic Commodities and Activities can simply be aggregated the same way as taxes. The only noteworthy difference is the erasure of the Supply Matrix. As this is a diagonal matrix, the Supply Matrix can simply be excluded from the SAM without any complications.

3. *Dealing with Regional Household*

Conceptually, Regional Household consists of Private Household and Government Household. On the relatively easy task, row components can simply be transferred in its entirety directly to either Private Household or Government. Distributed Factor Incomes from Factors are transferred entirely to Private Household, whereas taxes and duties are transferred directly to Government. Column-wise, it is not quite as simple.

Although Private Household Income and Government Income can be entirely dropped off from the SAM as they are included as components of Distributed Factor Incomes as well as duties and taxes, additional information is needed to balance the SAM. The key lies in Savings. Knowing the government's fiscal balance and using its ratio to GDP for the reference year is essential. In this regard, ASEAN Statistical Yearbook is sufficient to fulfill this requirement.

Once known, the ratio can then be used to find the nominal value for Government Savings and differentiate it from Private Household Savings. For the purpose of balancing the SAM, total Private Household Income is held constant with adjustments being made in the Government transfer to Private Household, i.e. Net Government Transfer.

4. *Creating Firms*

Adding a new block for Firms is quite straightforward for countries in which recent SAMs are available, i.e. Indonesia, Philippines, Thailand, and Vietnam. This is particularly true as only Private Household Savings, Private Household Factor

Incomes, and Net Government Transfer need to be disaggregated. These can be done by taking the ratio between the two institutions.

In the case of Singapore, the Household Income Expenditure Survey is sufficiently complete to disaggregate these components. As for Malaysia, Savings and Net Government Transfer are disaggregated using ratios obtained from the Income and Capital Accounts Distribution. However, for lack of a better data, Private Household Factor Incomes disaggregation uses the 1970 SAM. The use of such an old dataset may be debatable. However, until the 2000 Malaysian SAM becomes publicly available this will have to suffice.

Note that the entirety of Private Demand goes to Private Household as Firms' demand has already been taken into account by Intermediate Inputs. Bear in mind as well that the Firms block does not receive any Distributed Factor Incomes from Unskilled Labor and Skilled Labor as only Private Household can provide these Factors. Also, assumptions have to be made as sets for Factors may differ from the Global SAM, e.g. Natural Resources may have to use the same ratio as Capital, Land, or Non-Labor Factors in its disaggregation between Private Household and Firms.

At this point, a short explanation is needed with regard to the construction of the ASEAN-SAM. Up to this point, steps taken above can be applied generically for any Global SAMs. In other words, the reasoning behind the steps taken hold true for non-ASEAN countries as well without any significant fundamental differences from any official country SAMs. Conversely, steps taken hereon are aimed at making these SAMs, and in turn the ASEAN-SAM, compatible with the IRSA-ASEAN model while bearing in mind economic characteristics of ASEAN countries.

5. *Removing Direct Taxes*

In the Global SAM, Direct Taxes receive payments from Factors and send payments to Government. This can be simplified with Factors sending payments directly to Government. This is very straightforward and does not require any adjustments elsewhere. Once this is done, the column and row of Direct Taxes can be expunged.

6. *Transferring Indirect Taxes*

From a previous step, Indirect Taxes consist of Sales Taxes, Factor Taxes, and Production Taxes. These taxes are paid by Production Activities, Private Household, Government, and Capital. In order to conform to the IRSAM, only Production Activities pay Indirect Taxes as Sales Taxes do not apply to Indonesia. To resolve this, Sales Taxes in the other three blocks must be "returned".

The solution to this is by adding payments made to Indirect Taxes into their respective demand. Column-wise, this method does not change the total expenditure of these three blocks. The next stage would be to increase payments from Production Activities to Indirect Taxes by the total amount of Sales Taxes paid by the three blocks.

7. *Transferring Labor Payments*

Similar to Step 4 in which only Private Household receives payments from both Unskilled and Skilled Labors, the same condition also applies for Government. As such, labor payments to Government are transferred to Private Household. In order to maintain a balanced SAMs, adjustment needs to be made in the transfer payment from Government to Private Household, i.e. Net Government Transfer.

8. *Transferring Depreciation*

One small "quirk" of the Global SAM is the existence of Depreciation, which is a direct payment from Factors to Saving-Investment[13]. This simplify the SAM, Depreciation is added to Factor payments to Firms. This is balanced by adding Depreciation to Firms payments to Saving-Investment created in Step 4.

9. *Disaggregating Private Household*

This step is the final step before combining individual country SAMs into the ASEAN-SAM. Incidentally, this is also the hardest step in terms of external data requirements. This step is optional, even with regards to IRSA-ASEAN model. However, disaggregating Private Household by socio-economic groups would simply provide much richer results for analytical purposes.

[13] In the Global SAM, the Saving-Investment block is called the Capital block as shown in Appendix 1. The terminology is changed to avoid confusion with Capital as a component of Factors.

As such, Private Household is disaggregated into four different groups, namely Rural-Low, Rural-High, Urban-Low, and Urban-High. The terms “rural” and “urban” are quite straightforward, although for Singapore, neither Rural-Low nor Rural-High exists as all of its population lives in an urban area. As for Thailand, the country uses the terms “non-municipal” and “municipal” areas in its surveys. For the purpose of uniformity, those terms are treated exactly as “rural” and “urban” areas respectively without any complications. One minor adjustment to this is “Greater Bangkok” area, which is sometimes separated in surveys. In cases when this area exists, it is added into “urban” area. Meanwhile, the terms “low” and “high” neither refer to the poverty line nor half of the population. The terms instead refer to those below and above the average income per capita or, whenever possible, the average income per household respectively.

The key in disaggregating Private Household lies in three areas, namely determining Private Demand, Savings, and Distributed Factor Incomes. This is then balanced by the Government Transfer. In most cases, the demand pattern for imported goods and services is the same as domestic goods and services. This is due to the lack of data as household expenditure surveys do not differentiate between imported goods andservices with domestic goods and services, nor should it matter much as arguably deciding *what* product to buy is more important than deciding *which* of the same product to buy based on origins. Nevertheless, the substitution between imported and domestics is included in GTAP as it has differentiated imported *vis-à-vis* domestic commodities

In the case of Indonesia, disaggregation of Private Household can be done in one stage using the 2005 SAM. Urban and rural areas are explicitly defined as such in the 2005 SAM although adjustments still have to be made for the low and high categories. This is because, aside from areas, household and labor blocks are categorized by professions instead of income per capita. However, the accompanying document lists the average income per capita for each profession such that assumptions can be made to disaggregate household income groups (BPS, 2008). These assumptions are also used as labor block in the 2005 SAM is aggregated, whereas in GTAP, and by extension the ASEAN-SAM, labor is disaggregated into unskilled and skilled labors.

For Vietnam, disaggregation of rural and urban is carried out using information from the 1997 SAM, while disaggregation of income groups uses information from the 2004 Living Standard Survey (LSS). The 2006 LSS also exists, however, it is not used for reasons that GTAP reference year is also 2004 and the 2006 survey no longer separates rural and urban areas. Thailand basically uses the same method as Vietnam although it relies also on the Household Socio-Economic Survey (HSES) for the disaggregation between rural and urban areas. Whereas Singapore uses the Household Expenditure Survey (HES) to disaggregate income groups only as it is assumed that rural area does not exist in the country.

Disaggregation of the Private Household for Philippines is similar to the method used for Thailand. However, its disaggregation uses two reference years of the same survey, namely the Household Income Expenditure Survey (HIES), instead of one. This is because the 1997 HIES separates rural and urban areas, while the 2006 HIES separates income groups. In contrast, the 2000 and 2003 HIES do neither. One added assumption in the case of Philippines is that the ratio of income groups is the same for both urban and rural areas. In other words, the proportion of those below and above the income per capita in rural and urban areas is the same.

Last is the disaggregation of Malaysia. It is the hardest to do due to data constraint. Disaggregating Private Demand and Savings is similar to the case of Thailand although the population census is needed in order to find the total values of household expenditure as they are presented in percentage form in the survey. They greatest assumption has to be made for disaggregating Distributed Factor Incomes as income statistics are generally unavailable to the public. As such, information on income distribution from World Development Indicators (WDI) has to be used with adjustments made to Net Government Transfer.

### 3.4.3 Phase 3: Combination SAM

10. *Combining Country SAMs into a Multi-Country SAM*

The next stage is to combine these six country SAMs into one single multi-country SAM. To simply this process, the square matrix containing Factors, Institutions, Indirect Taxes, and Saving-Investment blocks can be pasted and combined to make up the diagonal matrices. At this point, inter-country matrices can only be filled by Saving-Investment transfer. Note that this is a one way flow, i.e. Net Saving-Investment, so as to avoid double-accounting problems. Other blocks, namely

Imported Commodities, Import Taxes, Transport Margins, Export Margins, and Trade Accounts require some treatments. Also, Rest of the World is also included as the seventh region in the combined SAM.

11. *Transferring Other Accounts*

One component from Other Accounts is still missing, namely Import Taxes. In this regard, row and column should be left alone and inserted to fill in the inter-country matrix. A note of caution is needed here as import tariffs refer to payment received by country 1 from country 2 for goods and services from country 2 to country 1. Referring back to the previous section, $a_{43}^{21}$ corresponds to $a_{22}^{12}$ , $a_{32}^{12}$, $a_{33}^{12}$, and $a_{34}^{12}$; not $a_{22}^{12}$ , $a_{32}^{12}$, $a_{33}^{12}$, and $a_{34}^{12}$.

12. *Dealing with Imported Commodities*

This step essentially deals with the trade aspect of inter-country link. As the Global SAM consists of balanced SAMs, there are two ways to obtain these values, from either the export or import side. However, because Imported Commodities are disaggregated it is better to look at trade link from imports rather than exports. Three blocks in the ASEAN-SAM receive Imported Commodities, namely Institutions, Production Activities, and Saving-Investment. In order to fill in these blocks, use ratios obtained from Trade Margins and multiply them with Imported Commodities.

One important assumption resulting from this method is that substitution of a given product by country of origins only occurs at the country level. Thus, once a product enters the country, it is "pooled" together and domestic consumers can no longer differentiate the country of origins. As such, for example, if 40 percent of all imported paddy in Indonesia comes from Vietnam then 40 percent of imported paddy purchased by each household group also comes from Vietnam.

Bear in mind that Imported Commodities send payment to Indirect Taxes. Thus, disaggregate Indirect Taxes by countries using the same ratios from Trade Margins then add these values to Import Taxes as all taxes paid by foreign goods and services are classified as Import Taxes. To balance this, simply subtract the total value of Indirect Taxes paid by Production Activities abroad from Indirect Taxes payments to Government in the diagonal matrix, while adding the same value to Import Taxes payments to Government.

13. *Removing Transport Margins and Export Margins*

As for Transport Margins and Export Margins, these two blocks can be inserted into the combined matrix without too much complication. Simply take into account countries of origin and destination. Note that once this is done, total values for Transport Margins and Export are exactly the same. As such, redefine the Export Margins column as Transport Margins then remove the original Transport Margins column and Export Margins row. As Imports of Transported Services is a diagonal matrix, removing the previously-mentioned column and row requires no further adjustment.

Removing Transport Margins is done by transferring payments to Transport Margins by Production Activities into Intermediate Inputs. These values are then transferred to Capital in the diagonal matrix, which increase its transfer to Firms. In turn, the entirety of Transport Margins is transferred back into Saving-Investment by Firms. Finally, simply remove Transport Margins row and column for each country.

At this juncture, the combined SAM should be balanced. Any existing imbalances are caused by human errors. Double-check that all six SAMs resultant of Step 9 are balanced. If so, redo Step 10 to Step 13. Otherwise, retrace each step before Step 9 and make sure that between each step, the SAMs are balanced.

14. *Adding Remittance*

In the ASEAN-SAM, remittance is the component that makes up basically inter-institutional international transfers, or in other words, transfers between households in different countries. Bilateral Remittance Estimates provide these values although they have to be adjusted by the ratio of GTAP GDP to World Bank 2005 GDP. The resulting bilateral remittance values between the six countries chosen can then be used in the ASEAN-SAM.

The method of inserting these values is quite straightforward. Use the bilateral remittance value between two countries and subtract household transfer to Saving-Investment in the receiving country. This is then followed by subtracting the total remittance value from Net Saving-Investment and adding the same value in the household transfer to Saving-Investment in the sending country. Lastly, add remittance in the inter-household transfer within the inter-country matrix. This procedure is also valid if started from the inter-household transfer within the inter-country matrix.

Difficulties do not arise from the procedure. They arise from the deciding how to disaggregate total remittance among household groups. No data exists to resolve this problem such that arbitrary decisions based on common sense must be taken. This will be further discussed in the next section when the resultant ASEAN-SAM is discussed.

15. *Finishing the ASEAN-SAM*

This marks the final step in the construction of the ASEAN-SAM. It consists of, among others, moving all negative values by transposing them to avoid problem with the GAMS program. Lastly, check import tariff rates as these values might change slightly due rounding off and treatments of exogenous accounts, e.g. transport cost. Lastly, final balancing may be necessary due to rounding off in which case it is recommended that these residuals are added into the exogenous accounts, i.e. Rest of the World. Otherwise, the ASEAN-SAM should already be balanced.

The last thing to consider is the disaggregation of carbon emissions. Note that this is strictly optional and depends on the model to be used. Also, these dataset is not included in the ASEAN-SAM and it is kept as a separate matrix. Nevertheless, in order to make this dataset compatible with the ASEAN-SAM, disaggregation of Private Household must be carried out.

For carbon emissions, simply disaggregate Private Household using household group expenditure ratios for the following commodities: Coal, Oil, Gas, Petroleum and Coal Products, Electricity, and Gas Manufacture Distribution. Note, however, Electricity does not actually emit any $CO_2$ emission. Also, Oil, Gas, and Petroleum and Coal Products are combined to comply with the ASEAN-SAM as definitions slightly differ between the two dataset. Nevertheless, the resulting classifications for fossil fuel combustion are coal, oil, and gas, i.e. gas manufacture distribution.

### 3.5 Consistency of the ASEAN-SAM

This section presents some highlights from the resulting ASEAN-SAM. It starts off by checking for inconsistencies in the ASEAN-SAM. Table 2 does so by comparing macroeconomic from the original database with those derived from the resulting ASEAN-SAM. The top row for each country shows the original data whereas the bottom row shows data from the ASEAN-SAM. Also, from here on, all nominal values are in million US dollar.

**Table 2. Macroeconomic data**

| | **Private Consumption** | **Investment** | **Government Expenditure** | **Export** | **(Import)** | **GDP** |
|---|---|---|---|---|---|---|
| **Indonesia** | 174,751 | 49,317 | 20,035 | 87,546 | 76,947 | 254,702 |
| | *174,751* | *49,317* | *20,035* | *89,212* | *78,612* | *254,703* |
| **Malaysia** | 37,373 | 17,316 | 11,641 | 154,900 | 106,330 | 114,899 |
| | *37,373* | *17,316* | *11,641* | *154,873* | *106,302* | *114,901* |
| **Philippines** | 58,937 | 14,118 | 8,754 | 51,493 | 48,825 | 84,476 |
| | *58,936* | *14,118* | *8,754* | *51,491* | *48,822* | *84,476* |
| **Singapore** | 55,286 | 31,396 | 13,912 | 166,879 | 160,659 | 106,814 |
| | *55,286* | *31,396* | *13,911* | *168,038* | *161,818* | *106,813* |
| **Thailand** | 86,874 | 40,344 | 16,129 | 121,157 | 102,807 | 161,698 |
| | *86,874* | *40,344* | *16,129* | *121,174* | *102,823* | *161,698* |
| **Vietnam** | 29,139 | 15,073 | 2,798 | 32,654 | 36,637 | 43,026 |
| | *29,139* | *15,073* | *2,798* | *32,660* | *36,643* | *43,027* |
| **Rest of the World** | 24,731,806 | 8,562,155 | 6,992,848 | 9,874,941 | 9,957,366 | 40,204,384 |
| **Total** | 25,174,166 | 8,729,719 | 7,066,115 | 10,489,570 | 10,489,570 | 40,970,000 |

*Source: GTAP Version 7 Data Base and author's calculation. Unit is in 2004 US$ million.*

Overall, the macroeconomic indicators are mostly consistent with the original GTAP 7 database. The most obvious thing to check at first is, of course, GDP. For most countries, the differences arise only from the final unit. This is quite acceptable as it is most likely due to rounding of figures. Looking at the GDP breakdown, it is clear that the largest discrepancies arise in the trade data. Bear in mind, however, trade data contains the largest matrix dimension with 26 commodities by 26 sectors by 6 inter-country links. As such, residuals are more prevalent here than in any other blocks. Also, some differences arise as some accounts are exogenized in the ASEAN-SAM, e.g. export margins and transportation cost. Nevertheless, their effects cancel out each other and the values of GDP, Private Consumption, Government Expenditure and Fixed Investment are consistent.

Moreover, another purpose of constructing the ASEAN-SAM is to look at the impacts of an economic policy on household disaggregated by socio-economic groups, namely Rural-Low, Rural-High, Urban-Low, and Urban-High. Table 3 breaks down Private Consumption to look at expenditure patterns of these households. Note that goods and services have been aggregated further into 14 categories for the simple reason of convenience.

**Table 3. Household expenditure patterns**

| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Indonesia** | **Rural** | **Low** | 35.92 | 5.34 | 3.13 | 2.73 | 13.74 | 1.32 | 6.64 | 7.20 | 0.72 | 14.17 | 2.50 | 4.46 | 2.06 | 0.07 | 100 |
| | | **High** | 22.87 | 3.12 | 3.68 | 4.66 | 18.50 | 2.21 | 10.39 | 9.12 | 1.53 | 13.34 | 3.13 | 3.26 | 4.07 | 0.12 | 100 |
| | **Urban** | **Low** | 21.75 | 3.25 | 2.92 | 3.94 | 23.47 | 2.19 | 8.81 | 8.34 | 1.27 | 13.21 | 3.54 | 3.48 | 3.74 | 0.10 | 100 |
| | | **High** | 18.28 | 2.73 | 2.71 | 4.03 | 20.06 | 2.93 | 11.37 | 10.19 | 1.67 | 13.11 | 4.51 | 3.06 | 5.22 | 0.14 | 100 |
| **Malaysia** | **Rural** | **Low** | 30.72 | 8.50 | 5.80 | 7.56 | 2.63 | 2.94 | 24.15 | 3.08 | 0.55 | 8.66 | 2.79 | 0.26 | 2.36 | 0.00 | 100 |
| | | **High** | 13.05 | 4.54 | 5.36 | 4.36 | 1.52 | 1.69 | 36.40 | 12.33 | 0.75 | 9.42 | 6.00 | 0.36 | 4.21 | 0.01 | 100 |
| | **Urban** | **Low** | 21.76 | 7.10 | 5.67 | 8.89 | 3.10 | 3.46 | 26.44 | 5.07 | 0.86 | 10.07 | 4.27 | 0.31 | 3.00 | 0.01 | 100 |
| | | **High** | 9.33 | 3.08 | 3.65 | 6.22 | 2.17 | 2.42 | 37.98 | 11.85 | 1.01 | 9.17 | 8.07 | 0.45 | 4.62 | 0.01 | 100 |
| **Philippines** | **Rural** | **Low** | 41.58 | 7.32 | 3.13 | 2.10 | 4.54 | 2.37 | 5.65 | 3.17 | 1.05 | 17.70 | 1.19 | 1.81 | 8.28 | 0.11 | 100 |
| | | **High** | 25.84 | 3.88 | 3.78 | 2.24 | 6.94 | 2.53 | 9.27 | 6.79 | 2.25 | 18.19 | 3.39 | 5.71 | 9.06 | 0.11 | 100 |
| | **Urban** | **Low** | 34.98 | 4.94 | 2.86 | 2.52 | 6.18 | 2.84 | 6.13 | 5.80 | 1.92 | 19.25 | 2.16 | 2.38 | 7.92 | 0.13 | 100 |
| | | **High** | 19.42 | 2.34 | 3.08 | 2.40 | 8.43 | 2.71 | 9.09 | 11.11 | 3.68 | 17.67 | 5.48 | 6.73 | 7.73 | 0.12 | 100 |
| **Singapore** | **Urban** | **Low** | 8.74 | 2.87 | 4.13 | 0.79 | 8.33 | 2.01 | 16.09 | 7.46 | 1.64 | 28.09 | 3.46 | 11.34 | 5.06 | 0.00 | 100 |
| | | **High** | 5.27 | 1.14 | 3.67 | 0.44 | 7.23 | 1.11 | 14.77 | 13.93 | 1.16 | 25.86 | 3.71 | 10.68 | 11.05 | 0.00 | 100 |
| **Thailand** | **Rural** | **Low** | 24.12 | 6.10 | 12.02 | 4.86 | 10.23 | 2.88 | 11.26 | 4.71 | 0.42 | 14.47 | 3.54 | 0.82 | 3.95 | 0.61 | 100 |
| | | **High** | 12.18 | 4.85 | 12.21 | 6.29 | 7.01 | 1.96 | 12.15 | 17.03 | 1.33 | 13.00 | 5.43 | 1.01 | 5.01 | 0.55 | 100 |
| | **Urban** | **Low** | 15.93 | 8.61 | 7.52 | 4.43 | 7.98 | 3.24 | 11.16 | 8.46 | 1.87 | 16.34 | 6.23 | 1.68 | 5.88 | 0.69 | 100 |
| | | **High** | 6.71 | 2.78 | 9.41 | 7.27 | 8.11 | 2.21 | 10.31 | 19.99 | 2.07 | 13.87 | 8.48 | 1.84 | 6.36 | 0.58 | 100 |
| **Vietnam** | **Rural** | **Low** | 36.53 | 7.59 | 12.99 | 3.08 | 0.01 | 5.53 | 12.14 | 6.56 | 0.22 | 0.82 | 0.67 | 6.98 | 6.45 | 0.43 | 100 |
| | | **High** | 26.62 | 7.59 | 10.80 | 3.60 | 0.01 | 8.27 | 13.15 | 8.41 | 0.37 | 1.22 | 4.12 | 7.48 | 8.08 | 0.27 | 100 |
| | **Urban** | **Low** | 24.84 | 7.07 | 8.62 | 4.00 | 0.01 | 4.15 | 16.12 | 10.23 | 0.45 | 0.83 | 2.35 | 10.32 | 10.70 | 0.32 | 100 |
| | | **High** | 16.17 | 6.11 | 6.17 | 4.03 | 0.01 | 5.36 | 15.15 | 11.54 | 0.66 | 1.07 | 12.43 | 9.55 | 11.58 | 0.18 | 100 |

*Source: Author's calculation*

| | | | | | |
|---|---|---|---|---|---|
| **1** | **Food** | **6** | **Water, Electricity, and Gas** | **11** | **Recreation Services and Culture** |
| **2** | **Beverages and Tobacco** | **7** | **Furnishings, Household Equipment, and Maintenance** | **12** | **Public Administration, Defence, Health, Education** |
| **3** | **Clothing and Footwear** | **8** | **Transport** | **13** | **Business and Financial Services** |
| **4** | **Petroleum and Coal Products** | **9** | **Communication** | **14** | **Miscellaneous Goods and Services** |
| **5** | **Housing** | **10** | **Trade** | **15** | **Total** |

In Table 3, the first noticeable pattern is that share of food consumption decreases as income increases. Those at lower income groups tend to spend most of their income on food. Meanwhile, the opposite holds true for Trade in which those within higher income groups trade more. One important result from these two phenomena is that even without knowing the exact average income for each household group; it can be inferred within a country, which household group has a higher average income per household.

As for energy and environmental policy implications, there are three related sectors in the table, namely Petroleum Products, Transport, and Utilities. Petroleum Products appears to be similarly used by all household groups in most countries, except for Indonesia and Thailand. Meanwhile, the use of transportation increases progressively with income in all countries. At the same time, utility consumption patterns are quite different between countries.

As such, should a regional policy in energy be adopted across the board, its impact would be quite significantly different between countries. Arguably, an undertaking in which such a policy is adopted is doomed to fail from the start unless country-specific considerations are granted, e.g. a compensation scheme for low-income groups.

Meanwhile, Table 4 shows a breakdown of household income sources. Basically, households receive incomes from Labors, both Unskilled and Skilled Labors, Land, Natural Resources, Capital, Government Transfer, and Remittance. Also, aggregating incomes and subtracting Savings yields Private Consumption.

The most interesting thing to note here is Government Transfer. Note that a positive sign shows a net transfer from the government, i.e. subsidy, whereas a negative sign shows a net transfer to the government. In other words, a negative sign under Government Transfer means that the household is giving more than it receives from the government in terms of cash transfer. Surprisingly, in Indonesia, Philippines, Thailand, and Vietnam, the lowest income group receives less government help than some higher income groups. One possible explanation is geography. Those in the lowest income group, i.e. Rural-Low, receive less help from form the government because they cannot be reached due to their location. Those living in the remote areas with few government facilities are most likely to fall under this household income group.

Furthermore, by inverse logic, those in the highest income group, i.e. Urban-High, are also less likely to receive government handouts than those in Urban-Low and Rural-Low groups. Also, classifying those living in urban area based on income group is much easier to do, such that capture, or “leakage”, from a government policy to help low income groups is less likely to occur. These holds true for all countries, except for Vietnam.

**Table 4. Household incomes**

| | | | Labors | | Land | Natural | Capital | Government | Remittance | (Savings) | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Unskilled | Skilled | | Resources | | Transfer | | | |
| Indonesia | Rural | Low | 7,250 | 212 | 274 | 181 | 1,952 | 21,535 | 298 | 4,923 | 26,777 |
| | | High | 26,261 | 4,756 | 2,093 | 1384 | 14,928 | 35,932 | 29 | 15,384 | 70,000 |
| | Urban | Low | 7,519 | 1,818 | 995 | 657 | 7,093 | 32,577 | 216 | 7,041 | 43,833 |
| | | High | 35,582 | 12,464 | 1,018 | 673 | 7,260 | -11,230 | 74 | 11,700 | 34,141 |
| Malaysia | Rural | Low | 2,484 | 793 | 19 | 80 | 520 | 2,275 | 29 | 1,624 | 4,622 |
| | | High | 7,452 | 2,378 | 57 | 241 | 1,561 | -323 | 143 | 6,009 | 5,403 |
| | Urban | Low | 7,457 | 2,379 | 58 | 241 | 1,562 | 4,989 | 87 | 5,307 | 11,718 |
| | | High | 22,370 | 7,138 | 173 | 724 | 4,687 | -477 | 316 | 18,038 | 16,691 |
| Philippines | Rural | Low | 827 | 339 | 396 | 104 | 1,178 | 1,139 | 138 | 410 | 3,711 |
| | | High | 4,721 | 1,938 | 788 | 207 | 6,702 | 3,172 | 68 | 2,172 | 15,424 |
| | Urban | Low | 2,313 | 950 | 543 | 143 | 2,895 | 1,007 | 140 | 946 | 7,044 |
| | | High | 13,214 | 5,424 | 1,079 | 284 | 16,467 | 2,539 | 146 | 6,393 | 32,760 |
| Singapore | Rural | Low | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | High | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Urban | Low | 7,278 | 4,376 | 10 | 7 | 5,998 | 7,410 | 0 | 4,461 | 20,616 |
| | | High | 21,134 | 12,707 | 30 | 20 | 17,417 | -7,500 | 0 | 8,438 | 35,370 |
| Thailand | Rural | Low | 3,316 | 1,354 | 673 | 9 | 750 | 10,719 | 61 | 848 | 16,035 |
| | | High | 5,912 | 2,415 | 1,031 | 133 | 5,582 | 12,079 | 1 | 1,800 | 25,353 |
| | Urban | Low | 6,213 | 2,537 | 588 | 193 | 2,448 | 5,496 | 21 | 1,478 | 16,017 |
| | | High | 12,837 | 5,243 | 911 | 676 | 14,527 | -2,335 | 4 | 2,380 | 29,483 |
| Vietnam | Rural | Low | 4,502 | 500 | 558 | 468 | 0 | 1,675 | 5 | 152 | 7,555 |
| | | High | 5,634 | 1,673 | 1,297 | 1,088 | 0 | 3,652 | 0 | 242 | 13,103 |
| | Urban | Low | 1,234 | 449 | 36 | 31 | 0 | 1,229 | 2 | 162 | 2,820 |
| | | High | 1,545 | 1,502 | 85 | 71 | 0 | 2,720 | 0 | 262 | 5,660 |

*Source: Author’s calculation. Unit is in 2004 US$ million.*

Table 5 provides disaggregated bilateral remittance estimates modified from the work of Ratha and Shaw (2006). The table shows that households in Indonesia receive about US$ 617 million in from Indonesians working abroad in 2004 within the region. These payment transfers come from Indonesians working in Malaysia, Philippines, Singapore, and Thailand. Note that Indonesia also receives remittance from other countries outside of ASEAN, e.g. Middle East. However, these transactions are not listed and disaggregated as these would all be “lumped” together in the exogenous account along with other transactions from the rest of the world.

## Table 5. Bilateral remittance estimates in 2004

| | | Malaysia | | | | Philippines | Singapore | | Thailand | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Rural-Low | Rural-High | Urban-Low | Urban-High | Urban-Low | Urban-Low | Urban-High | Rural-Low | Urban-Low | | |
| **Indonesia** | **Rural-Low** | 92.43 | | 145.94 | | 1.78 | 56.93 | | | 0.59 | 297.68 | 616.55 |
| | **Rural-High** | | 29.19 | | | | | | | | 29.19 | |
| | **Urban-Low** | 72.97 | | 97.29 | | 0.89 | 44.28 | | | 0.3 | 215.74 | |
| | **Urban-High** | | | | 48.65 | | | 25.30 | | | 73.95 | |
| **Malaysia** | **Rural-Low** | | | | | | 28.69 | | | 0.56 | 29.25 | 575.53 |
| | **Rural-High** | | | | | | | 143.46 | | | 143.46 | |
| | **Urban-Low** | | | | | | 86.08 | | | 1.11 | 87.19 | |
| | **Urban-High** | | | | | | | 315.62 | | | 315.62 | |
| **Philippines** | **Rural-Low** | 29.29 | | 107.38 | | | | | 0.27 | 0.8 | 137.74 | 492.37 |
| | **Rural-High** | | 68.33 | | | | | | | | 68.33 | |
| | **Urban-Low** | 48.81 | | 87.86 | | | | | 0.8 | 2.4 | 139.87 | |
| | **Urban-High** | | | | 146.43 | | | | | | 146.43 | |
| **Thailand** | **Rural-Low** | 43.97 | | 16.54 | | | | | | | 60.52 | 87.07 |
| | **Rural-High** | | 1.31 | | | | | | | | 1.31 | |
| | **Urban-Low** | 15.67 | | 5.22 | | | | | | | 20.90 | |
| | **Urban-High** | | | | 4.35 | | | | | | 4.35 | |
| **Vietnam** | **Rural-Low** | | | | | | | | 1.63 | 3.26 | 4.89 | 7.33 |
| | **Urban-Low** | | | | | | | | 0.81 | 1.63 | 2.44 | |
| **Total** | | 303.14 | 98.83 | 460.25 | 199.43 | 2.67 | 215.99 | 484.39 | 3.51 | 10.65 | | |
| | | 1061.65 | | | | | 700.37 | | 14.16 | | | |

*Source: Ratha and Shaw (2007) and author's calculation. Unit is in 2004 US$ million.*

Meanwhile, Malaysia receives from Singapore and Thailand, whereas Philippines receives from Malaysia, and Thailand. Also, Thailand receives from Malaysia and Vietnam from Thailand. Interestingly, there are not remittance transfers from Indonesia and Vietnam, while Singapore does not receive remittance from any other countries in the region. However, these do not imply the absence of workers migration within these countries as they simply mean that the amount being transferred is not significant.[14]

There is, however, an underlying assumption being imposed upon when bilateral remittance estimates are disaggregated. There is no readily available data on inter-institutional transfers such that, limited as they are, author's judgment and knowledge of each country's economic characteristics are the main basis for disaggregating remittance estimates.

## 4.0 A COMPUTABLE GENERAL EQUILIBRIUM MODEL FOR ANALYSIS

Along with econometric models, computable general equilibrium (CGE) or applied general equilibrium (AGE) models have become a standard tool for policy analysis in many countries. Johansen (1960) was a pioneer in the field of multi-sectoral equilibrium models. However, it was not before the early seventies, perhaps stimulated by Scarf's (1967) work on the computation of equilibria, that several research groups, e.g. three at the World Bank, began to build general equilibrium models (Breuss, 1991).

As summarized by Shoven and Whalley (1992), the Walrasian general equilibrium model provides an ideal framework for appraising the effects of policy changes on resource allocation and for assessingwho gains and loses, policy impacts that are not well coveredby empirical macro models. The term "general equilibrium" corresponds to the well-knownArrow-Debreu model developed in 1954.Thenumber of consumers in the model is specified. Each consumer has aninitial endowment of $N$ commodities and a set of preferences, resultingin demand functions for each commodity. Market demands are the sum of each consumer's demands. Commodity market demands depend on all prices, continuous, non-negative, homogeneous of degree zero, i.e. no money illusion, and satisfy Walras' law in which at any set of prices, the total value of consumer expenditures equals consumer incomes.

On the production side, technology is described by either constant returns-to-scale activities or non-increasingreturns-to-scale productionfunctions. Producers maximize profits. The zero homogeneity of demandfunctions and the linear homogeneity of profits in prices, i.e. doublingall prices doubles money profits, imply that only relative prices are of

[14] The cut-off value is US$ 1 million in Ratha and Shaw (2007).

anysignificance in such a model. The absolute price level has no impact onthe equilibrium outcome.Equilibrium in this model is characterized by a set of prices and levelsof production in each industry such that the market demand equals supplyfor all commodities. Since producers are assumed to maximize profits, this implies thatin the constant-returns-to-scalecase,no activity or cost-minimizing techniquefor production functions does any better than break even at theequilibrium prices (Shoven and Whalley, 1992).

A *computable* general equilibrium (CGE) model uses realistic economic data to observe how an economy reacts to any possible changes in, among others, input market, technology, and government policy. There are various types of CGE models. Single-country models are used to study thestructural consequences of exogenous shocks, questions of incomes distribution, and sectoraleffects of tax reforms.The standard national CGE model is a type of CGE models that mainly concerns itself with a single country and analyzes its economic structure at the national level. The data source for this type of CGE model usually either comes from the national input-output (I-O) table or the social accounting matrix (SAM). It typically has no sub-national features, thus, aggregating the entire country into one single economy.

This model is also a disaggregated model in the sense that it allows multi-product industries and multi-industries products. It incorporates detailed estimates of elasticities of substitution between domestically produced products and similar imported products. This type of models usually contains detailed modeling of margin industries and allows freedom to reclassify variables between the exogenous and endogenous categories. Much recent research is devoted to constructing dynamic, both inter-temporal and recursive, CGE models. Such overlapping generations (OLG) models are used to analyze policy changes in a variety of cases, e. g. tax policy and environmental policy, on economic growth and the allocation of resources. Several attempts have been made to capture features of imperfect competition and increasing returns to scale. Others include financial CGE, which looks specifically at the financial impact of a policy change (Shoven and Whalley, 1992; Resosudarmo *et al.*, 2008).More recently, environmental problems and questions of economic growth have gained favor with CGE models.

Many single country CGE models have been developed for Southeast Asia countries alone, particularly for Indonesia, such as a model by Lewis (1991), one of the first CGE model for Indonesia; Indorani by Abimanyu (2000), an Indonesian adaptation of the ORANI-G model developed by the Centre of Policy Studies at Monash University used to analyzed trade policies on the environment; financial CGE by Azis (2000) that consists of real and financial sectors of the Indonesian economy; environmental CGE by Resosudarmo (2002), the first published inter-temporal dynamics CGE model based on SAM table; Wayang by Warr (2005), a modified version of ORANI-G with innovative treatments of the agricultural sector; recursive model by Oktaviani *et al.* (2005), a recursive dynamic ORANI-G model; and a model by Yusuf and Resosudarmo (2007), which has 100 rural household and 100 urban household groups and disaggregates energy sectors as well as incorporates GHG emissions (Resosudarmo *et al*. 2008).

CGE models of other countries in the region include, among others, models for Brunei by Duraman and Asafu-Adjaye (1999); an adaptation of the ORANI-G model for Cambodia by Oum (2009); Malaysia by Jaafar *et al*. (2008); the Philippines by Corong and Cororaton (2006) and Savard (2010); an adaptation of the Global Trade Project Analysis (GTAP) model for Singapore by Siriwardana and Iddamalgoda (2003); Thailand by Karunaratne (1998); and Vietnam by Chan and Dung (2001) as well as Fujii and Roland-Holst (2005).

Multi-country models, on the other hand,deal with cross-boundary issues including, but not limited to,world trade questions. This type of models is mainly concerned with creating a CGE model that captures the country/region/global economy by incorporating many countries into the model. Number of countries is this type of model ranges from two all the way to a global model. Countries, which consist of multiple sectors, are typically inter-connected through trade. The model can then be used to conduct policy analysis on, among others, the impact of tariffs, tax changes, and capital movements on the global or a particular country/region economy (Resosudarmo *et al*., 2008). Starting with Harris (1984) who estimated the welfare effects of the free trade arrangement between the U. S. and Canada, this type of models are being used to study the sectoral consequences of the completion of the single market on European Community (EC) countries (Harrison *et al*., 1989; Smith and Venables, 1988), the European Free Trade Association (EFTA) countries (Norman, 1989; Haaland, 1990) as well as the effects on EC and EFTA countries combined (Norman, 1990). Other early works include Whalley (1985) as well as Deardorff and Stem (1986) that use world trademodels to quantify the effects of a multilateral reduction of tariffs within GATT on the welfareof individual countries and the world as a whole (Shoven and Whalley, 1992).

For more recent works, the most widely used is probably the Global Trade Analysis Project (GTAP) model housed in the Department of Agricultural Economics at Purdue University. This is an I-O-based comparative static model with a multi-region, multi-sector general equilibrium model using perfect competition and constant return to scale assumptions

(Hertel, 1997). The World Bank also maintains a global CGE model, the LINKAGE. LINKAGE model is a recursive dynamic global CGE model capturing population and labor dynamics as well as the role of savings and investment on capital accumulation and productivity in multiple countries (Mensbrugghe, 2005). Another prominent model is the Globe model that has been calibrated using data derived from the GTAP database. Aside from its SAM-based feature, this model is distinctive as it uses a “dummy” region, known as Globe, that allows for the recording of inter-regional transactions where either the source or destination are not identified. Examples of such transactions include trade and transportation margins and data on remittances. The Globe construct provides a general method for dealing with any transactions data where full bilateral information is missing (McDonald *et al*., 2007).

## 4.1 Overview of the IRSA-ASEAN Model

The IRSA-ASEAN model is a multi-country CGE model is a direct descendant of the Inter-Regional System of Analysis for Indonesia Five Regions (IRSA-Indonesia5) developed by Resosudarmo *et al.* (2008) such that it bears many similarities with the latter. However, numerous features of the IRSA-ASEAN model also stem from other developments in CGE modeling over the last 20 years; some of these sources of inspiration are direct and easily identified, including one of the first CGE models for Indonesia by Lewis (1991), GTAP model (Hertel, 1997), and Globe model (McDonald et al., 2007). The IRSA-ASEAN model itself is a multi-country model that solves at the country level, meaning that optimizations are done at this level. This approach allows price as well as quantities to vary independently by countries, which means that variation in price as well as in quantity of each country can be observed using this model. This approach enables the user of the model to observe the impact of a specific shock in a country to other countries, the whole ASEAN economy, and the country itself.

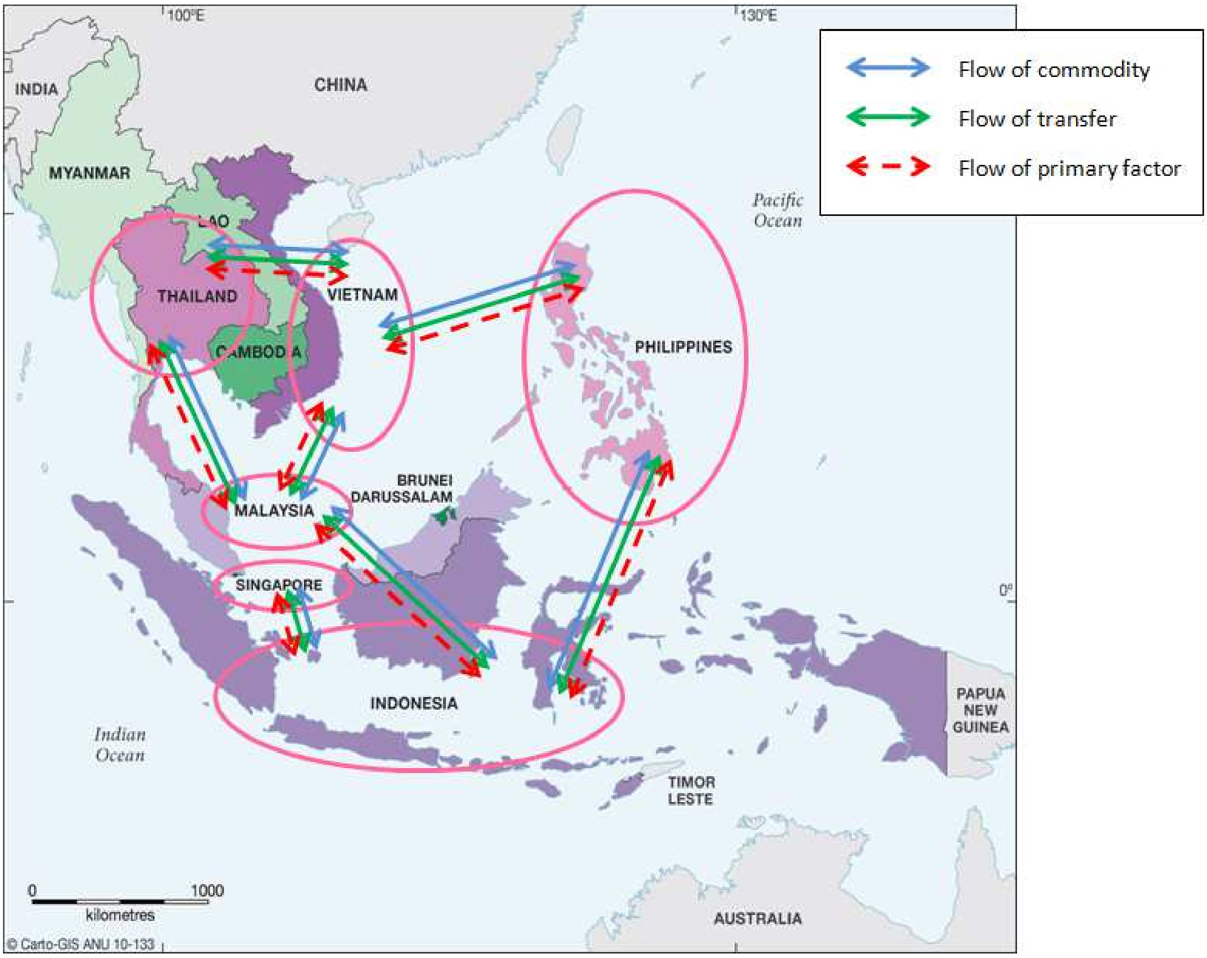


**Figure 8. The IRSA-ASEAN model**

Figure 8 provides a graphical representation of the IRSA-ASEAN. The IRSA-ASEAN consists of six of ASEAN's member countries, namely Indonesia, Malaysia, Philippines, Singapore, Thailand, and Vietnam. As optimization is done at the country level, and taking into account the "sovereignty" element of each country[15], the model uses neither a bottom-up nor a top-down approach. Each country is instead connected through flow of commodity, i.e. trade of goods and services, as well as flow of transfer, i.e. remittance and saving-investment. The model also allows direct transfer of primary factors production, e.g. fragmentation, however, due to data scarcity, this last feature is not included in the empirical study.

As a consequence of the sovereignty element in the IRSA-ASEAN model, each country has its own balance of payment as well as saving and investment accounts. Each country deals directly with other countries in terms of trading and is allowed its own set of tariff barriers. For examples, in the IRSA-ASEAN model, each country can export/import

[15] This is in line with real world evidence in which unlike the EU, ASEAN is not a supranational organization.

goods and services directly to/from rest of the world (ROW).Figure 5 provides an illustration of the production structure of the IRSA-ASEAN model.

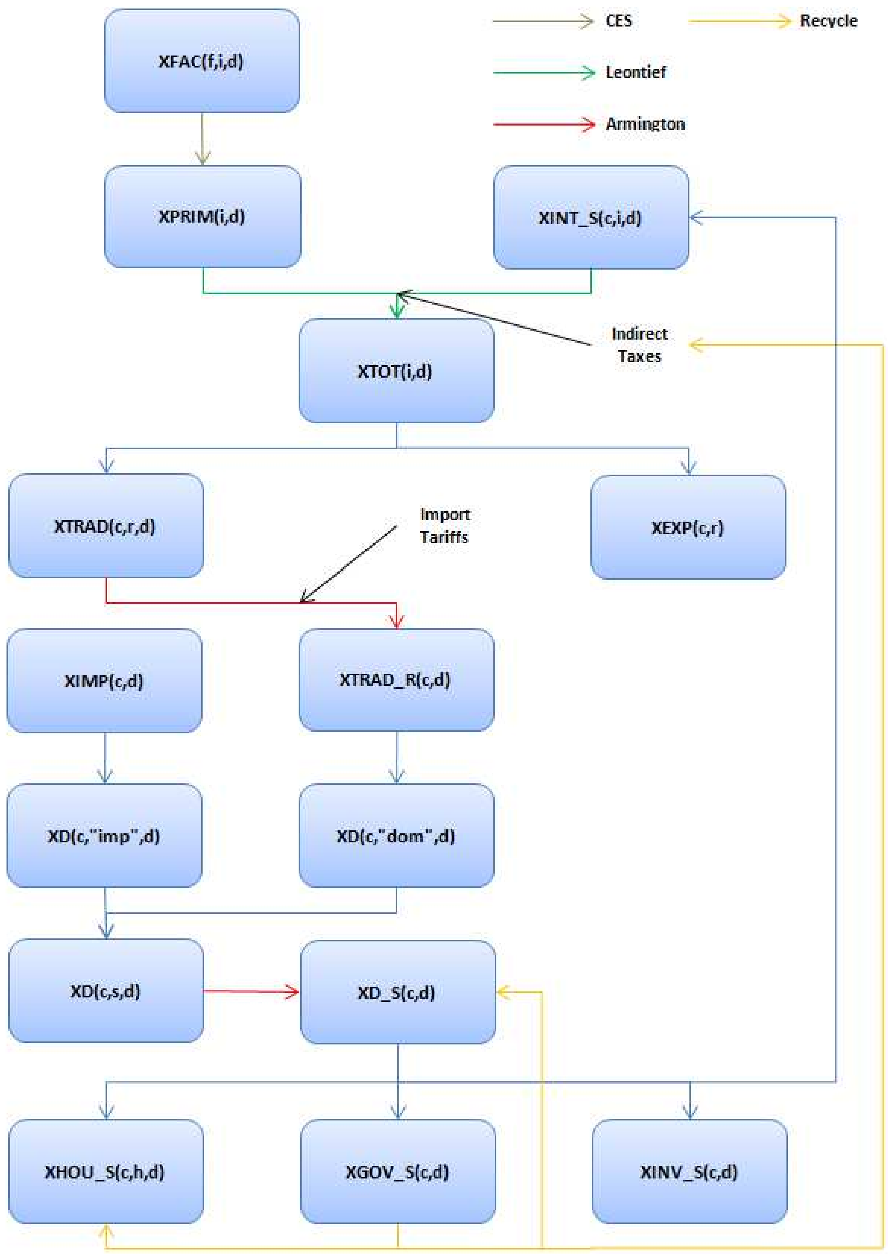


**Figure 9. Production structure of the IRSA-ASEAN model**

The following defines the subscript notations in Figure 9:

- *c* commodity;
- *d* country destination of commodity;
- *f* factor of production;
- *h* household;
- *i* industry;

*r* countrysource of commodity; and

*s* source of commodity, composite between *"dom"* [16] and *"imp"*[17].

Meanwhile, *XTOT(i,d)* is output, *XINT_S(c,i,d)* is the intermediate good, and *XPRIM(i,d)* is the primary input. Meanwhile, *XTRAD_R(c,d)* is the domestic demand composite, *XD_S(c,d)* is the domestic and import demand composite, and *XFAC(f,i,d)* is the demand for factor of production.*XEXP(c,r)* represents exports to rest of the world, while the term *XIMP(c,d)* refers to imports from rest of the world. Meanwhile, XHOU_S(c,h,d) represents household demand, XGOV_S(c,d) represents government demand, and XINV_S(c,d) represents investment demand. Also note that indirect taxes affect production output while import taxes affect the composite demand. *CES* refers to the constant elasticity of substitution (CES) production function, while *Leontief* refers to the fixed proportion production function.

Furthermore, in an open economy CGE model, the standard assumption that is usually applied is the Armington assumption.[18] This assumption implies that imperfect substitutes can have different prices in different countries (Plassmann, 2005). A major benefit of using the Armington assumption is that it permits prices of immobile input factors to differ across regions. If markets are competitive, then differences in input prices lead to differences in output prices. The Armington assumption also provides an intuitive explanation of why consumers do not buy output exclusively from the country with the lowest price.

Another important highlight of the IRSA-ASEAN model deals with the issue of double-dividend. Although the IRSA-ASEAN model can be used for a wide-range of policy simulations, e.g. trade and fiscal simulations, the main motivation to its development in this study is to assess the economic impact of environment-related policies, namely a carbon tax. As such, the IRSA-ASEAN model takes a step further with regards to the issue of environment by allowing for the possibility of the double-dividend hypothesis. The model internalizes the double-dividend hypothesis by intrinsically and explicitly incorporating various recycling mechanisms. In this regard, aside from the government increasing its expenditure, the carbon tax revenue can either be recycled directly to household, e.g. direct one-time lump-sum cash transfer to low-income households, or recycled back to the industry,

[16] The word *"dom"* refers to domestic, i.e. intra-ASEAN goods and services.
[17] The word *"imp"* refers to import, i.e. extra-ASEAN goods and services.
[18]The term comes from the name Paul Armington, an International Monetary Fund (IMF) economist.

e.g. indirect tax reduction, such that it creates a less distortionary tax system, or supposedly so.[19]

For empirical results, the IRSA-ASEAN model uses the Social Accounting Matrix for ASEAN (ASEAN-SAM) which has been calibrated from the input-output (I-O)-based Global Trade Analysis Project (GTAP) Version 7 Data Base.[20] The database uses a common reference year of 2004 and a common currency of United States million dollars (USD million) for all six countries in the region. The database has been heavily modified using various country-specific dataset, e.g. social accounting matrices and household income/expenditure surveys, so as to provide greater insight and flexibility for policy analysis.

The following lists the additional datasets required to build the so-called ASEAN-SAM. For Indonesia, the additional data needed are (1) 2005 Social Accounting Matrix and (2) 2005 Inter-Regional Social Accounting Matrix (Resosudarmo *et al.*, 2008); Malaysia, (1) 2004/2005 Household Expenditure Survey, (2) 2004 Distribution and Use of Income Accounts and Capital Account, (3) 2000 Population and Housing Census, and (4) 1970 Social Accounting Matrix (Pyatt *et al.*, 1984); Philippines, (1) 2006 Family Income Expenditure Survey, (2) 2000 Social Accounting Matrix (Cororaton and Corong, 2009), and (3) 1997 Family Income Expenditure Survey; Singapore, (1) 2008 Yearbook of Statistics and (2) 2002/2003 Report on the Household Expenditure Survey; Thailand, (1) 2008 Key Statistics, (2) 2002 Household Socio-Economic Survey, and (3) 1998 Social Accounting Matrix (Li, 2002); Vietnam, (1) 2004 Living Standard Survey and (2) 1997 Social Accounting Matrix (Nielsen, 2002). Other data sets needed are the 2010 World Development Indicators, 2008 ASEAN Statistical Yearbook, 2005 ASEAN Statistical Yearbook, 2005 Bilateral Remittance Estimates (Ratha and Shaw, 2007), and 2004 Combustion-Based $CO_2$ Emissions Data for GTAP Version 7 (Lee, 2008).

Procedures in constructing the ASEAN-SAM for modeling purposes are divided into three phases. The first phase involves the preparation of the GTAP Version 7 Data Base and transforming it into individual Global SAMs; i.e. Indonesia, Malaysia, Philippines, Singapore, Thailand and Vietnam. Phase 2 is a set of steps required to transform each individual Global SAM into a standard SAM form. Phase 3 is when all individual SAMs are combined to form the ASEAN-SAM. Some adjustments are needed to combine these

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[19]A more detailed and technical explanation of the IRSA-ASEAN model is provided in the following section.
[20] Parameter values are also obtained from the GTAP Version 7 Data Base.

individual SAMs.[21] Table 1 provides a detailed list of sets of the ASEAN-SAM can be seen in Table 6. Lastly, the latest version of Generalized Algebraic Modeling System (GAMS) program is used to run the IRSA-ASEANmodel.

**Table 6. Final List of Sets**

| **Production Sectors** | | **Regions** |
|---|---|---|
| Agriculture | Trade | Indonesia |
| Farming | Transportation | Malaysia |
| Forestry | Communication | Philippines |
| Fishing | Financial services | Singapore |
| Coal | Public administration, defense, health, and education | Thailand |
| Oil | | Vietnam |
| Gas | Dwellings and other services | Rest of the World |
| Minerals *nec* | | |
| Food and beverages | **Factors** | **Institutions** |
| Textile and leather products | | |
| Wood and paper products | Unskilled Labor | Rural-Low Household |
| Petroleum and coal products | Skilled Labor | Rural-High Household |
| Chemical, rubber, and plastic products | Land | Urban-Low Household |
| | Natural resources | Urban-High Household |
| Mineral products *nec* | Capital | Corporate |
| Metal products | | Government |
| Manufacturing | **Other Accounts** | |
| Electricity | | |
| Gas manufacture distribution | Indirect Tax | |
| Water | Import Tax | |
| Construction | Saving-Investment | |

## 4.2 Construction of the IRSA-ASEAN Model

Referring back to Figure 5, the principal activity of any industry is to turn inputs into outputs. In this model, the relationship between inputs and outputs is formalized by a nested CES-Leontief production function in each production sector. The structure of the production function is the same for all sectors. Unlike the basic model of CGE, this model assumes that inputs of production are divided into two categories: the composite of primary factors, i.e. unskilled labor, skilled labor, land, natural resources, and capital; and the intermediate goods. The source of the composite primary factors only comes from the domestic[22] market, but the

[21] See previous section for a detailed step-by-step procedure on the construction of the ASEAN-SAM.
[22] Again, the word “domestic” refers to within ASEAN region. And thus, used interchangeably.

source of intermediate goods can come from both domestically produced intermediate goods and imported[23] intermediate goods. The nested CES-Leontief production function plays an important role dealing with the complication of inputs. Within this setup, industries have a separable optimization problem between minimization cost for composite primary factors and minimization cost for intermediate goods.

At the first stage, industries face two different optimization problems: choosing the combination of their primary factors i.e. unskilled labor, skilled labor, land, natural resources, and capital; and their choice of the composite intermediate goods to optimize cost efficiency. In the second stage, each industry minimizes its production cost by choosing the most efficient level of composite primary factors, sometimes called value added, and composite intermediate goods using Leontief production function.[24]

### 4.2.1 Output of Production

On the second stage, the relationship between all the inputs, composite of primary factors and intermediate goods, is represented by the Leontief production function as follows:[25]

$$\max_{\{XPRIM_{i,d},\, XINT\_S_{c,i,d}\}} f\left(XPRIM_{i,d}, XINT\_S_{c,i,d}\right) \text{ s.t. } XTOT_{i,d} = \min\left(XPRIM_{i,d}, XINT\_S_{c,i,d}\right) \quad [1]$$

with

$$f\left(XPRIM_{i,d}, XINT\_S_{c,i,d}\right) s.t.\, XTOT_{i,d} = PPRIM_{i,d} \cdot XPRIM_{i,d} + \sum_c PQ\_S_{c,d} \cdot XINT\_S_{c,i,d} \quad [2]$$

where $XTOT_{i,d}$ is output for industry *i* at destination country*d*, $XINT\_S_{c,i,d}$ is the intermediate good, and $PQ\_S_{c,d}$ is the price for domestic-import composite. The use of intermediate goods and primary factors is assumed to be proportional to the output level of the produced commodity, i.e.

$$XINT\_S_{c,i,d} = \alpha^{\text{int}}_{c,i,d} . XTOT_{i,d} \quad [3]$$

[23] Analogously, the word “import” refers to extra ASEAN region, i.e. rest of the world.
[24] Although significantly different in the overall model structure, mathematical and technical notations of the IRSA-ASEAN model are similar to the IRSA-Indonesia5 model developed by Resosudarmo *et al*. (2008) as shown in this section.
[25] This production function was introduced by a Russian-American economist, Wassily Leontief. He was a pioneer in the development of input-output analysis. In an input-output analysis, production is assumed to take place with a fixed-proportions technology.

$$XPRIM_{i,d} = \alpha_{i,d}^{prim}.XTOT_{i,d} \quad [4]$$

where $\alpha_{c,i,d}^{\text{int}}$ is the proportion of intermediate goods used to produce the output and $\alpha_{i,d}^{prim}$ is the proportion of composite primary factors used to produce the output.

Admittedly, one important outcome, or even limitation, to this setup is that substitution between intermediate inputs is not allowed. Aside from the technical limitation of allowing intermediate input substitution, this is also a short-run model static model. Thus, it would be logical to assume that intermediate input substitution cannot be done so easily in the real world as well.[26]

### 4.2.2 Demand for Primary Factors

The primary factors' optimization problem for each industry is represented as follows:

$$\min_{\{XFAC_{f,i,d}\}} f\left(XFAC_{f,i,d}\right) \text{ s.t. } XPRIM_{i,d} = CES\left[XFAC_{f,i,d} \mid \sigma_i\right] \quad [5]$$

with

$$f\left(XFAC_{f,i,d}\right) = \sum_f PFAC_{f,d} \cdot XFAC_{f,i,d} \quad [6]$$

$PFAC_{f,d}$ is a factor price[27], $XFAC_{f,i,d}$ is the demand for primary factor, $XPRIM_{i,d}$ is the composite of primary factors, and $CES\left[XFAC_{f,i,d} \mid \sigma_i\right]$ is a CES functional form that represents the relationship between the primary factors. $\sigma_i$ is the elasticity of substitution for each industry.

The first stage of the industry's optimization is represented by a more familiar form as follows:

$$\min_{\{X_{f,i}\}} f\left(X_{f,i}\right) \text{ s.t. } Y_i = \alpha_{i,f}\left(\sum_f \delta_{f,i} X_{f,i}^{-\rho}\right)^{-\frac{1}{\rho}}, \ \delta \ \left(0 \le \delta \le 1\right) \quad [7]$$

with

$$f\left(X_{f,i}\right) = \sum_f P_f X_{f,i} \quad [8]$$

[26] The implications of this assumption will be discussed further in the empirical section later in this study.
[27] We are in the perfectly competitive world, where everybody in economy is a price taker. Therefore, there is no subscript *i* for price because all industries face the same primary factor prices.

$P_f$ is the price for each primary factor and $X_{f,i}$ is the demand for primary factor $f$ in industry $i$. Following the derivation by Resosudarmo *et al*. (2008), Equation 7 can be solved as follows.

$$X_{f,i} = Y\alpha_{i,f}^{-\frac{\rho}{(\rho+1)}}\delta_{f,i}^{\frac{1}{1+\rho}}\left(\frac{P_f}{\tilde{P}}\right)^{-\frac{1}{(1+\rho)}} \qquad [9]$$

where $\tilde{P} = \left(\sum_f P_f^{(1+\rho)}\delta_f^{-1}\right)^{-\frac{1}{(1+\rho)}}$. The above equation gives the demand for primary factors, which are applicable to each industry, $XFAC_{f,i,d}$. Transforming this result into a functional form as what is done in solving the problem in Equations 1 gives

$$XFAC_{f,i,d} = \alpha_{i,d}^{\frac{-\rho}{\rho+1}} \cdot XPRIM_{i,d} \cdot \delta_{f,i,d}^{\frac{1}{\rho+1}} \cdot \left(\frac{PFAC_{f,d}}{PPRIM_{i,d}}\right)^{\frac{-1}{\rho+1}} \qquad [10]$$

where $PPRIM_{i,d}$ is the price of composite primary factors paid by industry $i$ in country $d$ [28], $\alpha_{i,d}$ is the shift parameter of value-added, $\delta_{f,i,d}$ is the share parameter of value-added, and $\rho_{i,d}$ is a parameter of valued-added derived from the elasticity of substitution. The removal of subscripts for $\rho_{i,d}$ in Equation 10 is done for the sake of simplicity.

Meanwhile, market clearing for factors is as follows.

$$\begin{aligned}(\sum_i XFAC_{f,i,d}) + XFACRO_{f,d} &= (\sum_h\sum_r XFACS_{r,h,d,f}) + (\sum_r XFGR_{r,d,f}) \\ &\quad + (\sum_r XFCO_{r,d,f}) + XFRO_{d,f}\end{aligned} \qquad [11]$$

where $XFACRO_{f,d}$ is the demand for factor by rest of the world, $XFACS_{r,h,d,f}$ is the supply of factors by households, $XFGR_{r,d,f}$ is the supply of factors by governments, $XFCO_{r,d,f}$ is the supply of factors by corporate, and $XFRO_{d,f}$ is the supply of factors by rest of the world. The left hand side variables in the above equation are treated as exogenous.

### 4.2.3 Inter-Regional Trade and Import

Using the CES aggregation function, we can establish demand of commodity *c* with source country*r* to destination country*d*.

[28] The price of composite primary factors for each industry is different since each industry has different combination of primary factors.

$$\min_{\{XTRAD_{c,r,d}\}} f\left(XTRAD_{c,r,d}\right) \text{ s.t. } XTRAD\_R_{c,d} = CES\left[XTRAD_{c,r,d} \mid \sigma_{c,d}\right] \qquad [12]$$

with

$$f\left(XTRAD_{c,r,d}\right) = \sum_r (1+itxm_{c,r,d}) \cdot PDOM_{c,r} \cdot XTRAD_{c,r,d} \qquad [13]$$

where $PDOM_{c,r}$ is the producer price for commodity *c* at source country*r*, $XTRAD_{c,r,d}$ is the demand of commodity *c* from source country*r* to destination country*d*, and $CES\left[XTRAD_{c,r,d} \mid \sigma_{c,d}\right]$ is a CES functional form representing the demand for commodity *c* from all source countries to a destination country*d*, with $\sigma_{c,d}$ as the elasticity of substitution for commodity *c* from a different source country*r* at a destination country*d*.

This optimization problem leads to the following solution:

$$XTRAD_{c,r,d} = \alpha_{c,d}^{\frac{-\rho}{1+\rho}} \cdot XTRAD\_R_{c,d} \cdot \delta_{c,r,d}^{\frac{1}{\rho+1}} \cdot \left(\frac{(1+itxm_{c,r,d}) \cdot PDOM_{c,r}}{PQ_{c,"dom",d}}\right)^{\frac{-1}{\rho+1}} \qquad [14]$$

where $PQ_{c,"dom",d}$ is the domestic purchaser's price for commodity *c* at country*d* as $itxm_{c,r,d}$ is the import tariff for commodity *c* from country *r* to country *d*.

Meanwhile, the total demand for commodity $c$ at each destination country $d$ is a CES aggregation of the commodity from all different source countries.

$$\min_{\{XD_{c,s,d}\}} f\left(XD_{c,s,d}\right) \text{ s.t. } XD\_S_{c,d} = CES\left[XD_{c,s,d} \mid \sigma_{s,d}\right] \qquad [15]$$

with

$$f\left(XD_{c,s,d}\right) = \sum_s PQ_{c,s,d} \cdot XD_{c,s,d} \qquad [16]$$

The solution for the above optimization problem is:

$$XD_{c,s,d} = \alpha_{c,d}^{\frac{-\rho}{1+\rho}} \cdot XD\_S_{c,d} \cdot \delta_{c,r,d}^{\frac{1}{\rho+1}} \cdot \left(\frac{PQ_{c,s,d}}{PQ\_S_{c,d}}\right)^{\frac{-1}{\rho+1}} \qquad [17]$$

where $XD\_S_{c,d}$ is the demand for commodity *c* from composite sources, i.e. domestic countries and imported, at destination country *d*. $PQ_{c,s,d}$ is the purchaser's price of commodity *c* from source country *s* at destination country *d*. $PQ\_S_{c,d}$ is the purchaser's price of commodity *c* from composite sources at destination country *d*.

Part of the total demand for commodity *c*, $XD\_S_{c,d}$, is then used as an intermediate goods $\left(XINT\_S_{c,i,d}\right)$. The remainder will be consumed by households $\left(XHOU\_S_{c,h,d}\right)$, governments $\left(XGOR\_S_{c,d}\right)$, and investment purposes $\left(XINV\_S_{c,d}\right)$. That is:

$$XD\_S_{c,d} = (\sum_i XINT\_S_{c,i,d}) + (\sum_h XHOU\_S_{c,h,d}) + XGOR\_S_{c,d} + XINV\_S_{c,d} \qquad [18]$$

#### 4.2.4 Market Clearing for Commodity and Zero Profit Conditions

In an equilibrium condition, all the output supplied for commodity *c* from region *r* $\left(XTOT_{c,r}\right)$ must equal the sum of the demand for commodity *c* at all domestic destinations $\left(XTRAD_{c,r,d}\right)$ and the demand for commodity *c* from outside the region $\left(XEXP_{c,r}\right)$, i.e. rest of the world.

$$XTOT_{c,r} = (\sum_d XTRAD_{c,r,d}) + XEXP_{c,r} \qquad [19]$$

At optimum, the total amount of commodity *c* supplied is produced by satisfying the first order necessary condition (FONC) of its optimization problem, where the marginal revenue of producing the commodity equals its marginal cost. This condition can also be represented by the optimum of its dual problem that holds under a zero profit condition. Zero profit condition is the situation where total revenue of producing the commodity equal its total cost. The total revenue is represented by the arguments on the left hand side of the Equation 20 and the total cost is shown in its right hand side.

$$\begin{aligned}(1-itxr_{i,d} + tco2_d) \cdot PDOM_{i,d} \cdot XTOT_{i,d} &= PPRIM_{i,d} \cdot XPRIM_{i,d} \\ &\quad + \sum_c (1+stx_{c,d}) \cdot PQ\_S_{c,d} \cdot XINT\_S_{c,i,d} \qquad [20]\end{aligned}$$

where $itxr_{i,d}$ is the indirect tax rate, $tco2_d$ is the indirect tax reduction rate recycled from the carbon tax revenue, and $stx_{c,d}$ is the sales tax rate when a carbon tax is implemented. Note that in the absence of a carbon tax, $tco2_d$ and $stx_{c,d}$ are empty sets.

### 4.2.5 Demand for Commodities

The demand for commodity *c* in this case is established through a CES aggregation of the commodity from source country *r* to a destination country *d* $\left(XD_{c,"dom",d}\right)$, which is identical to $XTRAD\_R_{c,d}$ in Equation 12. Therefore, the optimization problem can be represented as follows:

$$\min_{\{XD_{c,r,d}\}} f\left(XD_{c,r,d}\right) \text{ s.t } XD_{c,'dom',d} = CES\left[XD_{c,r,d} \mid \sigma_{c,d}\right] \qquad [21]$$

with

$$f\left(XD_{c,r,d}\right) = \sum_{r} PDOM_{c,r} \cdot XD_{c,r,d} \qquad [22]$$

The solution for above problem is:

$$XD_{c,r,d} = \alpha_{c,d}^{\frac{-\rho}{1+\rho}} \cdot XD_{c,"dom",d} \cdot \delta_{c,r,d}^{\frac{1}{\rho+1}} \cdot \left(\frac{PDOM_{c,r}}{PQ_{c,"dom",d}}\right)^{\frac{-1}{\rho+1}} \qquad [23]$$

where $XD_{c,r,d}$ is the demand for commodity *c* from source domestic country *r* to destination country *d*.

The optimization problem faced by imported commodities is similar to those that come from domestic producing countries. Therefore, Equations 21 and 22 can be used to define the structural relationship for imported commodity just by changing the subscript "*dom*" with the subscript"*imp*". And change $PDOM_{c,d}$ with $PQ_{c,"imp",d}$, i.e. domestic import price. $XD_{c,"dom",d}$ and $XD_{c,"imp",d}$ are then combined using a CES aggregator.

$$\min_{\{XD_{c,s,d}\}} f\left(XD_{c,s,d}\right) \text{ s.t. } XD\_S_{c,d} = CES\left[XD_{c,s,d} \mid \sigma_{s,d}\right] \qquad [24]$$

where

$$f\left(XD_{c,s,d}\right) = \sum_{s} PQ_{c,s,d} \cdot XD_{c,s,d} \qquad [25]$$

The same explanation to that of Equations 12 and 13 applies. However the subscript *s* = {"*dom*" , "*imp*"} in the above problem needs to be emphasized. It represents the source of the commodity, where, "*dom*" represents domestic sources, i.e. with ASEAN, and "*imp*" stands for imported sources from outside of ASEAN.Since the demand for commodity *c* for intermediate goods has been defined, institutional demands for consumption of commodity *c* by households, governments, and investment purposes will be explained next.

### 4.2.6 Household Optimization

Final users of commodity *c* consist of households, governments, and investments. In this model, all three share a common solution to their respective optimization problem. Each chooses its combination of commodities based on a constant budget share. Similarly, each household maximized its utility:

$$U_{h,d} = \prod_{c} \left( XHOU\_S_{c,h,d} \right)^{\beta_{c,h,d}} \qquad [26]$$

$$\text{s.t. } EH_{h,d} = \sum_{c} (1 + stx_{c,d}) \cdot PQ\_S_{c,d} \cdot XHOU\_S_{c,h,d}$$

The utility function gives a linear expenditure system in which the demand for one specific commodity *c* for household *h* at destination *d* is defined as follows:

$$XHOU\_S_{c,h,d} = \frac{\beta_{c,h,d}}{PQ\_S_{c,d}}.(EH_{h,d} - \sum_{i=cc}^{n} (1 + stx_{c,d}) \cdot PQ\_S_{c,d}) \qquad [27]$$

where $\beta_{c,h,d}$ is the budget share parameter. $EH_{h,d}$ is the household disposable income that comes from the following identity condition:

$$EH_{h,d} = (1 - \sum_{hh} \sum_{r} strhh_{hh,r,h,d}) \cdot (1 - savh_{h,d}) \cdot (1 - ytaxh_{h,d}) \cdot YH_{h,d} \qquad [28]$$

where $strhh_{hh,r,h,d}$ is the share parameter for inter-household transfer, e.g. remittance, $savh_{h,d}$ is the share parameter for household saving, and $ytaxh_{h,d}$ are the share parameter for household income tax. Meanwhile, $YH_{h,d}$ is the pre-tax household income, which comes from the identity below.

$$\begin{aligned} YH_{h,d} = & (\sum_{f} \sum_{r} YFAC_{f,r} \cdot SFACHH_{r,h,d,f}) + (\sum_{r} strgrh_{h,r,d} \cdot YGR_{r}) + (\sum_{r} strcohh_{h,r,d} \cdot YCO_{r}) \\ & + (\sum_{hh} \sum_{r} strhh_{h,d,hh,r} \cdot (1 - savh_{hh,r}) \cdot (1 - ytaxh_{hh,r}) \cdot YH_{hh,r}) \\ & + strco2h_{h,d} \cdot TCH_{d} \end{aligned} \qquad [29]$$

$YFAC$ is the total factor income, $SFACHH$ is the share factor income of household, $YGR$ is the government revenue, $YCO$ is the corporate revenue, while $strgrh$ and $strcohh$ are the share transfer to household respectively. Note that only households receive income from both unskilled and skilled labors. Lastly, $TCH$ is the nominal carbon tax revenue recycled back to households and $strco2h$ is the share parameter. Two important things to note here are that the second line in Equation 29 adds up to how much the household *receives* from other households; while in Equation 28, summation of $strhh_{hh,r,h,d}$ adds up to how much the household *gives* to other households. Lastly, the third line in Equation 29 refers to the second carbon tax revenue recycling mechanism aside from $tco2_d$ mechanism in the previous section.

#### 4.2.7 Government Optimization

Similarly, the government needs to find its optimum combination of commodities from different sources. As such, the government also chooses its combination of commodities based on a constant budget share.

$$UGOR_{c,d} = \prod_c \left( XGOR\_S_{c,d} \right)^{\beta_{c,d}} \qquad [30]$$

s.t.

$$\begin{aligned} YGR_d = {} & (\sum_i (itxr_{i,d} - tco2_d) \cdot PDOM_{i,d} \cdot XTOT_{i,d}) \\ & + \sum_f \sum_r PFAC_{f,d} \cdot SFACGR_{r,d,f} YFAC_{f,r} + \sum_h ytaxh_{h,d} \cdot YH_{h,d} \\ & + \sum_c \sum_r itxm_{c,r,d} \cdot PDOM_{c,d} \cdot XTRAD_{c,r,d} \\ & + \sum_c itxn_{c,d} \cdot PFIMP_{c,d} \cdot XIMP_{c,d} \cdot EXR_d \end{aligned} \qquad [31]$$

Briefly explained, the first line in Equation 31 refers to government income indirect tax, or production tax, minus the amount recycled back to the industry from the carbon tax revenue. The second line refers to government income from factors of production that it owns, i.e. land, natural resources, and capital, as well as income tax. The third line refers income generated from import tariff of goods and services from countries within the region, i.e. ASEAN, while the fourth line refers to income generate from import tariff of goods and services from countries outside the region, i.e. rest of the world.

Bear in mind, net government expenditure in Equation 30 must abide by the following identity:

$$EGR_{h,d} = (1 - \sum_h \sum_r strgrh_{h,d,r}) \cdot YGR_d + TCG_d - SGR_d \qquad [32]$$

Equation 32 shows that government expenditure on goods and services must first be reduced by the total government subsidy to households and government savings. It is important to note that government subsidy in Equation 32 is not an empty set regardless whether a carbon tax is implemented or not. Also, government saving can be a negative value, which will then represent a government deficit. Lastly, $TCG$ is the third mechanism by which the government can recycle carbon tax revenue. Note also that by using this scheme, all the revenue held by the government is recycled back to the economy through an expenditure in its expenditure and none is used to increase/decrease government saving/deficit.

### 4.2.8 Investment and Export Demands

Two additional demands for commodity *c* arise from investment and export. For the former case, investment demand adheres to the following identity:

$$PQ\_S_{c,d} \cdot XINV\_S_{c,d} = \lambda_{c,d} \cdot (SAV_d - \sum_r TRSAVINV_{r,d}) \qquad [33]$$

where $\lambda_{c,d}$ is the share parameter and $SAV_d$ is the aggregate saving in country *d* from household, government, corporate, and transfer savings. A transfer saving, $TRSAVINV$, refers to a net transfer of saving-investment between countries.[29]

This model also allows foreign demand for locally-produced goods to be price-sensitive. If the local price of a good rises relative to the world price, export demand will fall. That is:

$$XEXP_{c,r} = \alpha_{c,r} \left( \frac{P_{c,r}}{\pi_r P^w_{c,r}} \right)^{\varepsilon_{c,r}} \qquad [34]$$

where $\alpha_{c,r}$ is a shift parameter, $P_{c,r}$ is domestic price, $\pi_r$ is nominal exchange rate[30], and $\varepsilon_{c,r}$ is the elasticity of demand. In words, exports of commodity *c* are a declining function of the price in foreign currency, relative to the world price.[31] As opposed to Equation 31, the ex-change rate in Equation 34 converts local currency to a foreign currency unit.

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[29] Although not usually common, this account is needed to reconcile the data derived from the GTAP database and the CGE model.
[30] This leads to a limitation in the model in which nominal exchange rate only exists between each ASEAN country with rest of the world, which also applies to Equation 31. As such, exchange rate movement between ASEAN countries are not taken into consideration in this model due to the complexity it will entail.
[31] Although in this model all currencies are in common 2004 USD, an exchange rate is included here for future cases in which this no longer holds.

### 4.2.9 Balance of Payments and Model Closures

One final important account before the closures deals with the balance of payment. As this is a multi-country model without the existence of a supranational entity, each country has its own set of balance of payment. In order words, total transfer payment coming into the country must equal total transfer payment going out of the country.

$$\begin{aligned} ERO_d = & \sum_r TRSAVINV_{d,r} + SRO_d \\ & + \sum_h \sum_{hh} \sum_r strhh_{h,d,hh,r} \cdot (1 - savh_{hh,r}) \cdot (1 - ytaxh_{hh,r}) \cdot YH_{hh,r} \\ & + \sum_c PDOM_{c,d} \cdot XEXP_{c,d} \\ & + \sum_c \sum_r PDOM_{c,d} \cdot XTRAD_{c,d,r} \quad , \quad XTRAD_{c,r,d} \neq XTRAD_{c,d,r} \end{aligned} \qquad [35]$$

Equation 35 shows that total payment inflow comes from the total value of saving-investment transfers, i.e. financial transfers, coming from other ASEAN countries, $\sum_r TRSAVINV_{d,r}$, and rest of the world, $SRO_d$; international inter-household transfers, e.g. remittance; total export value to rest of the world; and total export value goods and services to other ASEAN countries.

By definition, payment coming in must equal payment going out. Payment outflow is defined as follows:

$$\begin{aligned} YRO_d = & \sum_r TRSAVINV_{r,d} \\ & + \sum_h \sum_{hh} \sum_r strhh_{h,r,hh,d} \cdot (1 - savh_{hh,d}) \cdot (1 - ytaxh_{hh,d}) \cdot YH_{hh,d} \\ & + \sum_c PFIMP_{c,d} \cdot XIMP_{c,d} \cdot EXR_d \\ & + \sum_c \sum_r PDOM_{c,d} \cdot XTRAD_{c,r,d} \quad , \quad XTRAD_{c,r,d} \neq XTRAD_{c,d,r} \end{aligned} \qquad [36]$$

Equation 35 must equal Equation 36 in order to have a *balanced* balance of payment, such that the two equations are similar in form, with important differences in the subscript. Other things to note include the absence of any transfer of saving-investment to rest of the world. As previously mentioned, transfers of saving-investment between country refer to the *net* transfers such that $SRO_d$ is not needed as to avoid double accounting. Also, total import value from rest of the world is calculated at local currency unit, thus, the necessity for the nominal exchange rate.[32]

[32] Another reason for the nominal exchange rate is *technical* in nature, which it allows movement in the balance of payment when running the model using Generalized Algebraic Modeling System (GAMS) program.

Lastly, closure is an assumption to close the mathematical system/model where closing the system means the number of equations equal to the number of unknown variables. If this condition does not fulfill then the model cannot be solved. In order to close IRSA-ASEAN model the following closures, among others, are introduced to guarantee that the system is solvable:

1. All factor supplies are exogenous;
2. Unskilled and skilled labors are mobile;
3. Land, natural resources, capital are immobile;
4. All household and corporate saving rates are exogenous;
5. All shares of inter-institutional transfer rates are exogenous;
6. World import prices are exogenous;
7. Indirect tax and import tariff rates are exogenous; and
8. Output price index is set as a *numeraire*.

### 4.2.10 Carbon Pricing Mechanism

The carbon pricing mechanism is a somewhat unique feature of the IRSA-ASEAN model in which $CO_2$ emission data is held as a separate matrix, and yet, intrinsically and explicitly integrated in the model. Emissions basically come from households and industrial sectors, albeit some service sectors emit zero emission as shown through the following equations.

$$XCOH_{e,h,d} = cch_{e,h,d} \cdot XHOU\_S_{e,h,d} \quad [37]$$

and

$$XCOI_{e,i,d} = cci_{e,i,d} \cdot XINT\_S_{e,i,d} \quad [38]$$

$XCOH_{e,h,d}$ is the total $CO_2$ emission from households consumption of fossil fuels, i.e. coal, petroleum products, and gas, denoted by the subscript *e*. Similarly, $XCOI_{e,i,d}$ is the total $CO_2$ emission from industrial use of fossil fuels. $cch_{e,h,d}$ and $cci_{e,i,d}$ are the carbon-content-intensity for each household and industrial sector, which converts consumption in USD million into kiloton of $CO_2$ emission. It follows that carbon-content-intensity is the highest for coal followed by petroleum products and, least of all, gas. This holds true for all country although carbon-content-intensity may differ across households, industries, and countries.

With regard to carbon pricing, the most important equation deals with setting the rates for the carbon tax.

$$stx_{e,d} = cotax_d \cdot (\sum_i XCOI_{e,i,d} + \sum_h XCOH_{e,i,d}) \\ / PQ\_S_{e,d} \cdot (\sum_i XINT\_S_{e,i,d} + \sum_h XHOU\_S_{e,h,d}) \qquad [39]$$

$stx_{e,d}$ is the sales tax for the consumption and use of fossil fuels born by households and industries, while $cotax_d$ is the level of carbon tax, e.g. USD 20 per ton of $CO_2$ emission. Note that the governments neither produce $CO_2$ emission nor pay for it. Revenue generated from the carbon tax is as follows.

$$TCTR_d = \sum_c stx_{c,d} \cdot PQ\_S_{e,d} \cdot \sum_h XHOU\_S_{e,h,d} \\ + \sum_c stx_{c,d} \cdot PQ\_S_{e,d} \cdot \sum_i XINT\_S_{e,i,d} \qquad [40]$$

and

$$TCTR_d = \alpha h_d TCH_d + \alpha i_d TCI_d + \alpha g_d TCG_d \quad , \quad \alpha h_d + \alpha i_d + \alpha g_d = 1 \qquad [41]$$

Equation 41 shows how the carbon tax revenue generated is recycled back into the economy through three different mechanisms, namely household cash transfer, industrial tax reduction, and government expenditure increase. Lastly, for the case of indirect tax reduction, one final equation is added.

$$TCI_d = tco2_d \cdot \sum_i (PDOM_{i,d} \cdot XTOT_{i,d}) \qquad [42]$$

In few words, Equation 42 establishes the indirect tax reduction rate in each country. As $tco2_d$ is a uniform rate across industries within a country, in cases where there is no indirect tax, this then becomes an industrial subsidy. Additionally, the nominal value of the tax reduction is proportional to the industrial size. Although this mechanism implies that carbon-intensive industries, e.g. electricity sector, also receive tax reductions, bear in mind that a carbon tax is still in effect means that the policy is not ineffective. In fact, this mechanism allows the greater possibility of the rebound effect albeit this may create technical problems in cases where the net effective tax is relatively small.[33]

[33] This technical difficulty will be discussed further in the following empirical section.

## 5.0 EMPIRICAL REVIEW OF THE IRSA-ASEAN MODEL

As previously mentioned, the IRSA-ASEAN model uses the ASEAN-SAM as its database. Reconciling the database and the model has been a main aim of this study. Understandably, few features available incorporated in the IRSA-ASEAN model, e.g. cross-boundary use of primary factors, due to the scarcity of data. As such, Figure 6 illustrates the financial flow of the IRSA-ASEAN model with specific use of the ASEAN-SAM database. Admittedly, it is a simplified schematic as it details out the flow within one country with another country representing all the others, including rest of the world. Nevertheless, Figure 10 provides a useful tool to see how changes occur throughout the economy. In other words, it is a useful tool for impact path analysis of aneconomic policy, particularly the implementation of carbon tax.

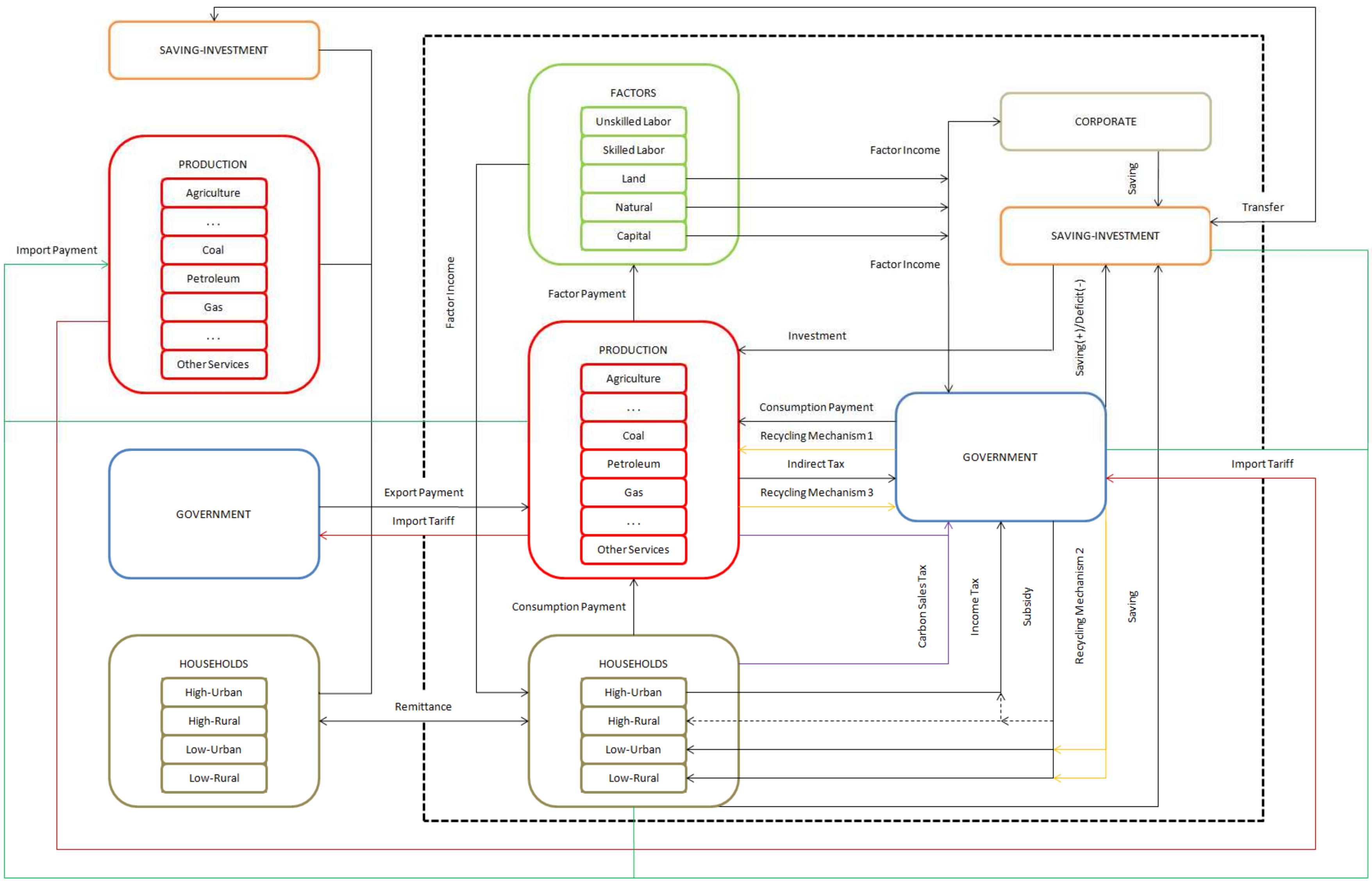


**Figure 10. Financial flow of the IRSA-ASEAN model**

Some highlights from Figure 10 include the three different mechanisms by which carbon tax revenue can be recycled back into the economy. The first mechanism is when the government uses all revenue generated to proportionally increase its expenditures. The second mechanism when chooses to redistribute some, or all, of the revenue generated to low-income households in both rural and urban areas in the form of a one-time lump-sum direct cash transfer to each household group. Note that high-income households in both rural and urban areas do not receive such a transfer. The third mechanism is some complicated in terms of practical and technical implementations. This mechanism occurs when the government recycles the revenue back to the industrial sector in the form of an indirect tax reduction proportional to the sectoral output size. Understandably, the larger the industry, the greater the nominal reduction would be. There are, of course, a number of possible combinations of these three mechanisms and this will explained further in the following policy simulations section.

Another important highlight from Figure 10 is how it shows the multiplier path effect of each mechanism once a carbon tax is implemented and paid by households and industries. For the first recycling mechanism in which the government increases its expenditure of goods and services, this will have a direct effect on production activities. Although production activities might contract due to the implementation of the carbon tax, the increase in government expenditure also expands production activities due to the increase in demand. Whether the net effect is positive or negative is yet unknown at this point. It is certain, however, that this will have an effect on the demand for primary factor inputwithin the country and intermediate input from both within and outside the country. This will also affect the government of other countries through the increase/reduction of total import tariff value. Within the country itself, aside from the feedback effect to the governmentthrough the indirect tax, a change to primary factor input demand affects factor income payment to households, corporate, and the government. This in turn affects these institutions' consumption of goods and services as well as saving; which then affects the production activities again, and the whole cycle repeats itself until the effect is no longer significantly felt.[34]

The second recycling mechanism in which the government shows its "generosity" to low-income households will immediately increase their income. With the increase in income,

[34] The stability of this system has been proven by Leontief through his I-O table which shows that marginal propensity to consume is less than one. Anecdotally, these changes will eventually, literally "run out of steam" in which a new equilibrium is achieved.

households can then increase their spending, and to a lesser extent saving, although this is somewhat dampened by the introduction of an additional tax, i.e. carbon tax. This change, however, will directly affect production activities within the country as well as abroad through import demand. This change in production activities then follows a similar a similar path as the first recycling mechanism. A slight difference arises in this mechanism with a more direct effect to households abroad, due to the existence of remittance, saving-investment account. Note that for the former, which also applies as well to the first recycling mechanism, changes are felt directly through remittance only if remittances are sent, not received. As to the latter, the change in saving-investment affects both production activities within the country and abroad. Financial transfer between saving-investment in different countries, however, is not affected.[35]

Lastly, the third recycling mechanism is done by reducing indirect tax, which is effectively the equivalent of giving a subsidy, proportional to the industrial size in term of total value output. The rate of indirect tax reduction, i.e. negative indirect tax, is the same for all industrial sectors within the country although the nominal would then differ accordingly. This “assistance” is somewhat dampened for carbon-intensive industries but could potentially be beneficial to other less-polluting sectors. The impact flow to the economy follows a similar pattern as in the first mechanism. However, the magnitude of the impact may significantly differ due to its direct nature in the production activities of commodities. Theoretically, the double-dividend hypothesis, if it exists, should appear more prominently through this mechanism as it supposedly creates a less distortionary tax system in the economy. Whether this holds true, running the numbers is required as it will be discussed in the next section.

One final note with regards to the recycling mechanisms is the fact that different combinationsof these mechanisms are possible. Indeed, it unlikely that in the real world situation, a government will choose to adopt solely one of these mechanisms. Accordingly, policy simulations conducted in the following section take this into account and create a number of combinations.

## 5.1 Policy Simulation Scenarios

With regards to policy simulations, this study focuses on the economic impact of carbon tax policies. This is done as even with only a single instrument, i.e. carbon tax, there

[35] Admittedly, this is more of a technical limitation issue of the model than a real world limitation.

are many ways in which this policy can be implemented and modeled. The simulations of the model are basically grouped into two scenarios based on how each is implemented, namely symmetric and asymmetric policies. A symmetric policy simply means that the chosen policy is implemented across the board in all six countries. In contrast, an asymmetric policy means that the chosen policy is only implemented in one or few countries. Though it may seems redundant to distinguish these two categories, due to the nature of the database and model of the IRSA-ASEAN, a change in one or more countries immediately affects the remaining countries albeit mainly through trade. In other words, here lies the distinction between multi-country CGE models, e.g. IRSA-ASEAN model, with multiple countries CGE models, e.g. country-specific CGE model.[36]

Aside from the two broad scenarios mentioned previously, there are four recycling mechanisms to the policy that are explored as well. These mechanisms deal with the revenue generated from the carbon tax policy implemented by the respective government as explained previously. The first recycling mechanism assumes that the government retains all the revenue generated and thereby increases its consumption proportionally where the total increase equals the carbon tax revenue. Note that whenever each government obtains this revenue, it "recycles" the entire revenue back to the economy through increased government consumption. In other words, none of the revenue goes into government saving.

The second mechanism assumes that the government redistributes some of the revenue back to households in the form of a direct cash transfer to improve social welfare. In this variant, in order to conform to the real world, the government only redistributes cash to those of low income households in both rural and urban areas. Furthermore, transfer shares between rural-low and urban-low income households are weighted based on the poverty incidence, i.e. percentage of population under the national poverty line. Effectively, with greater poverty incidence in rural areas, low income households in these areas receive a greater share of the cash transfer compared to low income households in urban areas. Logically, of course, high-income households in both rural and urban areas do not receive these cash transfers.

Meanwhile, the third variant assumes that the government uses part of the carbon tax revenue to reduce other distortionary taxes in order to achieve a double dividend. In the IRSA-ASEAN model, the respective government proportionally redistributes the revenue

[36] In the asymmetric simulations, only Indonesia imposes a carbon tax. This is in line with Indonesia being at the forefront in the region for climate change mitigation through its announced commitment.

obtained back to the industries through a negative indirect tax. This scheme is intended to achieve a less distortionary tax system, although for some industries where indirect tax already low, this scheme actually creates a new subsidy from the government to those sectors. The fourth and final mechanism combines the second and third mechanisms in which the government redistributes the revenue generated back to both households and industries.

Also, due to technical limitation of the model when it comes to intermediate input substitution, there are two additional scenarios in which technological change is treated exogenously to illustrate possible outcomes from efficiency gain in the energy sector. These technological changes are 10 percent efficiency gain of coal use and 10 percent efficiency gain of oil use. The carbon tax itself is set at USD 20 per ton of $CO_2$ emissions following the much cited work of Frankhauser (1992) fossil fuel usage, i.e. coal, petroleum products, and gas.[37]

Lastly, all of the above simulations are also conducted with a final variation in which the carbon tax is set at a lower rate of USD 10 per ton of $CO_2$ emissions. This is done for two reasons, namely to see the carbon tax elasticity and overcome a technical limitation arising from the third recycling mechanism. The technical limitation occurs as the net industrial tax in the selected countries are relatively small compared to the revenue generated from the carbon tax at such a high rate that it is impossible[38] to recycle anything above 25 percent of the revenue generated. As such, the following lists the various simulations conducted.[39]

<u>Scenario 1: Symmetrical Carbon Tax Policies</u>

A USD 20 per ton of $CO_2$ emissions tax in all six countries:

1a. Each government retains all carbon tax revenue to increase its consumption;

1b. Each government retains75 percent of the revenue to increase its consumption and redistributes 25 percent back to low-income households in rural and urban areas.

1c. Each government retains 75 percent of the revenue to increase its consumption and redistributes 25 percent to industries; and

[37] Oil and Gas as defined in Lee (2008) are assumed to be used solely as feedstock such that their use does not emit $CO_2$.
[38] This is in term of running the program using GAMS to achieve convergence. In other words, the model cannot be solved.
[39] All this simulations help to test the robustness of the model and their results are shown; however, not all results will be discussed in details as it would be redundant to do so.

1d. Each government retains 75 percent of the revenue to increase its consumption and redistributes 12.5 percent to households as well as 12.5 percent to industries.

Scenario 2: Asymmetrical Carbon Tax Policies

A USD 20 per ton of $CO_2$ emissions tax in Indonesia:

2a. Indonesian government retains all carbon tax revenue to increase its consumption;

2b. Indonesian government retains 75 percent of the revenue to increase its consumption and redistributes 25 percent back to low-income households in rural and urban areas.

2c. Indonesian government retains 75 percent of the revenue to increase its consumption and redistributes 25 percent to industries; and

2d. Indonesian government retains 75 percent of the revenue to increase its consumption and redistributes 12.5 percent to households as well as 12.5 percent to industries.

Scenario 3: Symmetrical Carbon Tax Policies

A USD 20 per ton of $CO_2$ emissions tax with 10 percent efficiency gain in the use of coal in all six countries. The four recycling mechanisms remain the same.

Scenario 4: Symmetrical Carbon Tax Policies

A USD 20 per ton of $CO_2$ emissions tax with 10 percent efficiency gain in the use of oil in all six countries. The four recycling remain the same.

Following the final variation with the implementation of a USD 10 tax per ton of $CO_2$ emissions, these subsequent scenarios are also conducted:

Scenario 5: Symmetrical Carbon Tax Policies

A USD 10 per ton of $CO_2$ emissions tax in all six countries:

5a. Each government retains all carbon tax revenue to increase its consumption;

5b. Each government retains 50 percent of the revenue to increase its consumption and redistributes 50 percent back to low-income households in rural and urban areas.

5c. Each government retains 50 percent of the revenue to increase its consumption and redistributes 50 percent to industries; and

5d. Each government retains none of the revenue to increase its consumption and redistributes 50 percent to households as well as 50 percent to industries.

Scenario 6: Asymmetrical Carbon Tax Policies

A USD 10 per ton of $CO_2$ emissions tax in Indonesia:

6a. Indonesian government retains all carbon tax revenue to increase its consumption;

6b. Indonesian government retains 50 percent of the revenue to increase its consumption and redistributes 50 percent back to low-income households in rural and urban areas.

6c. Indonesian government retains 50 percent of the revenue to increase its consumption and redistributes 50 percent to industries; and

6d. Indonesian government retains none of the revenue to increase its consumption and redistributes 50 percent to households as well as 50 percent to industries.

Scenario 7: Symmetrical Carbon Tax Policies

A USD 10 per ton of $CO_2$ emissions tax with 10 percent efficiency gain in the use of coal in all six countries. The four recycling mechanisms remain the same.

Scenario 8: Symmetrical Carbon Tax Policies

A USD 10 per ton of $CO_2$ emissions tax with 10 percent efficiency gain in the use of oil in all six countries. The four recycling remain the same.

## 5.2 Policy Simulation Results

Before looking at the policy impact, it is best to first know where the impact will be and the initial points are. Table 2 shows selected economic indicators and initial values used in the IRSA-ASEAN model, which uses 2004 as its reference year. The majority of these values are derived from GTAP Version 7 Data Base and its corresponding $CO_2$ emission database by Lee (2008). This holds truly for macroeconomic indicators and sectoral disaggregation. However, for the average income per capita, population, and poverty incidence, additional data has been gathered from the ASEAN Statistical Yearbook and the

World Development Indicators, with the closest reference year used in cases where the 2004 data is unavailable.[40]

### Table 7. Selected economic indicators and initial values

| | IDN | MYS | PHL | SGP | THA | VNM |
|---|---|---|---|---|---|---|
| **Macroeconomic Indicators** | | | | | | |
| (in USD million) | | | | | | |
| Private Consumption | 174,751 | 37,373 | 58,936 | 55,286 | 86,874 | 29,139 |
| Government Consumption | 20,035 | 11,641 | 8,754 | 13,911 | 16,129 | 2,798 |
| Fixed Investment | 49,317 | 17,316 | 14,118 | 31,396 | 40,344 | 15,073 |
| Export | 89,212 | 154,873 | 51,491 | 168,038 | 121,174 | 32,660 |
| Import | 78,612 | 106,302 | 48,822 | 161,818 | 102,823 | 36,643 |
| Gross Domestic Product | 254,703 | 114,901 | 84,476 | 106,813 | 161,698 | 43,027 |
| **Sectoral Disaggregation** | | | | | | |
| (in USD million) | | | | | | |
| Agriculture | 33,917 | 6,299 | 10,004 | 304 | 13,590 | 6,405 |
| Manufacture | 96,033 | 72,203 | 31,414 | 29,220 | 68,253 | 22,935 |
| Service | 124,752 | 36,397 | 43,059 | 77,289 | 79,855 | 13,687 |
| **Average Income per Capita** | | | | | | |
| (in USD) | | | | | | |
| Rural-Low | 460 | 1,225 | 215 | | 634 | 212 |
| Rural-High | 1,857 | 3,506 | 1,375 | | 1,531 | 549 |
| Urban-Low | 627 | 1,432 | 220 | 10,031 | 1,194 | 175 |
| Urban-High | 2,812 | 7,052 | 2,514 | 30,785 | 5,447 | 1,389 |
| **Population** | | | | | | |
| (in thousands) | | | | | | |
| Rural | 114,975 | 8,438 | 32,004 | | 44,350 | 60,720 |
| Urban | 101,469 | 16,736 | 51,908 | 4,167 | 20,928 | 21,312 |
| **Poverty Incidence** | | | | | | |
| (in percent) | | | | | | |
| Rural | 21.1 | 13.2 | 41.4 | | 12.6 | 45.0 |
| Urban | 14.4 | 3.8 | 15.0 | | 4.0 | 9.0 |
| **$CO_2$ Emission** | 357,387 | 145,012 | 76,641 | 40,838 | 216,977 | 86,708 |
| (in kiloton) | | | | | | |

[40] This mainly relates to poverty incidence, which is used solely for the purpose of determining the transfer share between rural low income household *vis-à-vis* urban low income household.

Few highlights from Table 7include the relative size of the economy in terms of GDP with Indonesia being the largest followed by Thailand, Malaysia, Singapore, Philippines, and Vietnam. In term of GDP per capita, on the other hand, reveals that Singapore is better off followed by Malaysia, Thailand, Indonesia, Philippines, and Vietnam. With regards to $CO_2$ emission, Indonesia is the highest emitter followed Philippines, Malaysia, Vietnam, Thailand, and Singapore. More interestingly, however, looking at the carbon intensity based on emission per monetary unit value, Vietnam is actually the worst emitter followed by Indonesia, Thailand, Malaysia, Philippines, and Singapore. Consequently, a carbon tax is more likely to affect the economies of Vietnam and Indonesia than those at the other end of the spectrum such as Philippines and Singapore. Whether it is for better or worse, the following simulations results will hopefully provide some insights.

**Table 8. Simulation results of Scenario 1**

| | $CO_2$ | Real GDP | Sectoral Change (%) | | | Household Income (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | % | % | Agri. | Manuf. | Serv. | Rural-Low | Urban-Low | Rural-High | Urban-High |
| **Simulation 1a** | | | | | | | | | |
| Indonesia | -7.59 | -0.41 | -0.54 | -2.16 | 0.96 | -3.53 | -3.49 | -3.06 | -0.99 |
| Malaysia | -8.53 | -0.95 | -0.34 | -1.40 | -0.17 | -2.12 | -2.09 | -1.92 | -1.92 |
| Philippines | -4.66 | 0.59 | -0.09 | -0.42 | 1.49 | -0.86 | -0.33 | -0.29 | 0.09 |
| Singapore | -2.05 | -0.22 | -0.04 | -0.73 | -0.02 | | -0.60 | | -0.81 |
| Thailand | -4.40 | 0.02 | -0.32 | -1.54 | 1.42 | -1.12 | -0.28 | -1.11 | -0.37 |
| Vietnam | -6.29 | 0.57 | -0.39 | -1.33 | 4.21 | -0.37 | 0.87 | -0.08 | 1.78 |
| **Simulation 1b** | | | | | | | | | |
| Indonesia | -7.70 | -0.76 | -0.50 | -2.16 | 0.24 | -0.62 | -2.40 | -3.41 | -1.87 |
| Malaysia | -8.45 | -1.16 | -0.24 | -1.37 | -0.90 | 5.95 | -1.47 | -2.32 | -2.32 |
| Philippines | -4.65 | 0.34 | -0.04 | -0.40 | 0.96 | 5.55 | 0.66 | -0.56 | -0.26 |
| Singapore | -2.05 | -0.30 | -0.03 | -0.73 | -0.13 | | 0.09 | | -0.92 |
| Thailand | -4.44 | -0.30 | -0.26 | -1.51 | 0.72 | 3.19 | 0.48 | -1.53 | -1.08 |
| Vietnam | -6.25 | 0.23 | -0.20 | -1.23 | 2.88 | 3.81 | 2.68 | -0.31 | 1.13 |
| **Simulation 1c** | | | | | | | | | |
| Indonesia | -5.18 | 1.61 | 0.46 | 0.56 | 2.73 | 1.66 | 1.88 | 2.43 | 4.20 |
| Malaysia | -9.44 | -2.01 | -0.64 | -1.98 | -2.30 | -5.65 | -5.34 | -4.02 | -4.02 |
| Philippines | -7.81 | -4.74 | -3.11 | -5.32 | -4.70 | -17.73 | -16.07 | -15.75 | -14.50 |
| Singapore | -4.62 | -3.31 | -0.65 | -3.14 | -3.39 | | -6.82 | | -6.58 |
| Thailand | -6.66 | -2.64 | -1.40 | -3.37 | -2.22 | -10.91 | -9.48 | -10.36 | -8.60 |
| Vietnam | 4.71 | 7.99 | 2.74 | 6.12 | 13.57 | 34.86 | 33.23 | 38.40 | 34.95 |
| **Simulation 1d** | | | | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Indonesia | -6.33 | 0.53 | 0.04 | -0.69 | 1.61 | 0.80 | 0.01 | -0.23 | 1.40 |
| Malaysia | -8.95 | -1.59 | -0.44 | -1.68 | -1.61 | 0.12 | -3.42 | -3.18 | -3.17 |
| Philippines | -6.23 | -2.20 | -1.50 | -2.87 | -1.88 | -6.40 | -7.93 | -8.36 | -7.56 |
| Singapore | -3.35 | -1.82 | -0.33 | -1.94 | -1.78 | | -3.42 | | -3.79 |
| Thailand | -5.55 | -1.47 | -0.82 | -2.44 | -0.76 | -3.96 | -4.57 | -6.01 | -4.90 |
| Vietnam | -0.47 | 4.72 | 1.98 | 2.94 | 8.99 | 19.15 | 17.85 | 18.53 | 17.81 |

Table 8 shows the results of Scenario 1, the implementation of a carbon tax at USD 20 per ton of $CO_2$ emissions on all countries. Overall, the exception of Vietnam, implementing a carbon tax with any variants reduces carbon emissions. However, this gain for the environment comes at a cost in terms of contraction in the GDP as well as household income reduction. Redistributing revenue generated to low-income households appears to alleviate the cost associated with the rising price of energy; but this comes at a cost in terms of greater GDP reduction.

More interestingly is how a carbon tax affects each country differently. Determining which countries stand to gain the most from a carbon tax scheme is not as clear cut as expected as it really depends on how the revenue generated will be redistributed. For Indonesia, a carbon tax has an adverse effect on the economy. However, should the revenue be redistributed back to the industry, Indonesia actually has a chance to gain from implementing such a scheme. In fact, redistributing the revenue back to the industry has a positive effect in terms of rising household income better than a direct transfer to low-income households.

Malaysia and Singapore, on the other hand, exhibit a similar pattern to each other that is in opposite to the Indonesian pattern. Although beneficial in terms of environmental improvement, the cost comes at a contraction to their respective economy. In few words, Malaysia and Singapore almost have no other incentive for implementing a carbon tax in their countries aside from environmental gain.

For Philippines, the pattern is somewhat different in which the best outcome for the country comes from the government keeping all the revenues to itself. Although redistributing some of the revenue gained back to low-income households will not hurt the economy as much either. This is consistent as Philippines does not subsidize its energy sector. As such, it can be assumed that this sector is already running as efficiently as possible. Introducing too many changes to this sector actually creates distortion to the economy that would have an adverse effect to its economy. Thailand exhibits a similar pattern as Philippines although in a lesser extent.

Vietnam is actually the country that would most likely gain from implementing a carbon tax. In all simulations, the net outcome is positive. This might not reflect so much on Vietnamese efficiency as it does on Vietnamese economic development. In terms of economic development, Vietnam is relatively lagging behind the other countries, however, this actually creates a situation in which Vietnam's economy has more room to grow and gain from a carbon tax scheme that is not enjoyed by the other countries. Admittedly, the household income gain in the third variant might seem somewhat exaggerated. However, this does not change the fact that Vietnam consistently gain from implementing a carbon tax scheme in all simulations.[41]

Lastly, Table 8 shows clearly the regressive nature of a carbon tax in Indonesia, Malaysia, Philippines and, to a lesser extent, Thailand. This phenomenon is not so much so evident in Singapore and Vietnam although those with the lowest income are still likely to pay from the implementation of a carbon tax. Thus, this implies that equity should be a major consideration when each government considers implementing such a tax. Although cash transfers to low-income households may not be a better solution, it would make public acceptance of such policy much more tolerable as improvement to the environment is not as quickly felt as a reduction in one's income.

Meanwhile, Table 9 provides the result of implementing a carbon solely in Indonesia. The results do not differ significantly with the previous table, however, it emphasizes the possibility that Indonesia could still actually gain from implementing a carbon tax unilaterally. This has a serious policy implication for Indonesia as it shows that Indonesia can gain or lose from implementing a carbon tax regardless of whether the other countries do so or not. The more important question for Indonesia is how it chooses to redistribute the income. In this regard, the greatest benefit from implementing a carbon tax scheme in the country arises when Indonesia redistributes the income back to the industrial sector, which would in turn make its industrial sector more competitive despite the added new tax.

[41] One final note of Vietnam, in May 2008, GTAP released version 7.1 of the database in which a new I-O table for Vietnam is introduced. Due to time constraint, the data has not been incorporated in this model as it is unlikely to change the final conclusion.

## Table 9. Simulation results of Scenario 2

| | $CO_2$ | Real GDP | Sectoral Change (%) | | | Household Income (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | % | % | Agri. | Manuf. | Serv. | Rural-Low | Urban-Low | Rural-High | Urban-High |
| **Simulation 2a** | | | | | | | | | |
| Indonesia | -7.08 | 0.05 | -0.34 | -1.70 | 1.49 | -2.27 | -2.21 | -1.82 | 0.16 |
| Malaysia | 0.01 | -0.01 | * | -0.01 | * | -0.02 | -0.02 | -0.02 | -0.02 |
| Philippines | * | * | * | * | * | -0.01 | -0.01 | -0.01 | -0.01 |
| Singapore | -0.03 | * | * | 0.01 | * | | -0.02 | | -0.07 |
| Thailand | * | -0.01 | * | -0.01 | -0.01 | -0.02 | -0.02 | -0.02 | -0.02 |
| Vietnam | -0.13 | -0.12 | -0.05 | -0.10 | -0.17 | -0.34 | -0.27 | -0.39 | -0.29 |
| **Simulation 2b** | | | | | | | | | |
| Indonesia | -7.19 | -0.30 | -0.30 | -1.69 | 0.77 | 0.65 | -1.11 | -2.15 | -0.70 |
| Malaysia | 0.01 | -0.01 | * | -0.01 | * | -0.02 | -0.02 | -0.02 | -0.02 |
| Philippines | * | * | * | * | * | -0.01 | -0.01 | -0.01 | -0.01 |
| Singapore | -0.03 | * | * | * | -0.01 | | -0.02 | | -0.07 |
| Thailand | * | -0.01 | * | -0.01 | -0.01 | -0.02 | -0.02 | -0.02 | -0.02 |
| Vietnam | -0.13 | -0.12 | -0.05 | -0.10 | -0.18 | -0.34 | -0.27 | -0.39 | -0.29 |
| **Simulation 2c** | | | | | | | | | |
| Indonesia | -6.93 | * | -0.21 | -1.05 | 0.88 | -2.78 | -2.68 | -2.04 | 0.05 |
| Malaysia | 0.01 | -0.01 | * | -0.01 | * | -0.02 | -0.02 | -0.01 | -0.01 |
| Philippines | * | * | * | * | * | -0.01 | -0.01 | -0.01 | * |
| Singapore | -0.03 | * | * | 0.02 | * | | -0.01 | | -0.05 |
| Thailand | * | -0.01 | * | -0.01 | * | -0.02 | -0.02 | -0.02 | -0.01 |
| Vietnam | -0.13 | -0.11 | -0.05 | -0.10 | -0.17 | -0.33 | -0.26 | -0.37 | -0.28 |
| **Simulation 2d** | | | | | | | | | |
| Indonesia | -7.06 | -0.15 | -0.25 | -1.37 | 0.83 | -1.06 | -1.89 | -2.10 | -0.33 |
| Malaysia | 0.01 | -0.01 | * | -0.01 | * | -0.02 | -0.02 | -0.01 | -0.01 |
| Philippines | * | * | * | * | * | -0.01 | -0.01 | -0.01 | -0.01 |
| Singapore | -0.03 | * | * | 0.01 | * | | -0.02 | | -0.06 |
| Thailand | * | -0.01 | * | -0.01 | * | -0.02 | -0.02 | -0.02 | -0.02 |
| Vietnam | -0.13 | -0.11 | -0.05 | -0.10 | -0.17 | -0.34 | -0.27 | -0.38 | -0.28 |

* - Neglible Value

**Table 10. Simulation results of Scenario 5**

| | $CO_2$ | Real GDP | Sectoral Change (%) | | | Household Income (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | % | % | Agri. | Manuf. | Serv. | Rural-Low | Urban-Low | Rural-High | Urban-High |
| **Simulation 5a** | | | | | | | | | |
| Indonesia | -3.96 | -0.15 | -0.25 | -1.06 | 0.58 | -1.71 | -1.69 | -1.46 | -0.39 |
| Malaysia | -4.46 | -0.45 | -0.17 | -0.69 | -0.03 | -1.05 | -1.03 | -0.94 | -0.94 |
| Philippines | -2.48 | 0.32 | -0.04 | -0.21 | 0.78 | -0.40 | -0.13 | -0.12 | 0.08 |
| Singapore | -1.05 | -0.10 | -0.02 | -0.36 | -0.01 | | -0.30 | | -0.40 |
| Thailand | -2.23 | 0.04 | -0.15 | -0.77 | 0.75 | -0.56 | -0.12 | -0.55 | -0.15 |
| Vietnam | -3.34 | 0.36 | -0.17 | -0.64 | 2.28 | -0.13 | 0.50 | 0.01 | 0.97 |
| **Simulation 5b** | | | | | | | | | |
| Indonesia | -4.07 | -0.51 | -0.21 | -1.06 | -0.17 | 1.31 | -0.55 | -1.82 | -1.30 |
| Malaysia | -4.36 | -0.67 | -0.06 | -0.66 | -0.80 | 7.38 | -0.39 | -1.35 | -1.36 |
| Philippines | -2.47 | 0.05 | 0.01 | -0.19 | 0.23 | 6.16 | 0.88 | -0.39 | -0.28 |
| Singapore | -1.06 | -0.18 | -0.01 | -0.36 | -0.12 | | 0.40 | | -0.51 |
| Thailand | -2.26 | -0.30 | -0.09 | -0.73 | 0.04 | 3.85 | 0.66 | -0.97 | -0.89 |
| Vietnam | -3.29 | * | 0.03 | -0.53 | 0.88 | 4.18 | 2.37 | -0.23 | 0.29 |
| **Simulation 5c** | | | | | | | | | |
| Indonesia | -1.60 | 1.87 | 0.73 | 1.69 | 2.33 | 3.60 | 3.81 | 4.16 | 4.90 |
| Malaysia | -5.39 | -1.56 | -0.48 | -1.30 | -2.25 | -4.74 | -4.44 | -3.14 | -3.13 |
| Philippines | -5.60 | -5.15 | -3.13 | -5.22 | -5.57 | -17.68 | -16.27 | -15.96 | -14.88 |
| Singapore | -3.64 | -3.23 | -0.63 | -2.79 | -3.41 | | -6.59 | | -6.25 |
| Thailand | -4.48 | -2.68 | -1.23 | -2.62 | -2.97 | -10.62 | -9.57 | -10.05 | -8.61 |
| Vietnam | 6.98 | 7.73 | 2.78 | 6.76 | 11.67 | 36.29 | 33.80 | 39.87 | 35.12 |
| **Simulation 5d** | | | | | | | | | |
| Indonesia | -1.72 | 1.50 | 0.76 | 1.68 | 1.56 | 6.68 | 4.96 | 3.78 | 3.96 |
| Malaysia | -5.29 | -1.78 | -0.37 | -1.27 | -3.02 | 3.61 | -3.80 | -3.56 | -3.55 |
| Philippines | -5.59 | -5.42 | -3.07 | -5.20 | -6.12 | -11.34 | -15.29 | -16.24 | -15.25 |
| Singapore | -3.64 | -3.31 | -0.62 | -2.79 | -3.52 | | -5.91 | | -6.37 |
| Thailand | -4.51 | -3.01 | -1.17 | -2.58 | -3.70 | -6.32 | -8.82 | -10.47 | -9.33 |
| Vietnam | 7.02 | 7.38 | 2.92 | 6.84 | 10.36 | 41.23 | 36.00 | 39.82 | 34.54 |

* - Neglible Value

Meanwhile, Table 10 shows the result of implementing a USD 10 tax per ton of $CO_2$ emission across all countries. What is most interesting from this scenario is the fact that halving the carbon tax does not necessarily entail the same proportion of $CO_2$ emission reduction. This implies that there is return diminishing return in terms of environmental gain. Furthermore, in term of economic contraction, the cost associated with implementing a carbon tax at a lower rate appears to be much lower. Thus, a fundamental implication to these is the possibility of an existing *optimal* carbon price.[42]

In Appendices2, 3, 5, and 6, technological changes are introduced in the form of efficiency gain in terms of coal and petroleum products use by 10 percent. These technological improvements are introduced to compensate the lack of intermediate input substitution in the model. As such, these technological changes are introduced exogenously. In reality, these technological improvements can be seen as an industrial response to the implementation of a carbon tax in which now industries have an incentive to reduce their use of coal and petroleum products while maintaining the same amount of output, i.e. efficiency gain.

The results in the appendices show that improvements in the use of coal and petroleum products will have positive effects to the economy. The GDP contraction in all countries due to the implementation of the carbon tax decreases. In cases where GDP actually expands, improvements in energy use further increases GDP growth. Of course, all of these are results are not quite so surprising as they are very much logical. Two important highlights to note are: first, a 10 percent efficiency gain in the use of petroleum products creates a larger positive effect on the economy than a 10 percent efficiency gain the use of coal; and second, efficiency gain in the use of coal actually increases the likelihood of the rebound phenomena from occurring.

Following those observations, a more efficient use of petroleum products may encourage households and industries to switch from the “dirtier” coal to petroleum products. Aside from the economic gain, this also improves the gain in term of $CO_2$ emission reduction. Lastly, although efficiency in the use of coal has the possibility of creating a rebound effect, the phenomena is unlikely to occur in the region, barring few special cases in Vietnam. It appears that a carbon tax at both USD 10 and USD 20 per ton of $CO_2$ emission is more than sufficient to prevent this phenomenon from occurring. Considering the results, a USD 10 tax per of $CO_2$ emission might be a better choice than a USD 20 one. Even at the worst case scenarios, the economic contractions may be small enough to be tolerable, while their environmental benefits may compensate the losses.

[42] Further studies are required to find the actual optimal price for carbon tax, which is beyond the scope of this study.

## 6.0 CONCLUSIONS

The main goal of this paper is to understand the impact of coordinated and non-coordinated carbon tax policies on the economy and environmental performance of each country within ASEAN. This question is a relevant one, since, first, though it has been slow, the establishment of ASEAN community will most likely be happening soon in which synchronization of various policies will be required; and second, some of ASEAN member countries are among the top polluters of $CO_2$ emission so much so that they have to react soon to control their emission.

To be able to answer the above question, this paper builds a multi-country computable general equilibrium model (CGE) for ASEAN, known as the IRSA-ASEAN. Before doing so, this paper constructs the ASEAN-SAM as the main dataset for the CGE. This ASEAN-SAM is one of the first comprehensive data systems available for ASEAN, and hence the IRSA-ASEAN becomes one of the more comprehensive economic models for the region. There are several weaknesses of the data system and model built in this paper. The two most important ones are as follows. First, it is that the accuracy of the ASEAN-SAM is debatable, mainly due to the uncertainty on the reliability of some of its data sources. For example it remains to be seen how reliable are information available for Vietnam in GTAP version 7 or in any statistical data system. Second, parameters utilized in this CGE do not come from rigorous estimation works due to the unavailability of those works. There are many CGE models for Indonesia, some of which have produced reliable analysis, and so adopting parameters from those models is most likely to be appropriate. However, this is not true for other ASEAN countries. Hence, it remains to be seen the quality of parameters adopted in the CGE for this paper.

Taking into account those weaknesses, several conclusions, however, still can be drawn. First, in general, a carbon tax is an effective way of reducing carbon emissions. For most ASEAN countries, even if the revenues from this tax are recycled back to the economy, it does not seem to induce a rebound effect, i.e. more use of energy and so more emission.

Second, it is not obvious that ASEAN countries could always expect a double-dividend phenomenon to happen when they implement a combination of carbon tax and recycling policy. It is quite likely that implementing a carbon tax will contract the economies of these countries. Recycling the carbon tax revenue, though it is of outmost importance in terms of softening the impact of this policy on economic growth and household incomes, does not always induce a double dividend phenomenon. Some of the main reasons for this are as follows. Current effective tax rates for the higher polluter countries, namely Indonesia and Vietnam, have been relatively low. And so, there is much room to reduce other taxes to compensate the effects of carbon tax policy.

Third, as each country responds differently to the implementation of a carbon tax, particularly with regards to the revenue re-distribution, an across the board implementation will create “winners” and “losers”. Indonesia gain could, though not always, reap the greatest benefit by implementing a carbon tax and redistributing the revenue back to the economy. Malaysia and Singapore, on the other hand, are the likely “losers” as the implementation of a carbon tax creates an additional distortionary tax with the only possible gain in terms of environmental improvement. Philippines and Thailand stand to gain depending what the respective government does with the revenue, albeit the gains are not as clear. Vietnam is a potential “winner”, although this would more likely reflect the development level of Vietnam, which has more growth potential compared to the other countries, as to the efficiency of its economy.

Fourth, results show that there is a diminishing marginal return in the implementation of a carbon tax in term of environmental improvement with an increasing cost in term of economic reduction. This suggests that an optimal carbon price could exist in countries where economic contraction cannot be avoided, but the environmental gain could possibly compensate for the loss. Other methods, such as macroeconometric modeling, might be more appropriate to determine the exact level for such an optimum price.

Fifth, efficiency gain as a response from the industrial sector might alleviate the adverse effects of the additional tax as well. Finally, for Indonesia, which is the highest $CO_2$ emission among ASEAN members and so is required to response soon, whether other countries in the region implement a carbon tax or not, it does not change outcomes by much. And so, waiting for such a regional cooperation to happen is unnecessary and domestic considerations should be put first.

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## Appendix 1. Transactions in a Representative Region

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Imported Commod | Domestic Commod | Activities | Factors | Regional Household | Private Household | Trade Taxes | Import Sales Taxes | Domestic Sales Tax | Factor Taxes | Production Taxes | Direct Taxes | Govt | Capital | Import Margins | Export Margins | Rest of World |
| 1 | Imported Commodities | | | Intermediate Inputs | | | Private demand | | | | | | | Government demand | Investment demand | | | |
| 2 | Domestic Commodities | | | Intermediate inputs | | | Private demand | | | | | | | Government demand | Investment demand | | Exports of Transport Services | Exports of Goods and Services |
| 3 | Activities | | Supply matrix | | | | | | | | | | | | | | | |
| 4 | Factors | | | Payments to Factors | | | | | | | | | | | | | | |
| 5 | Regional Household | | | | Distributed Factor Incomes | | | Import Duties and Export duties | Import Sales Taxes | Domestic Sales Taxes | Factor Use Taxes | Production Taxes | Income Taxes | | | | | |
| 6 | Private Household | | | | | Private Household income | | | | | | | | | | | | |
| 7 | Trade Taxes | Import Duties | Export duties | | | | | | | | | | | | | | | |
| 8 | Import Sales Taxes | | | Sales Taxes - Imports | | | Sales Taxes - Imports | | | | | | | Sales Taxes - Imports | Sales Taxes - Imports | | | |
| 9 | Domestic Sales Tax | | | Sales Taxes - Domestic | | | Sales Taxes - Domestic | | | | | | | Sales Taxes - Domestic | Sales Taxes - Domestic | | | |
| 10 | Factor Taxes | | | Factor Use Taxes | | | | | | | | | | | | | | |
| 11 | Production Taxes | | | Production Taxes | | | | | | | | | | | | | | |
| 12 | Direct Taxes | | | | Factor Income Taxes | | | | | | | | | | | | | |
| 13 | Government | | | | | Government income | | | | | | | | | | | | |
| 14 | Capital | | | | Depreciation | Savings | | | | | | | | | | | Trade balance | Trade balance |
| 15 | Import Margins | Transport margins on imports | | | | | | | | | | | | | | | | |
| 16 | Export Margins | | | | | | | | | | | | | | | Imports of transport services | | |
| 17 | Rest of World | Imports of Goods and Services | | | | | | | | | | | | | | | | |

*Source: McDonald and Thierfelder (2004)*

## Appendix 2. Simulation Results of Scenario 3

| | $CO_2$ | Real GDP | Sectoral Change (%) | | | Household Income (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | % | % | Agri. | Manuf. | Serv. | Rural-Low | Urban-Low | Rural-High | Urban-High |
| **Simulation 3a** | | | | | | | | | |
| Indonesia | -8.29 | -0.29 | -0.47 | -2.03 | 1.10 | -3.32 | -3.28 | -2.85 | -0.80 |
| Malaysia | -9.11 | -0.85 | -0.29 | -1.31 | -0.05 | -2.02 | -1.97 | -1.80 | -1.80 |
| Philippines | -5.91 | 0.66 | -0.03 | -0.36 | 1.57 | -0.63 | -0.14 | -0.13 | 0.22 |
| Singapore | -2.04 | -0.21 | -0.04 | -0.72 | -0.02 | | -0.59 | | -0.79 |
| Thailand | -4.93 | 0.15 | -0.26 | -1.40 | 1.56 | -0.94 | -0.07 | -0.91 | -0.14 |
| Vietnam | -7.66 | 0.74 | -0.26 | -1.17 | 4.41 | -0.48 | 0.83 | -0.29 | 1.71 |
| **Simulation 3b** | | | | | | | | | |
| Indonesia | -8.40 | -0.64 | -0.43 | -2.03 | 0.38 | -0.44 | -2.20 | -3.20 | -1.67 |
| Malaysia | -9.03 | -1.06 | -0.19 | -1.28 | -0.78 | 6.01 | -1.36 | -2.19 | -2.20 |
| Philippines | -5.90 | 0.41 | 0.02 | -0.34 | 1.04 | 5.69 | 0.84 | -0.40 | -0.12 |
| Singapore | -2.04 | -0.29 | -0.03 | -0.72 | -0.13 | | 0.10 | | -0.90 |
| Thailand | -4.96 | -0.17 | -0.21 | -1.37 | 0.86 | 3.35 | 0.68 | -1.33 | -0.85 |
| Vietnam | -7.62 | 0.40 | -0.07 | -1.07 | 3.09 | 3.64 | 2.61 | -0.52 | 1.06 |
| **Simulation 3c** | | | | | | | | | |
| Indonesia | -5.82 | 1.80 | 0.55 | 0.76 | 2.95 | 2.08 | 2.31 | 2.85 | 4.58 |
| Malaysia | -10.00 | -1.90 | -0.59 | -1.88 | -2.17 | -5.52 | -5.21 | -3.89 | -3.88 |
| Philippines | -9.01 | -4.60 | -3.00 | -5.19 | -4.55 | -17.32 | -15.71 | -15.42 | -14.20 |
| Singapore | -4.61 | -3.30 | -0.65 | -3.12 | -3.38 | | -6.80 | | -6.56 |
| Thailand | -7.19 | -2.51 | -1.33 | -3.24 | -2.08 | -10.70 | -9.26 | -10.14 | -8.36 |
| Vietnam | 3.12 | 8.13 | 2.77 | 6.31 | 13.70 | 33.80 | 32.56 | 36.95 | 34.16 |
| **Simulation 3d** | | | | | | | | | |
| Indonesia | -7.01 | 0.68 | 0.11 | -0.54 | 1.77 | 1.08 | 0.30 | 0.06 | 1.68 |
| Malaysia | -9.52 | -1.48 | -0.39 | -1.58 | -1.48 | 0.21 | -3.30 | -3.05 | -3.05 |
| Philippines | -7.45 | -2.10 | -1.41 | -2.77 | -1.77 | -6.12 | -7.66 | -8.10 | -7.34 |
| Singapore | -3.34 | -1.81 | -0.33 | -1.93 | -1.77 | | -3.40 | | -3.78 |
| Thailand | -6.07 | -1.34 | -0.76 | -2.31 | -0.62 | -3.78 | -4.36 | -5.80 | -4.66 |
| Vietnam | -1.99 | 4.86 | 2.06 | 3.08 | 9.14 | 18.59 | 17.50 | 17.79 | 17.41 |

Symmetric Carbon Tax at USD 20 per ton of $CO_2$ Emission

10% Energy Efficiency in Coal Use

## Appendix 3. Simulation Results of Scenario 4

| | $CO_2$ | Real GDP | Sectoral Change (%) | | | Household Income (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | % | % | Agri. | Manuf. | Serv. | Rural-Low | Urban-Low | Rural-High | Urban-High |
| **Simulation 4a** | | | | | | | | | |
| Indonesia | -12.49 | 1.10 | 0.37 | -0.78 | 2.74 | -1.44 | -1.40 | -0.93 | 1.19 |
| Malaysia | -13.28 | 0.51 | 0.47 | -0.23 | 2.00 | -0.74 | -0.66 | -0.32 | -0.32 |
| Philippines | -10.58 | 1.34 | 0.50 | 0.08 | 2.46 | 0.32 | 0.79 | 0.76 | 1.10 |
| Singapore | -9.96 | 0.91 | 0.51 | 0.51 | 1.06 | | 0.53 | | 0.37 |
| Thailand | -9.80 | 1.53 | 0.96 | -0.50 | 3.36 | -0.19 | 1.23 | 0.18 | 1.74 |
| Vietnam | -10.73 | 1.99 | 0.71 | * | 5.93 | 0.85 | 1.83 | 1.07 | 2.67 |
| **Simulation 4b** | | | | | | | | | |
| Indonesia | -12.59 | 0.77 | 0.40 | -0.78 | 2.06 | 1.31 | -0.37 | -1.27 | 0.35 |
| Malaysia | -13.20 | 0.32 | 0.57 | -0.20 | 1.30 | 6.92 | -0.08 | -0.70 | -0.70 |
| Philippines | -10.57 | 1.10 | 0.54 | 0.10 | 1.96 | 6.33 | 1.72 | 0.51 | 0.77 |
| Singapore | -9.96 | 0.83 | 0.52 | 0.51 | 0.96 | | 1.16 | | 0.26 |
| Thailand | -9.82 | 1.22 | 1.02 | -0.47 | 2.70 | 3.87 | 1.95 | -0.22 | 1.06 |
| Vietnam | -10.69 | 1.66 | 0.89 | 0.10 | 4.64 | 4.82 | 3.55 | 0.85 | 2.04 |
| **Simulation 4c** | | | | | | | | | |
| Indonesia | -10.42 | 2.98 | 1.28 | 1.75 | 4.39 | 3.38 | 3.59 | 4.18 | 6.03 |
| Malaysia | -14.10 | -0.50 | 0.18 | -0.79 | -0.06 | -4.11 | -3.78 | -2.35 | -2.34 |
| Philippines | -13.39 | -3.70 | -2.31 | -4.53 | -3.42 | -15.72 | -14.18 | -13.93 | -12.76 |
| Singapore | -12.14 | -1.98 | -0.04 | -1.73 | -2.08 | | -5.27 | | -5.02 |
| Thailand | -11.87 | -1.04 | -0.04 | -2.26 | -0.16 | -9.53 | -7.60 | -8.68 | -6.22 |
| Vietnam | -0.56 | 9.53 | 3.79 | 7.50 | 15.61 | 35.63 | 33.61 | 39.01 | 35.21 |
| **Simulation 4d** | | | | | | | | | |
| Indonesia | -11.40 | 1.97 | 0.89 | 0.58 | 3.34 | 2.62 | 1.87 | 1.70 | 3.42 |
| Malaysia | -13.65 | -0.10 | 0.38 | -0.50 | 0.62 | 1.37 | -1.94 | -1.53 | -1.53 |
| Philippines | -11.98 | -1.30 | -0.81 | -2.22 | -0.74 | -4.97 | -6.44 | -6.89 | -6.15 |
| Singapore | -11.06 | -0.58 | 0.25 | -0.61 | -0.58 | | -2.10 | | -2.42 |
| Thailand | -10.84 | 0.09 | 0.50 | -1.36 | 1.26 | -2.92 | -2.89 | -4.51 | -2.63 |
| Vietnam | -5.38 | 6.16 | 3.01 | 4.25 | 10.83 | 19.98 | 18.43 | 19.36 | 18.36 |

* - Neglible Value

Symmetric Carbon Tax at USD 20 per ton of $CO_2$ Emission

10% Energy Efficiency in Oil Sector

## Appendix 4. Simulation Results of Scenario 6

| | $CO_2$ | Real GDP | Sectoral Change (%) | | | Household Income (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | % | % | Agri. | Manuf. | Serv. | Rural-Low | Urban-Low | Rural-High | Urban-High |
| **Simulation 6a** | | | | | | | | | |
| Indonesia | -3.72 | 0.07 | -0.16 | -0.84 | 0.83 | -1.09 | -1.07 | -0.86 | 0.17 |
| Malaysia | * | * | * | * | * | -0.01 | -0.01 | -0.01 | -0.01 |
| Philippines | * | * | * | * | * | * | * | * | * |
| Singapore | -0.02 | * | * | 0.01 | * | | -0.01 | | -0.03 |
| Thailand | * | * | * | -0.01 | * | -0.01 | -0.01 | -0.01 | -0.01 |
| Vietnam | -0.07 | -0.06 | -0.02 | -0.05 | -0.09 | -0.17 | -0.14 | -0.20 | -0.14 |
| **Simulation 6b** | | | | | | | | | |
| Indonesia | -3.83 | -0.29 | -0.12 | -0.83 | 0.09 | 1.93 | 0.08 | -1.20 | -0.72 |
| Malaysia | * | * | * | * | * | -0.01 | -0.01 | -0.01 | -0.01 |
| Philippines | * | * | * | * | * | * | * | * | * |
| Singapore | -0.02 | * | * | * | * | | -0.01 | | -0.03 |
| Thailand | * | * | * | * | * | -0.01 | -0.01 | -0.01 | -0.01 |
| Vietnam | -0.07 | -0.06 | -0.02 | -0.05 | -0.09 | -0.17 | -0.14 | -0.20 | -0.15 |
| **Simulation 6c** | | | | | | | | | |
| Indonesia | -3.58 | 0.02 | -0.03 | -0.17 | 0.18 | -1.62 | -1.54 | -1.09 | 0.05 |
| Malaysia | 0.01 | * | * | * | * | -0.01 | -0.01 | * | * |
| Philippines | * | * | * | * | * | * | * | * | * |
| Singapore | -0.01 | 0.01 | * | 0.02 | * | | 0.01 | | -0.02 |
| Thailand | * | * | * | * | * | -0.01 | -0.01 | -0.01 | * |
| Vietnam | -0.06 | -0.05 | -0.02 | -0.05 | -0.08 | -0.16 | -0.13 | -0.18 | -0.13 |
| **Simulation 6d** | | | | | | | | | |
| Indonesia | -3.68 | -0.34 | 0.01 | -0.17 | -0.57 | 1.41 | -0.39 | -1.43 | -0.84 |
| Malaysia | 0.01 | * | * | * | * | -0.01 | -0.01 | * | * |
| Philippines | * | * | * | * | * | * | * | * | * |
| Singapore | -0.01 | 0.01 | * | 0.02 | * | | * | | -0.02 |
| Thailand | * | * | * | * | * | -0.01 | -0.01 | -0.01 | * |
| Vietnam | -0.06 | -0.06 | -0.02 | -0.05 | -0.08 | -0.16 | -0.13 | -0.18 | -0.14 |

* - Neglible Value

Asymmetric Carbon Tax at USD 10 per ton of $CO_2$ Emission

## Appendix 5. Simulation Results of Scenario 7

| | $CO_2$ | Real GDP | Sectoral Change (%) | | | Household Income (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | % | % | Agri. | Manuf. | Serv. | Rural-Low | Urban-Low | Rural-High | Urban-High |
| **Simulation 7a** | | | | | | | | | |
| Indonesia | -4.70 | -0.03 | -0.19 | -0.94 | 0.71 | -1.52 | -1.50 | -1.27 | -0.20 |
| Malaysia | -5.05 | -0.35 | -0.11 | -0.60 | 0.09 | -0.95 | -0.93 | -0.82 | -0.83 |
| Philippines | -3.74 | 0.39 | 0.02 | -0.16 | 0.87 | -0.19 | 0.04 | 0.04 | 0.21 |
| Singapore | -1.05 | -0.10 | -0.02 | -0.35 | * | | -0.28 | | -0.39 |
| Thailand | -2.77 | 0.17 | -0.09 | -0.63 | 0.89 | -0.37 | 0.09 | -0.34 | 0.08 |
| Vietnam | -4.74 | 0.53 | -0.04 | -0.48 | 2.49 | -0.28 | 0.45 | -0.24 | 0.89 |
| **Simulation 7b** | | | | | | | | | |
| Indonesia | -4.81 | -0.39 | -0.15 | -0.94 | -0.04 | 1.48 | -0.37 | -1.63 | -1.10 |
| Malaysia | -4.96 | -0.57 | -0.01 | -0.57 | -0.67 | 7.43 | -0.29 | -1.24 | -1.24 |
| Philippines | -3.72 | 0.12 | 0.07 | -0.13 | 0.32 | 6.28 | 1.05 | -0.23 | -0.15 |
| Singapore | -1.05 | -0.18 | -0.01 | -0.34 | -0.11 | | 0.42 | | -0.50 |
| Thailand | -2.80 | -0.17 | -0.04 | -0.60 | 0.18 | 4.01 | 0.87 | -0.77 | -0.65 |
| Vietnam | -4.69 | 0.17 | 0.15 | -0.38 | 1.10 | 3.97 | 2.29 | -0.48 | 0.22 |
| **Simulation 7c** | | | | | | | | | |
| Indonesia | -2.29 | 2.07 | 0.82 | 1.88 | 2.55 | 4.02 | 4.24 | 4.57 | 5.29 |
| Malaysia | -5.97 | -1.45 | -0.42 | -1.21 | -2.12 | -4.62 | -4.31 | -3.02 | -3.01 |
| Philippines | -6.81 | -5.01 | -3.02 | -5.10 | -5.40 | -17.29 | -15.91 | -15.63 | -14.58 |
| Singapore | -3.64 | -3.23 | -0.63 | -2.78 | -3.41 | | -6.57 | | -6.24 |
| Thailand | -5.02 | -2.54 | -1.17 | -2.49 | -2.83 | -10.41 | -9.34 | -9.82 | -8.36 |
| Vietnam | 5.39 | 7.88 | 2.81 | 6.95 | 11.82 | 35.15 | 33.10 | 38.29 | 34.29 |
| **Simulation 7d** | | | | | | | | | |
| Indonesia | -2.41 | 1.69 | 0.85 | 1.87 | 1.79 | 7.08 | 5.38 | 4.19 | 4.36 |
| Malaysia | -5.87 | -1.67 | -0.32 | -1.18 | -2.89 | 3.68 | -3.68 | -3.43 | -3.42 |
| Philippines | -6.79 | -5.27 | -2.96 | -5.07 | -5.95 | -11.03 | -14.95 | -15.90 | -14.94 |
| Singapore | -3.64 | -3.31 | -0.62 | -2.77 | -3.52 | | -5.89 | | -6.35 |
| Thailand | -5.04 | -2.88 | -1.10 | -2.45 | -3.55 | -6.13 | -8.59 | -10.24 | -9.08 |
| Vietnam | 5.43 | 7.54 | 2.94 | 7.04 | 10.52 | 40.02 | 35.27 | 38.25 | 33.72 |

* - Neglible Value

Symmetric Carbon Tax at USD 10 per ton of $CO_2$ Emission

10% Energy Efficiency in Coal Sector

## Appendix 6. Simulation Results of Scenario 8

| | $CO_2$ | Real GDP | Sectoral Change (%) | | | Household Income (%) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | % | % | Agri. | Manuf. | Serv. | Rural-Low | Urban-Low | Rural-High | Urban-High |
| **Simulation 8a** | | | | | | | | | |
| Indonesia | -9.08 | 1.32 | 0.63 | 0.23 | 2.34 | 0.19 | 0.21 | 0.48 | 1.67 |
| Malaysia | -9.50 | 1.01 | 0.66 | 0.45 | 2.19 | 0.27 | 0.34 | 0.61 | 0.61 |
| Philippines | -8.52 | 1.08 | 0.55 | 0.28 | 1.79 | 0.74 | 0.96 | 0.91 | 1.08 |
| Singapore | -9.05 | 1.01 | 0.54 | 0.85 | 1.08 | | 0.81 | | 0.74 |
| Thailand | -7.74 | 1.56 | 1.13 | 0.25 | 2.75 | 0.32 | 1.38 | 0.69 | 1.94 |
| Vietnam | -7.87 | 1.79 | 0.92 | 0.67 | 4.08 | 1.07 | 1.48 | 1.17 | 1.89 |
| **Simulation 8b** | | | | | | | | | |
| Indonesia | -9.17 | 0.97 | 0.66 | 0.22 | 1.63 | 3.05 | 1.28 | 0.14 | 0.80 |
| Malaysia | -9.41 | 0.80 | 0.76 | 0.48 | 1.45 | 8.26 | 0.94 | 0.22 | 0.22 |
| Philippines | -8.51 | 0.83 | 0.60 | 0.30 | 1.27 | 6.89 | 1.91 | 0.65 | 0.74 |
| Singapore | -9.05 | 0.94 | 0.55 | 0.86 | 0.97 | | 1.45 | | 0.64 |
| Thailand | -7.77 | 1.24 | 1.19 | 0.29 | 2.06 | 4.48 | 2.12 | 0.29 | 1.24 |
| Vietnam | -7.81 | 1.44 | 1.11 | 0.77 | 2.72 | 5.18 | 3.25 | 0.93 | 1.24 |
| **Simulation 8c** | | | | | | | | | |
| Indonesia | -7.05 | 3.20 | 1.52 | 2.79 | 3.97 | 5.12 | 5.31 | 5.70 | 6.59 |
| Malaysia | -10.35 | -0.05 | 0.36 | -0.14 | 0.05 | -3.25 | -2.92 | -1.51 | -1.50 |
| Philippines | -11.30 | -4.09 | -2.32 | -4.44 | -4.24 | -15.69 | -14.38 | -14.15 | -13.13 |
| Singapore | -11.23 | -1.90 | -0.02 | -1.41 | -2.10 | | -5.06 | | -4.72 |
| Thailand | -9.80 | -1.06 | 0.12 | -1.52 | -0.86 | -9.27 | -7.69 | -8.40 | -6.23 |
| Vietnam | 1.65 | 9.29 | 3.83 | 8.12 | 13.80 | 37.03 | 34.18 | 40.45 | 35.40 |
| **Simulation 8d** | | | | | | | | | |
| Indonesia | -7.15 | 2.84 | 1.55 | 2.78 | 3.24 | 8.02 | 6.39 | 5.34 | 5.70 |
| Malaysia | -10.25 | -0.26 | 0.47 | -0.11 | -0.69 | 4.66 | -2.32 | -1.90 | -1.89 |
| Philippines | -11.29 | -4.34 | -2.26 | -4.41 | -4.77 | -9.74 | -13.47 | -14.41 | -13.47 |
| Singapore | -11.23 | -1.98 | -0.01 | -1.41 | -2.20 | | -4.44 | | -4.83 |
| Thailand | -9.82 | -1.37 | 0.18 | -1.48 | -1.55 | -5.21 | -6.98 | -8.80 | -6.91 |
| Vietnam | 1.69 | 8.95 | 3.96 | 8.20 | 12.53 | 41.71 | 36.26 | 40.39 | 34.83 |

* - Neglible Value

Symmetric Carbon Tax at USD 10 per ton of $CO_2$ Emission

10% Energy Efficiency in Oil Sector