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Economy-wide Impact of a Carbon Tax in ASEAN

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Abstract

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 CO_2 emission, particularly by implementing a uniform carbon tax across ASEAN. To achieve this goal, this paper uses a multi-country computable general equilibrium (CGE) for ASEAN, known as the Inter-Regional System of Analysis for ASEAN (IRSA-ASEAN) model. 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 Malaysia can potentially gain from the implementation of a carbon tax as it counteracts price distortions due to the existence of energy subsidies in these two countries.

1. Introduction

The scientific evidence is now overwhelming: climate change presents very serious global risks and it demands an urgent global response. Climate change is global in its causes and consequences, and international collective action will be critical in driving an effective, efficient, and equitable response on the scale required. This response will require deeper international cooperation in many areas, most notably in creating price signals and markets for carbon, spurring technology research, development and deployment, and promoting adaptation, particularly for developing countries (Stern, 2006).

Left unaddressed, climate change represents a serious threat to economic wellbeing. The world has now moved beyond the conventional view that economic growth objectives are incompatible with environmental objectives. 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 paper analyzes 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] In order to look at the economy-wide impact of implementing such a tax in terms of environmental improvement, economic growth, and income equity, this paper builds a multi-country computable general equilibrium (CGE) model called the Inter-Regional System Analysis for ASEAN (IRSA-ASEAN).

The first part of this paper provides a brief overview of current environmental issues at the global, regional, and national level with a particular emphasis on Indonesia. The second part provides a brief review of the IRSA-ASEAN model. The third part of this paper 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 paper.

2. 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

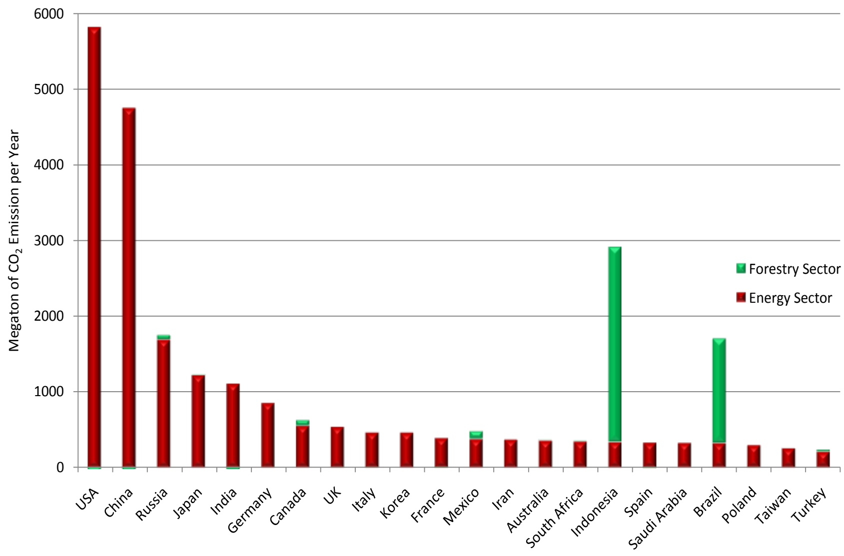
[1] In this paper, the definition of a carbon tax is limited to a levy on the emission of carbon dioxide only; and thus, the term "carbon tax" refers to CO_2 tax and is used interchangeably.
[2] Brunei Darussalam, Cambodia, Lao PDR, and Myanmar are not included due to the severe lack of data.

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 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 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 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.



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

Figure 1. Top Global Emitters of CO_2 in 2004

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 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).

According to the Stern Report (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

[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.

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.

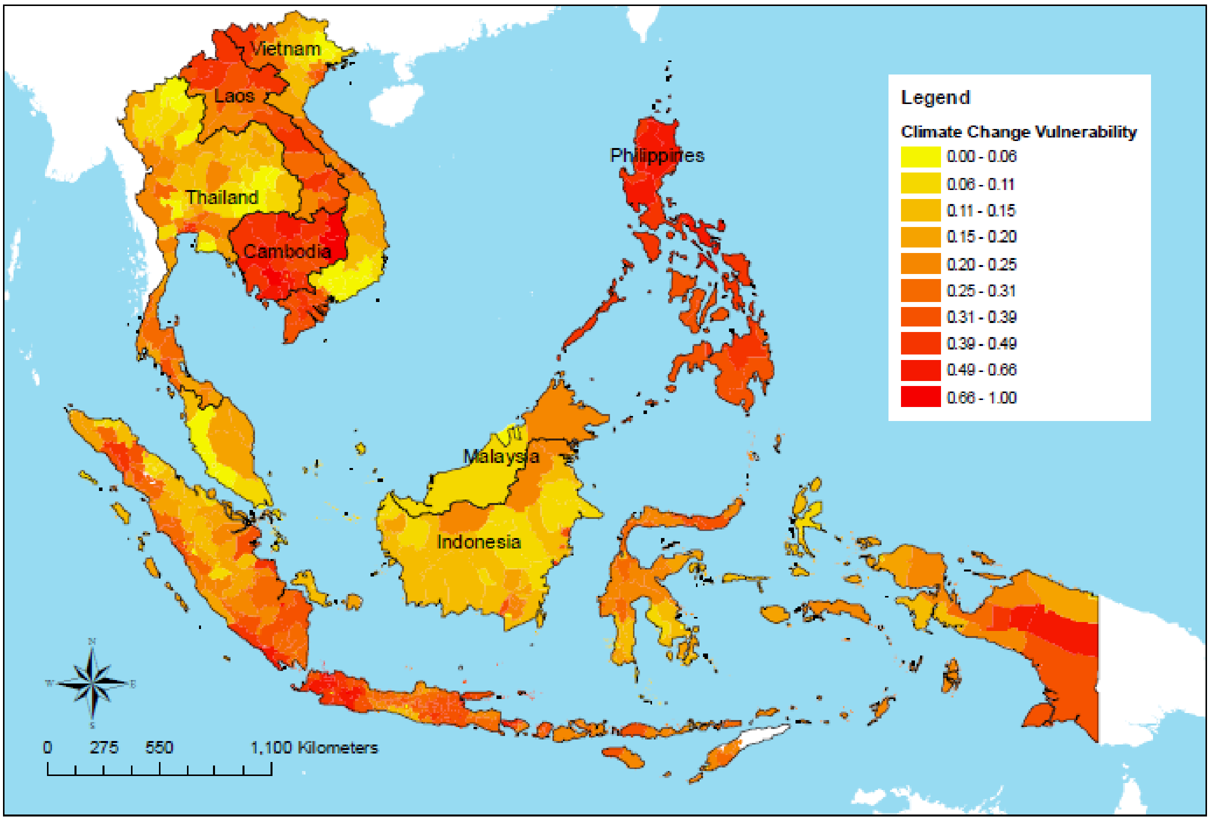
The Copenhagen Accord itself, nevertheless, recognized the scientific view that the increase in global temperature should be below 2 degrees Celsius. It also promised money up to US$100 billion annually by the year 2020 for mitigation and adaptation activities in developing countries. Another positive 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 limitations of what can be achieved on climate change through centralization and multilateralism, 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. However, ASEAN's total CO_2 emission produced from the combustion of fossil fuels, manufacture of cement and gas flaring in 1995 was "only" about 610 megaton of CO_2-equivalent, which increased to about 990 megaton in 2005. The total ASEAN CO_2 emission is still much lower than that of Europe at 6,230 megaton and North America 6,450 megaton (ASEAN, 2009).

Unfortunately, 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.



Source: Yusuf and Francisco (2009)

Figure 2. Climate Change Vulnerability Map of Southeast Asia in 2005

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 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

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

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).

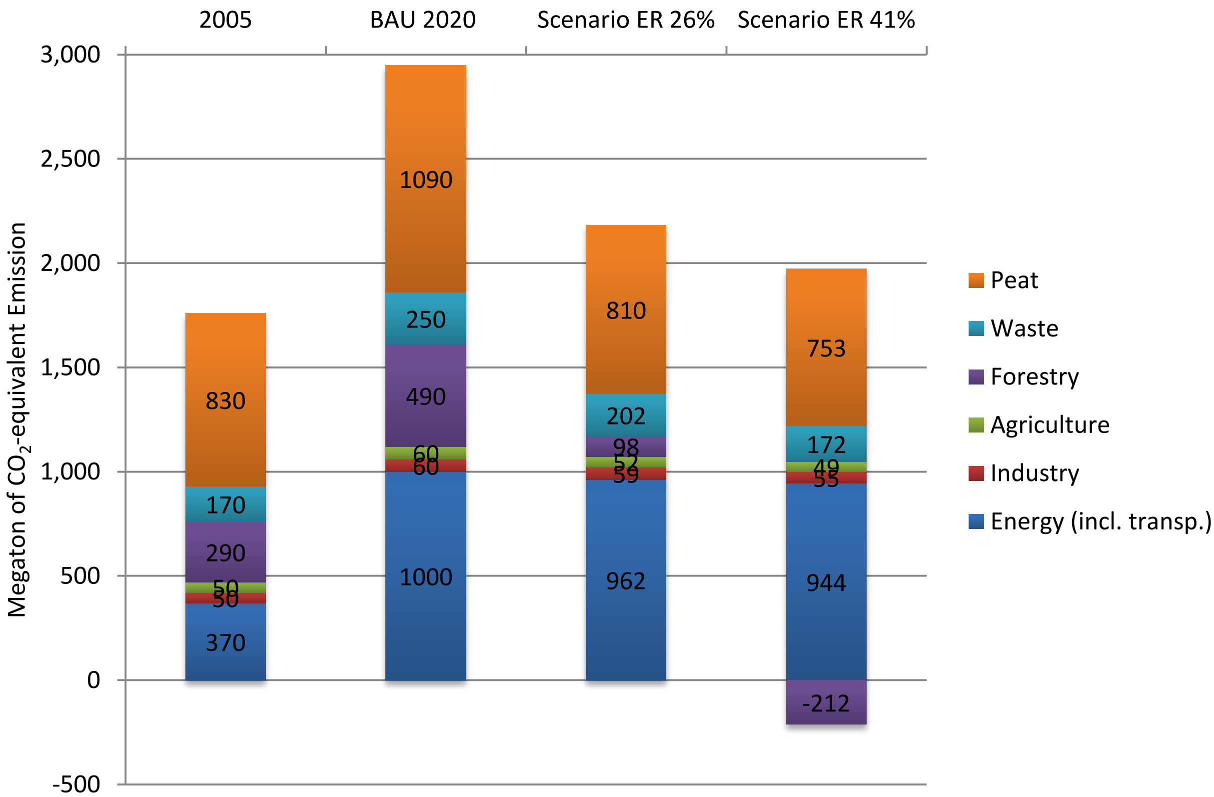
Indonesia stands to experience significant impacts from climate change. These include sea-level rise and saltwater inundation, droughts, increased frequency of extreme weather events, heavier rainfall events and flooding, and the spread of diseases. In turn, these may harm the country's agricultural, 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).

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 annual emission by 26 percent by 2020 from Business As Usual (BAU). With international support, it pledges an emission reduction by as much as 41 percent (Yudhoyono, 2009).

[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.

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.

Figure 3 illustrates Indonesia's sectoral emission in 2005. Quite obviously peatland, forestry, and energy make up the largest sectoral emitters of CO_2 in Indonesia. Under the BAU scenario, this composition will not change much by 2020. With continuing deforestation, the forest area in Indonesia will naturally decline by 2020 with a corresponding declining growth rate of CO_2 emissions from forest fires and less land clearing. The energy sector, on the other hand, is expected to grow continuously during this period, and thus its CO_2 emission grows at the fastest rate during this period, from approximately 370 megaton of CO_2-equivalent in 2005 to approximately 1,000 megaton of CO_2-equivalent in 2020.



Source: National Council on Climate Change (2009).

Figure 3. Indonesia's CO_2 Sectoral Emission Shares

Looking at the 26 percent reduction scenario, the forestry sector's emission share declines significantly. But under this scenario, Indonesia is able to maintain the size of its forest cover, as the primary reduction of CO2 emission will come from the prevention of deforestation. This in turn will make the energy sector the largest sectoral emitter of CO2 by 2020.

As such, 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. Emission from the energy sector, however small, is rapidly growing. As mentioned, Indonesia is a fast emerging economy consisting of an increasingly affluent population which aspires to better living conditions and as a consequence, consumes more energy per capita. As the population continues to grow and becomes richer, energy use will also grow. 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 will be dominated by emission from fossil fuel within a few decades (Ahmad, 2010; Jotzo and Mazouz, 2010).

And thus, herein lies a conundrum although 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 tax is 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 with the existence of uncertainty, the international carbon tax is more economically efficient than the cap and trade scheme of the Kyoto Protocol. Thus, most economic analyses of policy choice under uncertainty favor prices on efficiency grounds (Weitzman, 1974; Pizer, 2002; Strand, 2010).

2.5. Double Dividend Hypothesis

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. Furthermore, even if the double dividend hypothesis does not hold, an environmental tax reform may still be a so-called “no-regret” option. In other words, even if the environmental benefits are in doubt, an environmental tax reform may still be desirable as it induces economic efficiency, also called “efficiency dividend” (Pearce, 1991; Goulder, 1995; Bovenberg, 1999; Glomm *et al*., 2007).

Nevertheless, Schob (2005) theoretically argues that an environmental tax may have a multitude of possible effects which are sensitive to the underlying institutional framework.

Interaction of environmental regulation with the pre-existing tax system, the labor market institutions, and aspects of international cooperation influences the results of such regulation. The sign and magnitude of both environmental and non-environmental dividends are determined by the institutional framework in which a green tax reform takes place, the technology of polluting goods, and other possible sources of economic inefficiency to come to sound policy recommendations. On top of all this, the trade-off between efficiency and distributional considerations needs careful evaluation when environmental policy proposals enter the political process, both with respect to the welfare implications and the question of implementability.

Empirical studies have also suggested 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). Furthermore, 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 in order to reduce taxes on other phases of the production process. The revenues might then be employed to reduce other distortionary taxes on the “good” part of the economic process, which include regulatory measures and technological research, resulting in more efficient energy use. Other forms of financial recycling are also possible, such as lump-sum transfers to households or industries, consisting of recycling the revenues to households or to the industries in the form of one-off payments, or interventions in corporate profit taxes and value added tax. Alternatively, if the government were instead to keep the revenues without recycling them within the system, a reduction in growth rate would likely take place (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).

2.6. Regress and Rebound: The Limits

There are, of course, some *caveats* associated with the implementation of a carbon tax. Among such is the regressive nature of a carbon tax in which it imposes the heaviest 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 suggests, however, that a carbon tax generally are, or are expected to be, regressive in developed economies and progressive in developing economies (Pearce, 1991; Verde and Tol, 2009).

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. Brief Review of the IRSA-ASEAN Model

The IRSA-ASEAN model is a multi-country CGE model is a descendant of the Inter-Regional System of Analysis for Indonesia Five Regions (IRSA-Indonesia5) developed by Resosudarmo *et al.* (2008) such that it bears similarities with the latter in term of notational use. 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) such that the IRSA-ASEAN model is a unique model on its own right, both structure-wise and purpose-wise. 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 4 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, the model uses neither a bottom-up nor a top-down approach.[6] Each country is instead connected through the flow of commodity, i.e. trade of goods and services, as well as the 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 goods and services directly to/from rest of the world (ROW).

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

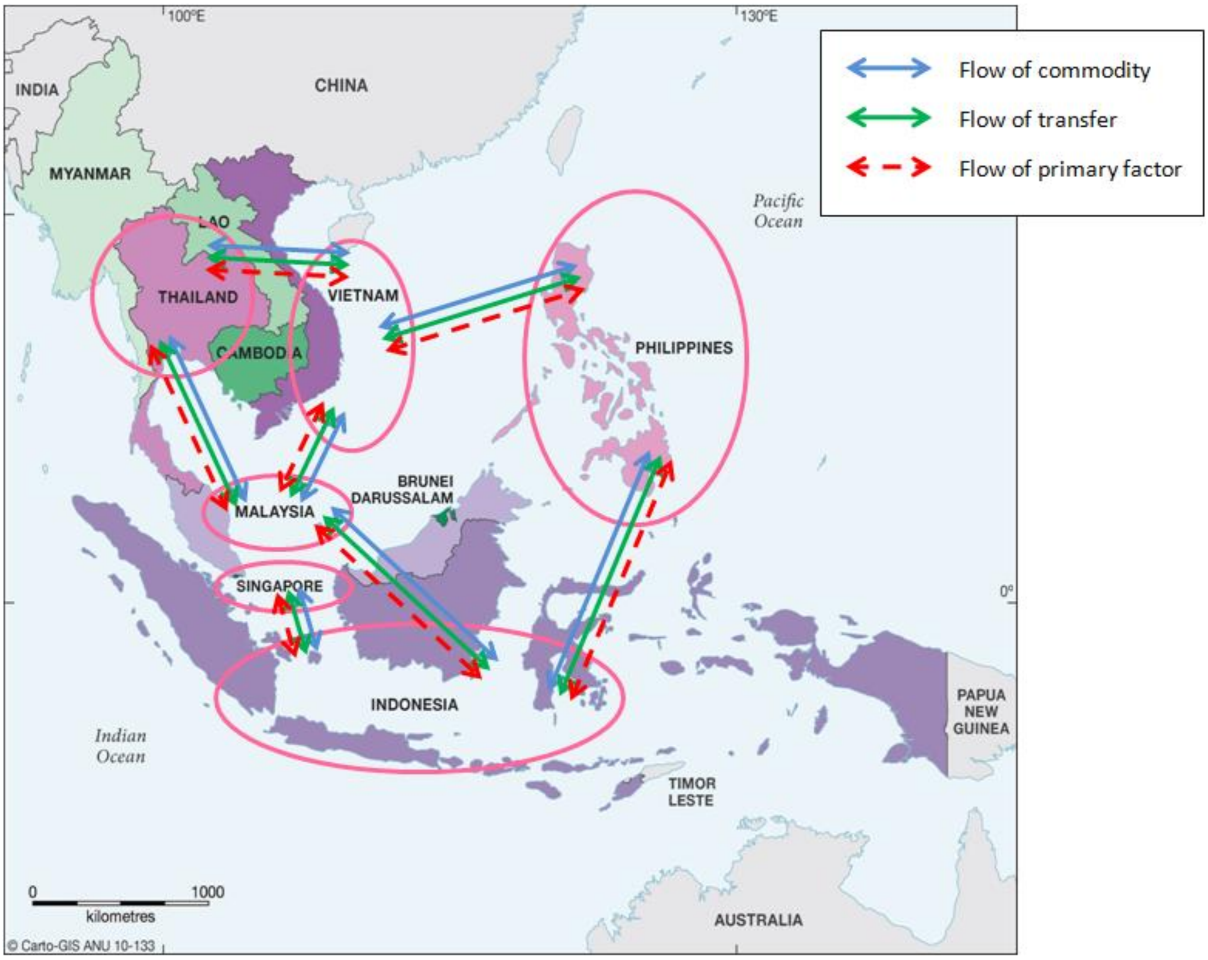


Figure 4. The IRSA-ASEAN Model

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 paper is to assess the economic impact of environment-related policies, namely carbon tax implementation and energy subsidy reduction. 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 and energy subsidy reduction 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, e.g. indirect tax reduction, such that it creates a less distortionary tax system, or supposedly so.

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 with parameter values, e.g. value-added and Armington elasticities, also obtained from this source. 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. Also, the latest version of Generalized Algebraic Modeling System (GAMS) program is used to run the IRSA-ASEAN model.

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), 2005 International Energy Prices (Metschies, 2005), 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 individual SAMs. Table 1 provides a detailed list of sets of the ASEAN-SAM.

Table 1. 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*		

	Factors	Institutions
Food and beverages		
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	

Meanwhile, Figure 5 illustrates the financial flow of the IRSA-ASEAN model. Admittedly, this is a simplified schematic as it details out only the flow within one country with only one other country representing all the others, including rest of the world. Nevertheless, Figure 5 provides a useful tool to see how changes occur throughout the economy, i.e. impact path analysis. In other words, it summarizes the IRSA-ASEAN model.

Some highlights from Figure 5 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 is when government 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 more 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 to these three mechanisms and this will explained further in the following section.

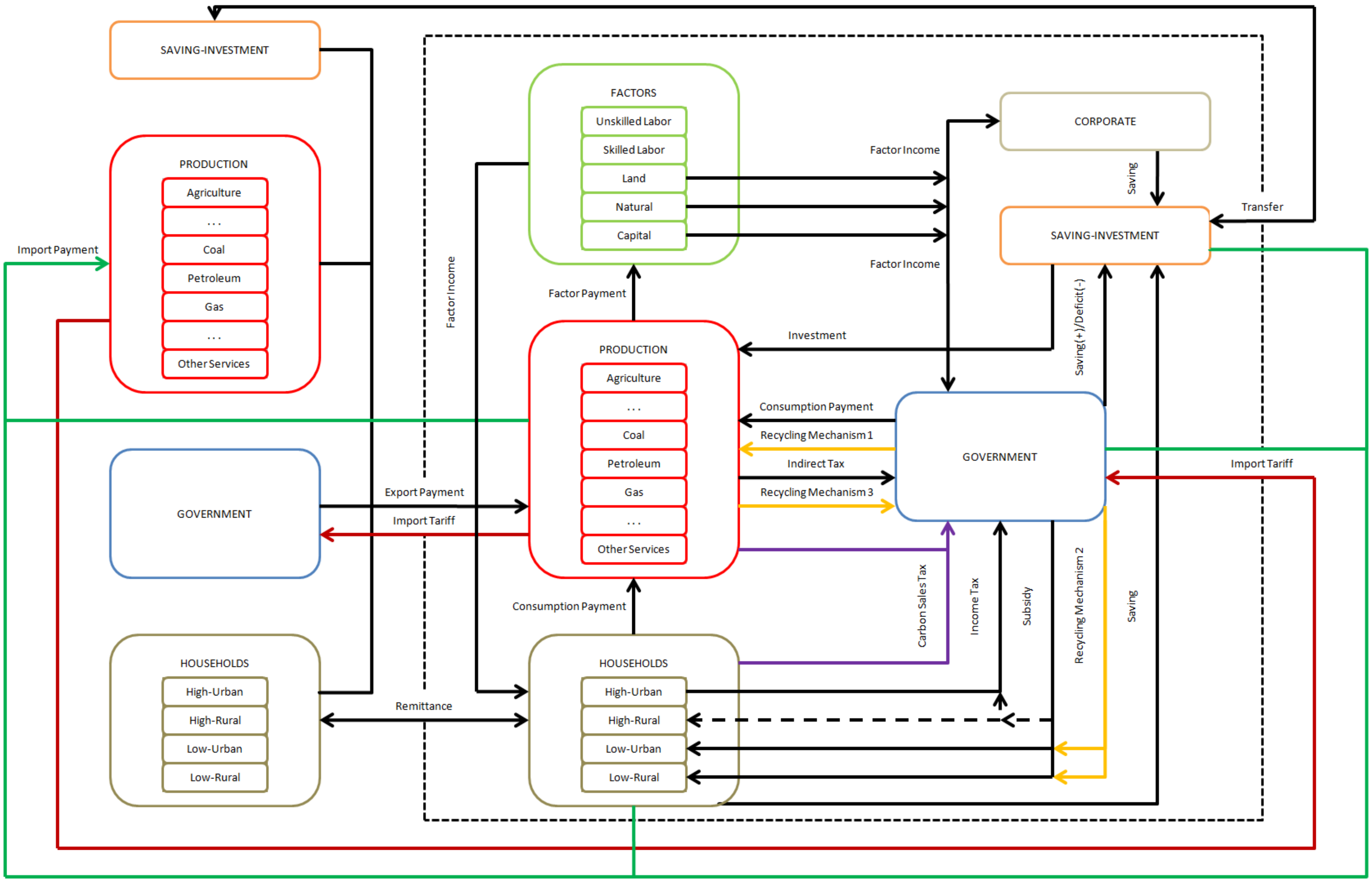


Figure 5. Financial Flow of the IRSA-ASEAN Model

3.1. Basic Structure of the IRSA-ASEAN Model

Figure 6 shows the basic flow of commodities and production structures in each country. *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[7] demand composite, *XD_S(c,d)* is the domestic and import[8] demand composite, and *XFAC(f,i,d)* is the demand for factor of production. The following defines the subscript notations:

- *c* commodity;
- *d* destination of commodity in domestic country;
- *f* factors of productions, labors, and capital;
- *h* households;
- *i* industry;
- *r* source of commodity in domestic country; and
- *s* source of commodity, composite between domestic country and import.

Note that *XEXP(c,r)* represents exports to the rest of the world, while the term *XIMP(c,d)* refers to imports from the 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.

[7] Note that the word "domestic" composite here refers to goods from within the country and within ASEAN.
[8] The word "import" refers to extra-ASEAN imports.

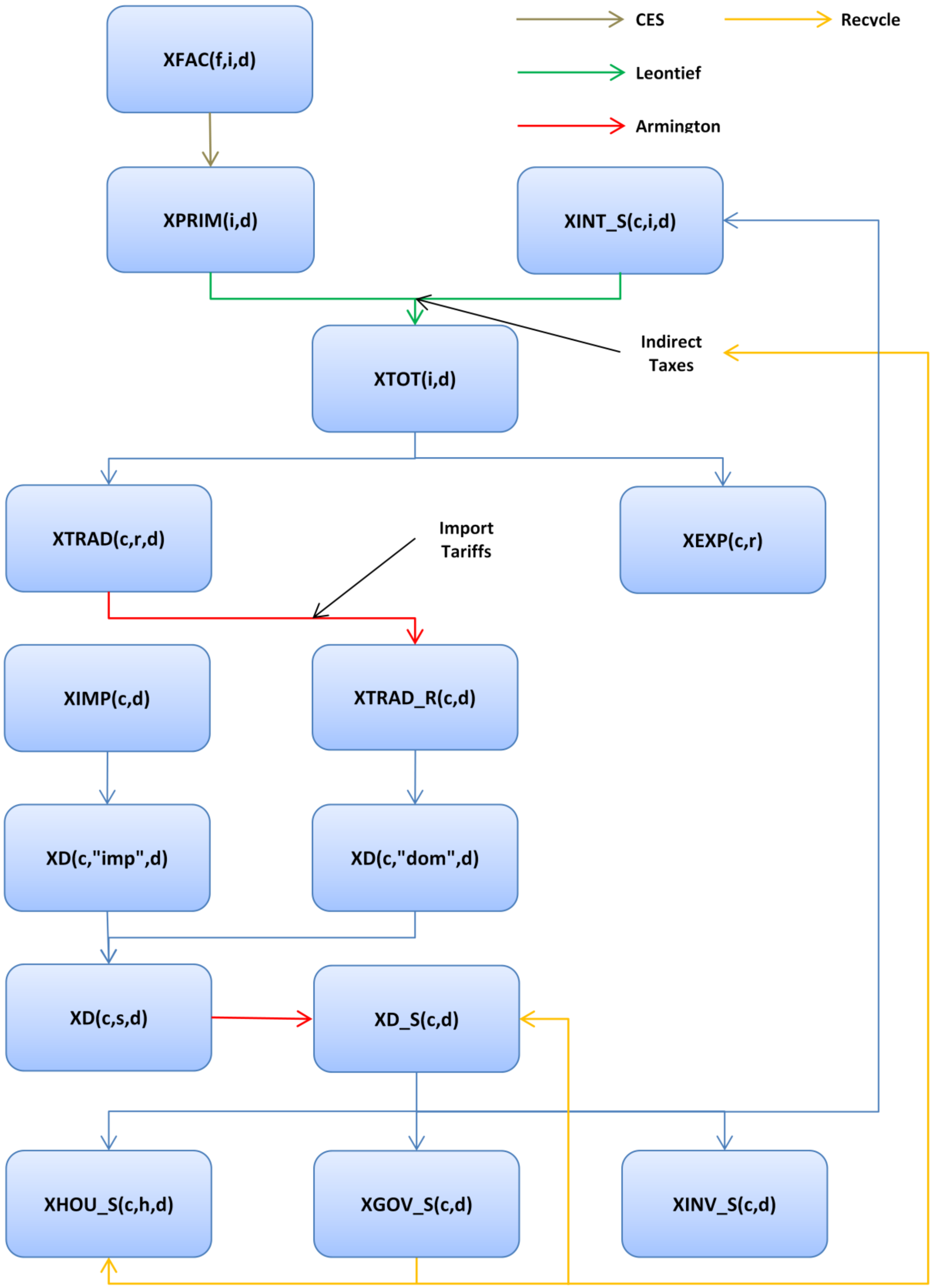


Figure 6. Production Structure of the IRSA-ASEAN Model

At the first stage, with only five factors of production, a constant elasticity of substitution (CES) function can be used to determine the demand for primary factors. At the second stage, firms' objective is to maximize profit with a Leontief production function. The Leontief production function determines the relationship between all the inputs, composite of primary factors and intermediate goods, to outputs. Admittedly, one notable limitation to this setup is that *endogenous* substitution between intermediate inputs is not allowed. This is mainly due to a technical limitation in which convergence, i.e. solution, to a model that allows endogenous substitution between intermediate goods is difficult to achieve once a “shock” is introduced. In other words, GAMS cannot solve the model as there are too many equations due to the number of commodities multiplied by the number of countries in the IRSA-ASEAN model.

However, the model does allow *exogenous* substitution. For example, suppose there is a 10 percent efficiency gain in the use of coal, a constant can be introduced which basically means that less use of coal is needed to achieve the same amount of output. By extension, the share uses of other inputs have increased, i.e. substitution effect, as well as share uses of primary factors, i.e. efficiency effect. As such, in this way, substitution and efficiency effects can be observed in the model despite the use a Leontief production function.

Furthermore, 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. Lastly, the following closures are incorporated into IRSA-ASEAN model 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*.

3.2. Carbon Pricing Mechanism

The carbon pricing mechanism as well as the subsequent recycling mechanisms are unique features 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. As such, this section describes the method in greater details. Emissions basically come from households and industrial sectors, albeit some service sectors emit zero emission as shown through the following equations.

$$XCOH_{e,h,d} = cch_{e,h,d} \cdot XHOU\_S_{e,h,d} \qquad [1]$$

and

$$XCOI_{e,i,d} = cci_{e,i,d} \cdot XINT\_S_{e,i,d} \qquad [2]$$

$XCOH_{e,h,d}$ 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.

$$\begin{aligned} stx_{e,d} = {} & cotax_d \cdot (\sum_i XCOI_{e,i,d} + \sum_h XCOH_{e,i,d}) \\ & / PQ\_S_{e,d} \cdot (\sum_i XINT\_S_{e,i,d} + \sum_h XHOU\_S_{e,h,d}) \end{aligned} \qquad [3]$$

$stx_{e,d}$ 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 10 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:

$$\begin{aligned} TCTR_d = {} & \sum_c (stx_{c,d} \cdot PQ\_S_{c,d} \cdot \sum_h XHOU\_S_{c,h,d}) \\ & + \sum_c (stx_{c,d} \cdot PQ\_S_{c,d} \cdot \sum_i XINT\_S_{c,i,d}) \end{aligned} \qquad [4]$$

The following equations determine how revenue generated from Equation 4 are recycled back into the economy through three different mechanisms, namely household cash transfer, industrial tax reduction, and government expenditure increase respectively:

$$TCH_d = \alpha h_d \cdot TCTR_d \qquad [5]$$

$$TCI_d = \alpha i_d \cdot TCTR_d \qquad [6]$$

$$TCG_d = \alpha g_d \cdot TCTR_d \quad [7]$$

$$\alpha h_d + \alpha i_d + \alpha g_d = 1 \quad \text{and} \quad 0 \leq \alpha h_d, \alpha i_d, \alpha g_d \leq 1 \quad [8]$$

Equation 4.33 is in actuality not so much an equation as it is a *share* condition *exogenously* determined to ensure that the amount of revenue generated equals the amount of revenue recycled back into the economy.

Lastly, for the case of indirect tax reduction, one final equation is added.

$$TCI_d = tco2_d \cdot \sum_i (PDOM_{i,d} \cdot XTOT_{i,d}) \quad [9]$$

In few words, Equation 9 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 and carbon tax value is relatively high.

3.3. Household Disaggregation

In the ASEAN-SAM, households are disaggregated into four groups, namely Rural-Low, Urban-Low, Rural-High, and Urban-High. These groups are upheld as well in the in model and throughout the various simulations conducted. Nevertheless, once a solution has been found for a particular simulation, household groups are disaggregated further through in a microsimulation. The microsimulation basically disaggregates household expenditure into one hundred group based on population percentile group in both rural and urban areas. In other words, there are now one hundred household groups in rural area and one hundred household groups in urban area. Appendix 1 shows the GAMS syntax for the microsimulation.

At this point, it should be noted that the microsimulation only disaggregates household expenditure, which is the main reason why this disaggregation has not been implemented on the ASEAN-SAM. The information required to disaggregate the entire household accounts, i.e. household saving, remittance, and others, for all six countries are simply an enormous task beyond the scope of this study. As such, the microsimulation ensures the consistency of all the simulation results and simply opens up another important dimension for analytical purposes.

Another important aspect to the household disaggregation is the method itself. For the case of Indonesia, disaggregation of household expenditure uses data from the IRSA-Indonesia5 model by Resosudarmo *et al*. (2008) in which all five regions of Indonesia, namely Sumatera, Java-Bali, Kalimantan, Sulawesi, and East Indonesia, are aggregated. Although the IRSA-Indonesia5 uses 2005 as the reference year, while the IRSA-ASEAN model uses 2004, it is logically assumed that household expenditure pattern should not change significantly within such a short period of time. The sectoral disaggregation is somewhat more complicated; fortunately, IRSA-ASEAN model has fewer production sectors with 26 sectors compared to the IRSA-Indonesia5 model with 35 sectors such that finding a corresponding sector for the IRSA-ASEAN model requires no additional data source.

Meanwhile, a strong assumption has to be imposed upon each other country. Due to the scarcity of data, households in Philippines, Thailand, and Vietnam are assumed to the same percentile share pattern as Indonesia as their economic developments are comparable. However, this is not the case for Singapore. As such, the percentile share pattern of Singapore uses the urban area of Java-Bali region only as this is the most developed region in Indonesia. As for Malaysia, the percentile share pattern uses the aggregate for Sumatera and Java-Bali regions with both rural and urban areas used correspondingly. Bear in mind that as the disaggregation is conducted separately as a microsimulation, it does not affect the overall results. In other words, although strong assumptions have to be applied, consistency of the model is not compromised and the microsimulation simply adds a new analytical tool. Appendices 2 and 3 show the initial conditions resulting from the disaggregation of household expenditure that can be used to analyze the reliability of the disaggregation method.

Appendix 2 shows the log household expenditure per capita for all six countries in both rural and urban areas. In rural area, the figure shows that Malaysia has the highest expenditure per capita followed closely by Thailand and Indonesia then Philippines, and Vietnam last. As for urban area, Singapore is at the top followed farther down by Thailand and Malaysia. Indonesia and Philippines have a very similar pattern followed again by Vietnam. These patterns reflect the level of economic development of each country with Singapore being the most developed and Vietnam as the least. Meanwhile, Malaysia, Thailand, Indonesia, and Philippines are somewhat more comparable to one another in term of economic development.

Appendix 3, on the other hand, shows the household expenditure distribution. Although similar, Appendix 3 does not show the Gini distribution as it shows household expenditure rather than income distribution. Nevertheless, the same logical conclusion can be drawn with expenditure disparity the largest in Malaysia, followed by Thailand, Philippines, Indonesia, and Vietnam in rural area. As for urban area, Singapore has the largest expenditure disparity followed by the same order as in rural area. Intuitively, the more developed the country is, the larger the disparity; and *vice versa*. Vietnam being the least developed economy compared to the other five countries has the least expenditure disparity; although nominal-wise, household consumption is the lowest as shown previously in Appendix 2.

4. Policy Simulations: Carbon Tax Implementation

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 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.[9]

Aside from the two broad scenarios mentioned previously, there are three 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

[9] 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.

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 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 endogenized intermediate input substitution, there are two additional scenarios in which technological change is treated exogenously to illustrate possible outcomes from intermediate input substitution, and by extension efficiency gain, in the energy sector. These technological changes are 10 percent efficiency gain of coal use and 5 percent efficiency gain of oil use. The carbon tax itself is set at USD 10 per ton of CO_2 emissions following the previous work of the Ministry of Finance (2009) for fossil fuel use, i.e. coal, petroleum products, and gas.[10]

Scenario 1: Symmetrical Carbon Tax Policies

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

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

1b. 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; and

1c. Each government retains 50 percent of the revenue to increase its consumption and redistributes 50 percent to industries.

Scenario 2: Asymmetrical Carbon Tax Policies

A USD 10 per ton of CO_2 emission tax in Indonesia:

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

2b. 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; and

[10] 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.

2c. Indonesian government retains 50 percent of the revenue to increase its consumption and redistributes 50 percent to industries.

Scenario 3: Symmetrical Carbon Tax Policies

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

Scenario 4: Symmetrical Carbon Tax Policies

A USD 10 per ton of CO_2 emission tax with 5 percent efficiency gain in the use of oil in all six countries. The three recycling remain the same.

4.1. Macroeconomic Results

The summary of emission, macroeconomy, and expenditure is shown in Table 2 for the symmetrical scenario for a USD 10 carbon tax without any efficiency gain. Appendix 4 summarizes the result for the asymmetrical scenario. Appendices 5 and 6 provide the same summary results but with 10 percent efficiency gain in coal use and 5 percent efficiency gain in oil use respectively for symmetrical scenarios. It is important to note, however, all changes are calculated at the original price level such that their changes are *real* changes.

Table 2. Simulation Results of Scenario 1**

	CO_2	Real GDP	Real Sectoral Change (%)			Real Household Expenditure Change (%)			
	%	%	Agri.	Manuf.	Serv.	Rural-Low	Urban-Low	Rural-High	Urban-High
Government									
Indonesia	-3.70	0.25	-0.14	-0.32	0.75	-1.10	-1.27	-1.20	-0.18
Malaysia	-4.06	0.04	0.01	-0.18	0.46	-1.36	-1.54	-1.13	-1.35
Philippines	-2.99	-0.04	-0.08	-0.43	0.25	-0.77	-0.71	-0.77	-0.73
Singapore	-0.95	-0.01	0.02	-0.35	0.12		-0.32		-0.34
Thailand	-2.38	-0.14	-0.18	-0.74	0.32	-0.91	-0.64	-1.14	-1.06
Vietnam	-6.29	-0.33	-0.06	-1.12	0.87	-1.84	-1.83	-1.77	-1.55
Household									
Indonesia	-3.40	0.27	0.01	0.07	0.47	2.18	0.12	-1.32	-0.90
Malaysia	-3.74	0.06	0.17	0.07	0.02	7.16	-0.76	-1.36	-1.56
Philippines	-2.82	-0.03	0.05	-0.18	0.07	5.85	0.43	-0.88	-0.90
Singapore	-0.88	-0.01	0.04	-0.26	0.09		0.45		-0.37
Thailand	-2.08	-0.08	0.01	-0.38	0.14	3.69	0.39	-1.32	-1.53
Vietnam	-5.77	-0.22	0.14	-0.65	0.32	2.44	0.26	-1.81	-1.81

Industry									
Indonesia	-3.34	0.26	-0.02	0.55	0.12	-1.61	-1.66	-1.35	-0.32
Malaysia	-4.03	0.04	*	0.24	-0.33	-2.76	-2.61	-0.78	-0.99
Philippines	-3.35	-0.05	-0.09	-0.28	0.12	-1.00	-0.63	-1.02	-0.60
Singapore	-0.94	-0.01	0.05	-0.10	0.02		-0.51		-0.22
Thailand	-2.49	-0.14	-0.12	-0.38	0.04	-2.59	-1.35	-2.25	-0.77
Vietnam	-3.67	-0.22	0.24	0.24	-1.19	-1.90	-2.62	-1.85	-2.65

* - Neglible Value

** - Symmetric Carbon Tax at USD 10 per ton of CO2 Emission with No Efficiency Gain

Table 2 shows the results of Scenario 1, the implementation of a carbon tax at USD 10 per ton of CO_2 emissions on all countries. Overall, 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 real household expenditure. 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 actually quite as expected as regardless how the revenue generated will be redistributed. For Indonesia and Malaysia, a carbon tax has a positive effect on the overall economy. However, some sectors will more likely be adversely affected than others, namely the manufacturing sector followed by the agricultural sector; whereas the service sector will actually benefit from the implementation of a carbon tax, assuming that the government retains all the revenue generated and recycles it all back all through its increase in expenditure.

All the other countries, on the other hand, exhibit a similar pattern to each other that is in opposite to Indonesia and Malaysia. Although beneficial in terms of environmental improvement, the cost comes at a contraction to their respective economy. This is especially true for the case of Vietnam in which the country will most likely suffer the most in term of economic contraction for all variants. For sectoral changes, these countries also exhibit the same pattern with Indonesia and Malaysia in which the manufacturing sector will more likely be adversely affected followed by the agricultural sector with the service sector more likely to gain.

In term of overall change, it is quite obvious why Indonesia and Malaysia are most likely to benefit compared to the other countries. In Indonesia and Malaysia, fuels are subsidized such that introducing a carbon tax is similar to reducing subsidies in these countries. In other words, a carbon tax actually promotes efficiency by creating a less distortionary tax system in which the double-dividend hypothesis and the no-regret option apply. This is not true in the other countries as they do not subsidize as much as Indonesia and Malaysia. As such, introducing a carbon tax will most likely create a more distortionary tax system with Vietnam suffering the most followed by Thailand, Philippines, and Singapore. The fact that Philippines and Singapore do not subsidize fuels at all allows a more efficient adjustment to take place in their respective economies such that they do not suffer as much as Vietnam and Thailand.

Meanwhile, although recycling mechanisms do not affect the overall results in terms of emission reduction and economic contraction, they do significantly affect sectoral changes and household expenditures. When part of the carbon tax revenue is recycled back to low-income households in both rural and urban areas, the first thing to note is that these two household groups are not longer as adversely affected as before. Those in the lower-income bracket are somewhat compensated by the changes as they are given a lump sum cash transfer by their respective government. As household expenditure patterns are different from government expenditure patterns, this in turn changes the sectoral output as household consumption share of manufacturing and agricultural goods are higher compared to services compared *vis-à-vis* government consumption share pattern. As such, these former two sectors are somewhat compensated by the increased consumption as opposed in the previous recycling mechanism.

As for the third recycling mechanism in which the government reduces indirect taxes, the first obvious thing to note is that households are no longer compensated that their expenditure consumption pattern changes are more similar to the first recycling mechanism. However, changes in sectoral output are more erratic as different things are occurring at once, e.g. carbon sales tax, indirect taxes, and price changes.

One final important thing to note is that overall results do not change with the recycling mechanisms, which is actually both interesting and logical. This means that that no leakage occurs between countries and the recycling mechanisms only change domestic patterns. As such, in terms of overall achievement, recycling mechanisms do not matter although for practical policy purposes, they become very important in terms of feasibility and acceptability.

Appendix 4, on the other hand, shows 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 from implementing a carbon tax regardless of whether other countries do so or not. The more important question for Indonesia is how it chooses to redistribute the income. In this regard, although the overall benefits do not change significantly, recycling mechanisms do changes domestic “winners” and “losers”.

Looking at the results, direct cash transfer may be the most feasible solution by minimizing the number of agents adversely affected by the carbon tax.

As to leakages, implementing a carbon tax unilaterally does not appear to significantly affect other countries. Nevertheless, Malaysia and Singapore are slightly more affected than others as they more integrated with Indonesia through trade and investment. However, these countries are affected differently with a carbon leakage more likely to occur with Malaysia although these changes are relatively very small.

Appendices 5 and 6 show the results when technological changes are introduced in the form of efficiency gain in terms of coal and petroleum products use by 10 percent and 5 percent respectively. These technological improvements are introduced to compensate the lack of endogenous 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, e.g. improving maintenance or better management, 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. As such, both substitution and efficiency are reflected in the results.

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. Although in the case of coal use efficiency, Singapore is almost unaffected at all, which is logical as Singapore uses relatively very small amount of coal in the first place. Two other important highlights to note are: first, a 5 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, a 5 percent efficiency gain in the use of petroleum products creates a much larger positive effect to the environment as well.

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 energy efficiency has the possibility of creating a rebound effect, the phenomena is unlikely to occur in the region. It appears that a carbon tax at USD 10 per ton of CO_2 emission is more than sufficient to prevent this phenomenon from occurring.

4.2. Sectoral Results

In order to understand why and how changes occur when a carbon tax is implemented, particularly for a welfare analysis, a more detailed look must be conducted at the sectoral level. Table 3 shows selected sectoral prices. It is important to note that Table 3 also implicitly shows price changes as the original prices are set at 1. This implies, for example, that a coal price of 1.29 in Indonesia means that the price of coal has increased by 29 percent in Indonesia after a carbon tax of USD 10 per ton of CO_2 has been implemented in the form of sales tax to industries and households.

Table 3. Selected Sectoral Prices and Exchange Rate

	Indonesia	Malaysia	Philippines	Singapore	Thailand	Vietnam
Government						
Coal	1.29	1.24	1.25	1.30	1.24	1.22
Petroleum Products	1.10	1.11	1.13	1.07	1.08	1.15
Manufactured Gas	1.01	1.02	1.01	1.03	1.02	1.01
Electricity	1.03	1.03	1.03	1.02	1.02	1.01
Transportation	1.02	1.02	1.01	1.00	1.01	1.06
Exchange Rate	0.99	1.00	1.00	1.00	1.00	1.00
Household						
Coal	1.29	1.24	1.25	1.30	1.25	1.22
Petroleum Products	1.10	1.12	1.13	1.07	1.08	1.15
Manufactured Gas	1.01	1.02	1.01	1.03	1.01	1.01
Electricity	1.03	1.03	1.03	1.02	1.02	1.00
Transportation	1.02	1.02	1.01	1.00	1.01	1.06
Exchange Rate	0.99	1.00	1.00	1.00	1.00	1.00
Industry						
Coal	1.34	1.22	1.12	1.27	1.14	1.78
Petroleum Products	1.04	0.98	0.87	0.97	0.89	1.56
Manufactured Gas	1.06	1.00	0.87	0.99	0.91	1.55
Electricity	1.08	1.01	0.89	0.98	0.91	1.54
Transportation	1.06	1.00	0.88	0.97	0.91	1.62
Exchange Rate	1.04	0.98	0.87	0.97	0.89	1.56

* - Symmetric Carbon Tax at USD 10 per ton of CO2 Emission with No Efficiency Gain

Table 3 shows that the once a carbon tax is implemented, the price of coal, petroleum products, and manufactured gas immediately increase. The price of coal increase the most followed by petroleum products and manufactured gas as coal is the "dirtiest" in term of CO_2 content compared to the others. Changes in these commodity prices have a secondary effect with the electricity and transportation sectors affected the most as these two sectors are the largest energy users. The logic is quite straightforward for the first two recycling mechanism. However, the explanation is not quite as straightforward when looking at the third recycling mechanism.

When the third recycling mechanism is implemented, other changes occur simultaneously that affect prices. Indirect tax reductions directly affect production activities such that prices change differently from the other two recycling mechanisms. As indirect taxes differ greatly between countries, e.g. existence of fuel subsidies in Indonesia and Malaysia, the third recycling mechanism affects the same sectors differently across countries.

Furthermore, aside from the forces exerted from indirect tax and subsidy changes as well as implementation of a carbon sales tax, exchange rate also changes. This change is most prominent in Vietnam where the country's currency depreciates greatly. Admittedly, this might be a technical limitation of the model. Nevertheless, the overall conclusion of the impact of a carbon sales tax does not change. Prices of coal, petroleum products, and manufacture gas are affected first and foremost followed by price changes in the electricity and transportation sectors.

Following the changes in commodity prices, production activities in turn changes as well. Figure 7 shows the real sectoral value-added changes in percent for Scenario 1. Note that this figure does not show real output changes because it is more important at this stage to look at the industrial changes while avoiding changes that arise from export and import of commodities. The distinction is important as value-added changes will affect households more than output changes. Also, the changes are in percent. Lastly, from top to bottom, the first ten sectors are categorized as services followed by 12 sectors categorized as manufacturing and 4 sectors categorized as agriculture.

Figure 7 shows that the manufacturing sectors undergo a general contraction. Meanwhile, the agricultural sectors are not affected as much, whereas service sectors generally contract with the exception of government-related sector. These imply that households that rely on income from the manufacturing sector are likely to suffer the most from an income reduction, which in turn reduces their ability to consume. Meanwhile, those in the in the agricultural sector will most likely be unaffected income-wise, although price changes may still affect their consumption level. Those who are most likely to gain are households in the service sector, particularly government-related sector such as defense, health, and education.

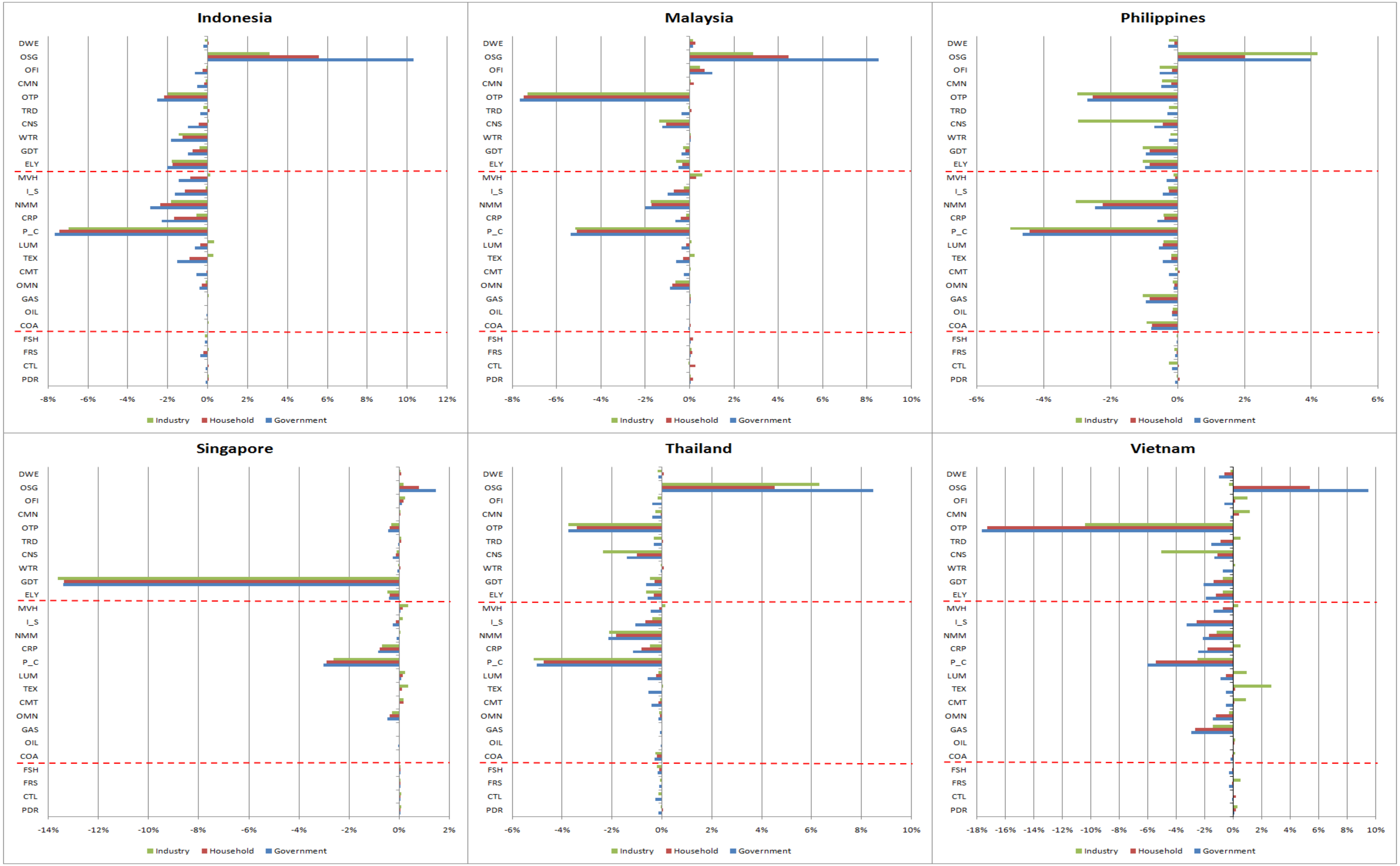


Figure 7. Real Sectoral Value-Added Changes in Percent

Bear in mind that it is not possible to see the overall impact on households from Figure 7 as it only shows the income side. To look at the overall impact on households, the direct impact of price changes on households must also be taken into account. Also, this figure assumes that government does not share the carbon tax revenue with either industries or households. Nevertheless, Figure 7 provides another important way that a carbon tax affects households aside from commodity price changes. The net impact on households has actually been shown in Table 2.

4.3. Distributional Results

As mentioned, the overall impact on household can be seen from Table 2. However, it is not possible to make any claim regarding the progressive or regressive nature of carbon tax solely based on that table. This is because the results in Table 2 much too aggregated. As such, it is necessary to disaggregate households further, namely by disaggregating them into 100 categories based on population percentile for both rural and urban areas. The percentile grouping goes from the poorest to richest based on their respective initial total expenditure. Figure 7 illustrates the percent change in real household consumption by percentile group based on Scenario 1.

Bear in mind that a carbon tax is generally progressive in developing countries and regressive in developed countries. Although most ASEAN countries would fall under the developing country category, with the possible exception of Singapore, a quick glance at Figure 7 may not provide such a straightforward answer. Singapore, understandably the most developed country in the region in economic term, shows clearly the regressive nature the carbon tax. Moving to the right on the horizontal axis, the trend shows an upward sloping line that indicates the richer household is, the less adversely affected it is by the implementation of a carbon tax. Vietnam, on the other hand, clearly shows the opposite in which the richer the household is, the more adversely affected it is by the implementation of a carbon tax. This is, of course, in accordance with the fact that Vietnam is the least develop country in the region in economic term.

For Indonesia, Malaysia, Philippines, and Thailand, the results are not as clear in which they exhibit a U-shape pattern. What are seemingly contradictory, the results should actually have been expected. These four countries neither fall under the developed country category such as Singapore nor do they fall under the developing category such as Vietnam. They are actually transitional economies, right in between those two categories. The U-shape actually shows that for those who are relatively poorer in their respective countries exhibit the same pattern as Vietnam representing a developing country in which a carbon tax is progressive. However, for the few in the right end of the horizontal axis, i.e. the rich and richest, they actually exhibit the same pattern as Singapore representing a developed country in which a carbon tax is regressive.

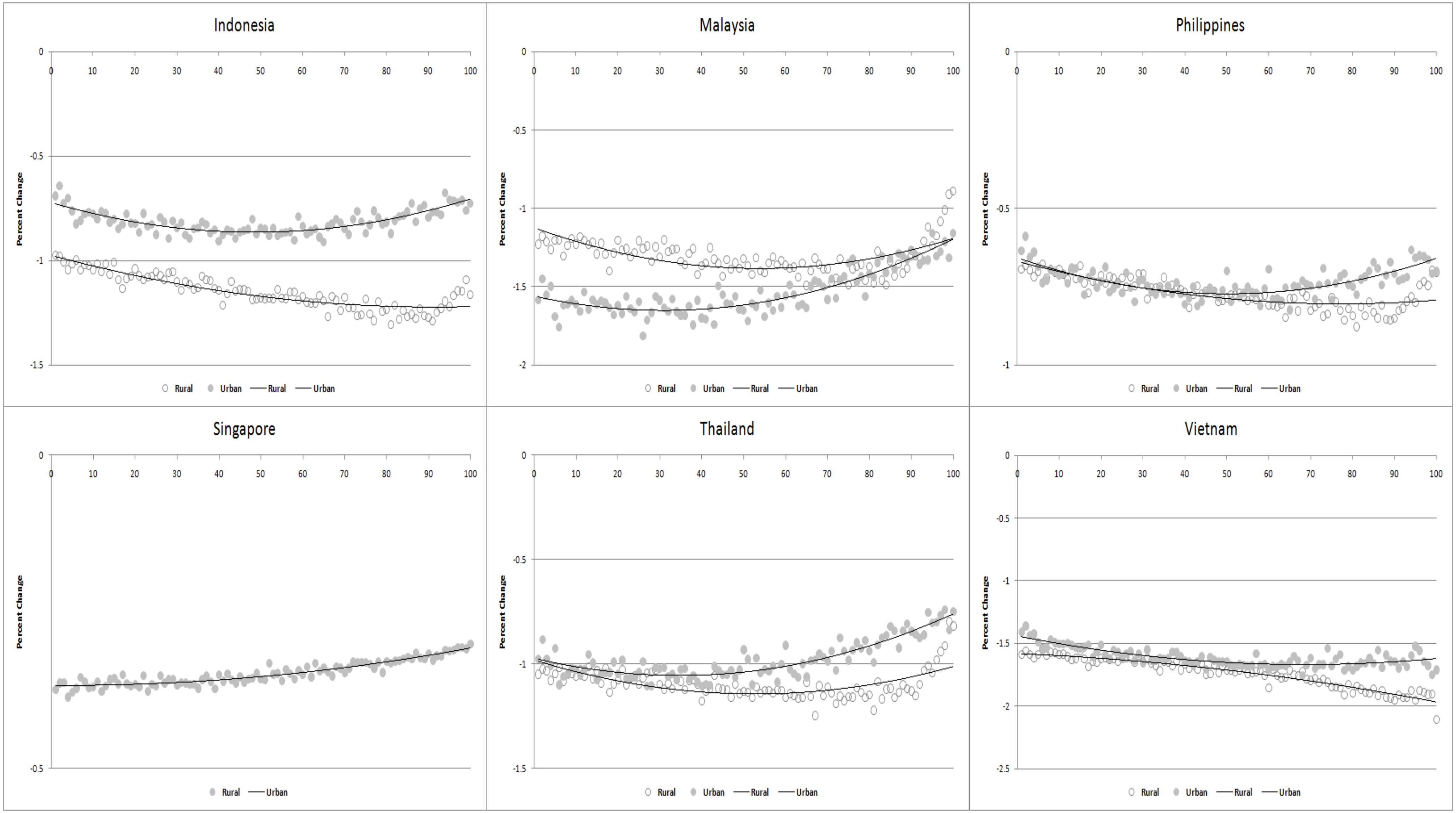


Figure 7. Real Household Expenditure Changes in Percent

Furthermore, for Indonesia, Philippines, and Thailand, those living in rural areas are more adversely affected than those living in urban areas. Such is not the case for Malaysia where those living in urban areas are more adversely affected than those living in rural areas. This difference arises from the population composition in which Malaysia is more urbanized than the others such that the overall adverse effect is greater in urban area than in rural area. Nevertheless, the U-shape pattern holds and the turning point in Malaysia occurs sooner for those in urban areas compared to the other three countries.

Meanwhile, Appendix 7 shows the results when the second recycling mechanism is implemented. Appendix 7 shows that households are better off in term of being less adversely affected by the carbon tax than in Figure 7. This is because in the second recycling policy, low-income households are given a one-time, lump-sum cash transfer. In Malaysia, Philippines, Thailand, and Vietnam, rural households are much better off than urban households compared to the case in Indonesia. This difference can easily be explained as low-income rural households receive a much greater share than low-income urban households as the share transfer are based on poverty incidence ratio. In these countries, rural households receive at least twice as much cash transfer in total than in urban areas. As for Indonesia, although more transfers are given out to the rural area, the amount is less than twice the total amount of transfers given out to urban households.

As for the third recycling mechanism, Appendix 8 shows the result when the third recycling mechanism is implemented. It is somewhat harder to find a similar pattern in this case because the third recycling mechanism does not directly affect households. Changes to households are the resultant of changes in the industrial sectors. As such, it is much harder to predict the impact on households. However, the U-shape pattern holds for Indonesia, Malaysia, Philippines, and Thailand although they are all affected in different ways; with Vietnam beginning to show the same U-shape pattern. Meanwhile, Singapore exhibits the same pattern as in the first recycling mechanism.

5. Conclusion

The main goal of this study 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, a multi-country CGE model for ASEAN, known as the IRSA-ASEAN, has been constructed. An ASEAN-SAM has also been constructed previously 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. Through the IRSA-ASEAN, few conclusions can be with regard to the implementation of a carbon tax in ASEAN. First, in general, a carbon tax is an effective way of reducing carbon emission. 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 these countries have been relatively low. And so, there is much room to reduce other taxes to compensate the effects of a 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 and Malaysia are the potential “winners” as at the moment they are subsidizing their respective energy sectors such that a carbon tax actually acts as a compensating mechanism that will promote efficiency and a less distortionary tax system, or in this case one arising from energy sector subsidy. Vietnam is the likely “loser” as the implementation of a carbon tax creates an additional distortionary tax with the only possible gain in terms of environmental improvement, which comes with a great cost in term of relatively large economic reduction. Philippines, Singapore, and Thailand can still gain depending on what the respective government does with the revenue. Although an economic reduction is unavoidable, the cost is not so great, which also comes with great benefit in terms environmental improvement and social equity.

Fourth, in terms of distributional impact, a carbon tax is strictly progressive in Vietnam and strictly regressive in Singapore. For Indonesia, Malaysia, Philippines, and Thailand a carbon is progressive for those in up to the 70 to 90 percentile income group and regressive for those in the right-end tail, or higher, income group.

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

Overall, the implementation of a carbon tax is an effective mechanism to reduce CO_2 emission. However, for cases such as Philippines, Singapore, Thailand, and Vietnam, this gain in the environment comes at a price in term of economic contraction. While, the cost may be significant for Vietnam, it is not so much as the case for Philippines, Singapore, and Thailand such that the implementation of a carbon tax might still be an option. For Indonesia and Malaysia, the implementation of a carbon tax yield a similar result as an energy subsidy reduction. Not only do they gain in term of environmental improvement, they also gain in term of economic growth. As such, a carbon tax implementation could be a feasible policy in the region although the distributional impact in terms of sectoral losses and adverse effect to certain segments of society must be taken into consideration, complicated as they might be.

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Appendix 1. Household Microsimulation GAMS Syntax

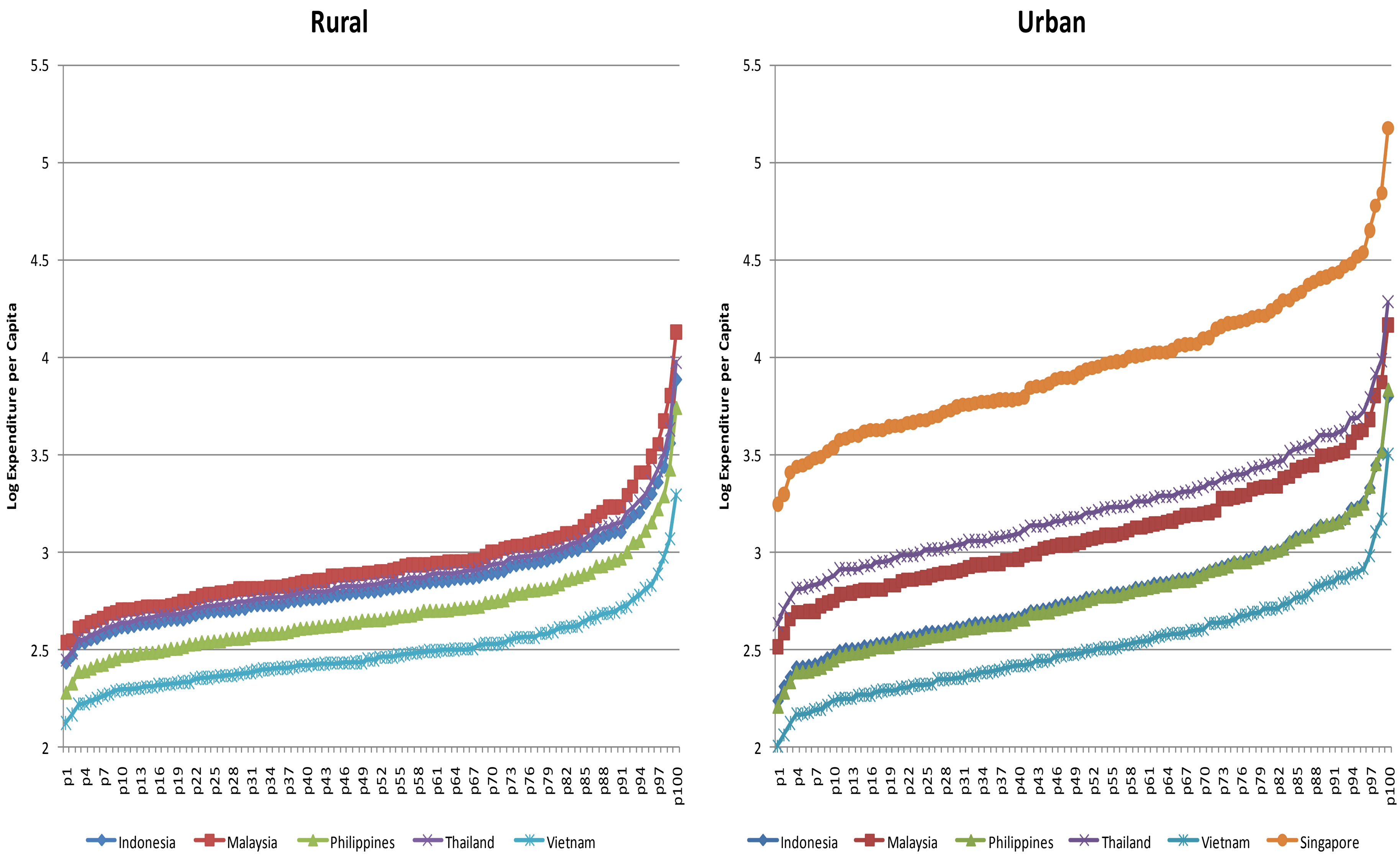
```
* run using this option: r=save\simco2 s=save\expenditure

set
hx       Household group
/
rural
urban
/

alias (hx, hhx)

parameter
 YHCAP(hx,d)              Income percapita in 2005 Rp
 POP(hx,d)                Population
;

table POP(hx,d)
             IDN         MYS         PHL        SGP         THA         VNM
rural  114974649    8438257   32003793          0    44350318    60719864
urban  101468591   16735541   51907568    4166700    20928337    21311836
;

 YHCAP('rural',d)$POP('rural',d) = [(YH0('HHRULOW',d)+YH0('HHRUHIGH',d))
                                   *(10**6)]/POP('rural',d);
 YHCAP('urban',d)$POP('urban',d) = [(YH0('HHURLOW',d)+YH0('HHURHIGH',d))
                                   *(10**6)]/POP('urban',d);

display YHCAP;

set p    / p1*p100 /; alias(p,pp);

parameter
 EHP0(hx,p,d)             Household total expenditure by percentile
 XHOU_SP0(c,hx,p,d)       Household cons. by percentile
 bdgshp(c,hx,p,d)         Budget share by percentile
;

* Get this from household survey data
parameter
 XHOU_SP0_RIDN(p,c)
 XHOU_SP0_UIDN(p,c)
 XHOU_SP0_RMYS(p,c)
 XHOU_SP0_UMYS(p,c)
 XHOU_SP0_RPHL(p,c)
 XHOU_SP0_UPHL(p,c)
 XHOU_SP0_RSGP(p,c)
 XHOU_SP0_USGP(p,c)
 XHOU_SP0_RTHA(p,c)
 XHOU_SP0_UTHA(p,c)
 XHOU_SP0_RVNM(p,c)
 XHOU_SP0_UVNM(p,c)
;

$libinclude xlimport XHOU_SP0_RIDN ruralexpenditure.XLS IDN!A1:AB101
$libinclude xlimport XHOU_SP0_UIDN urbanexpenditure.XLS IDN!A1:AB101
$libinclude xlimport XHOU_SP0_RMYS ruralexpenditure.XLS MYS!A1:AB101
$libinclude xlimport XHOU_SP0_UMYS urbanexpenditure.XLS MYS!A1:AB101
$libinclude xlimport XHOU_SP0_RPHL ruralexpenditure.XLS PHL!A1:AB101
$libinclude xlimport XHOU_SP0_UPHL urbanexpenditure.XLS PHL!A1:AB101
$libinclude xlimport XHOU_SP0_RSGP ruralexpenditure.XLS SGP!A1:AB101
$libinclude xlimport XHOU_SP0_USGP urbanexpenditure.XLS SGP!A1:AB101
$libinclude xlimport XHOU_SP0_RTHA ruralexpenditure.XLS THA!A1:AB101
$libinclude xlimport XHOU_SP0_UTHA urbanexpenditure.XLS THA!A1:AB101
$libinclude xlimport XHOU_SP0_RVNM ruralexpenditure.XLS VNM!A1:AB101
$libinclude xlimport XHOU_SP0_UVNM urbanexpenditure.XLS VNM!A1:AB101

 XHOU_SP0(c,'rural',p,'IDN') = XHOU_SP0_RIDN(p,c);
 XHOU_SP0(c,'urban',p,'IDN') = XHOU_SP0_UIDN(p,c);
 XHOU_SP0(c,'rural',p,'MYS') = XHOU_SP0_RMYS(p,c);
 XHOU_SP0(c,'urban',p,'MYS') = XHOU_SP0_UMYS(p,c);
 XHOU_SP0(c,'rural',p,'PHL') = XHOU_SP0_RPHL(p,c);
 XHOU_SP0(c,'urban',p,'PHL') = XHOU_SP0_UPHL(p,c);
 XHOU_SP0(c,'rural',p,'SGP') = XHOU_SP0_RSGP(p,c);
 XHOU_SP0(c,'urban',p,'SGP') = XHOU_SP0_USGP(p,c);
 XHOU_SP0(c,'rural',p,'THA') = XHOU_SP0_RTHA(p,c);
```

```
 XHOU_SP0(c,'urban',p,'THA') = XHOU_SP0_UTHA(p,c);
 XHOU_SP0(c,'rural',p,'VNM') = XHOU_SP0_RVNM(p,c);
 XHOU_SP0(c,'urban',p,'VNM') = XHOU_SP0_UVNM(p,c);

 EHP0(hx,p,d) = SUM(c,XHOU_SP0(c,hx,p,d));
 bdgshp(c,hx,p,d)$EHP0(hx,p,d) = XHOU_SP0(c,hx,p,d)/EHP0(hx,p,d);

parameter
 XHOU_S0CK(c,hx,d)
 sumbdgshp(hx,p,d);

 XHOU_S0CK(c,'rural',d)$(XHOU_S0(c,'HHRULOW',d)+XHOU_S0(c,'HHRUHIGH',d))
                 = SUM(pp,XHOU_SP0(c,'rural',pp,d))
                 /(XHOU_S0(c,'HHRULOW',d)+XHOU_S0(c,'HHRUHIGH',d));

 XHOU_S0CK(c,'urban',d)$(XHOU_S0(c,'HHURLOW',d)+XHOU_S0(c,'HHURHIGH',d))
                 = SUM(pp,XHOU_SP0(c,'urban',pp,d))
                 /(XHOU_S0(c,'HHURLOW',d)+XHOU_S0(c,'HHURHIGH',d));

 sumbdgshp(hx,p,d) = SUM(c,bdgshp(c,hx,p,d));

display XHOU_S0, EHP0, sumbdgshp, XHOU_S0CK;

parameter
 apc(hx,d)         propensity to consume
 apcp(hx,p,d)      propensity to consume percentile
 YHP0(hx,p,d)      Income percentile
 POPP(hx,p,d)      Population by percentile
;

 POPP(hx,p,d) = POP(hx,d)/100;

 parameter CHECKPOP(d);
 CHECKPOP(d) = SUM((hx,p),POPP(hx,p,d));

 display CHECKPOP;

 apc('rural',d)$(YH0('HHRULOW',d)+YH0('HHRUHIGH',d))
              = (EH0('HHRULOW',d)+EH0('HHRUHIGH',d))
              /(YH0('HHRULOW',d)+YH0('HHRUHIGH',d));
 apc('urban',d)$(YH0('HHURLOW',d)+YH0('HHURHIGH',d))
              = (EH0('HHURLOW',d)+EH0('HHURHIGH',d))
              /(YH0('HHURLOW',d)+YH0('HHURHIGH',d));

 display apc;

 apcp(hx,p,d) = apc(hx,d);
 YHP0(hx,p,d)$apcp(hx,p,d) = EHP0(hx,p,d)/apcp(hx,p,d);

 display apcp, YHP0;

parameter
 YHCAPP(hx,p,d)   Percapita income by centile
;

 YHCAPP(hx,p,d)$POPP(hx,p,d) = [YHP0(hx,p,d)*(10**6)]/POPP(hx,p,d);

parameter
  EHP(hx,p,d)          Household exps. by percentile
  SHP(c,hx,p,d)          Share of household exps. by percentile (constant)
  RCON(hx,p,d)         Real household consumption
  RCON0(hx,p,d)
;

alias (p,pp);

 SHP(c,'rural',p,d)$XHOU_SP0(c,'rural',p,d) = XHOU_SP0(c,'rural',p,d)
                  /(XHOU_S0(c,'HHRULOW',d)+XHOU_S0(c,'HHRUHIGH',d));
 SHP(c,'urban',p,d)$XHOU_SP0(c,'urban',p,d) = XHOU_SP0(c,'urban',p,d)
                  /(XHOU_S0(c,'HHURLOW',d)+XHOU_S0(c,'HHURHIGH',d));

 RCON('rural',p,d) = SUM(c,SHP(c,'rural',p,d)
                  *(XHOU_S.L(c,'HHRULOW',d)+XHOU_S.L(c,'HHRUHIGH',d)));
 RCON('urban',p,d) = SUM(c,SHP(c,'urban',p,d)
                  *(XHOU_S.L(c,'HHURLOW',d)+XHOU_S.L(c,'HHURHIGH',d)));
 RCON0('rural',p,d) = SUM(c,SHP(c,'rural',p,d)
                   *(XHOU_S0(c,'HHRULOW',d)+XHOU_S0(c,'HHRUHIGH',d)));
 RCON0('urban',p,d) = SUM(c,SHP(c,'urban',p,d)
```

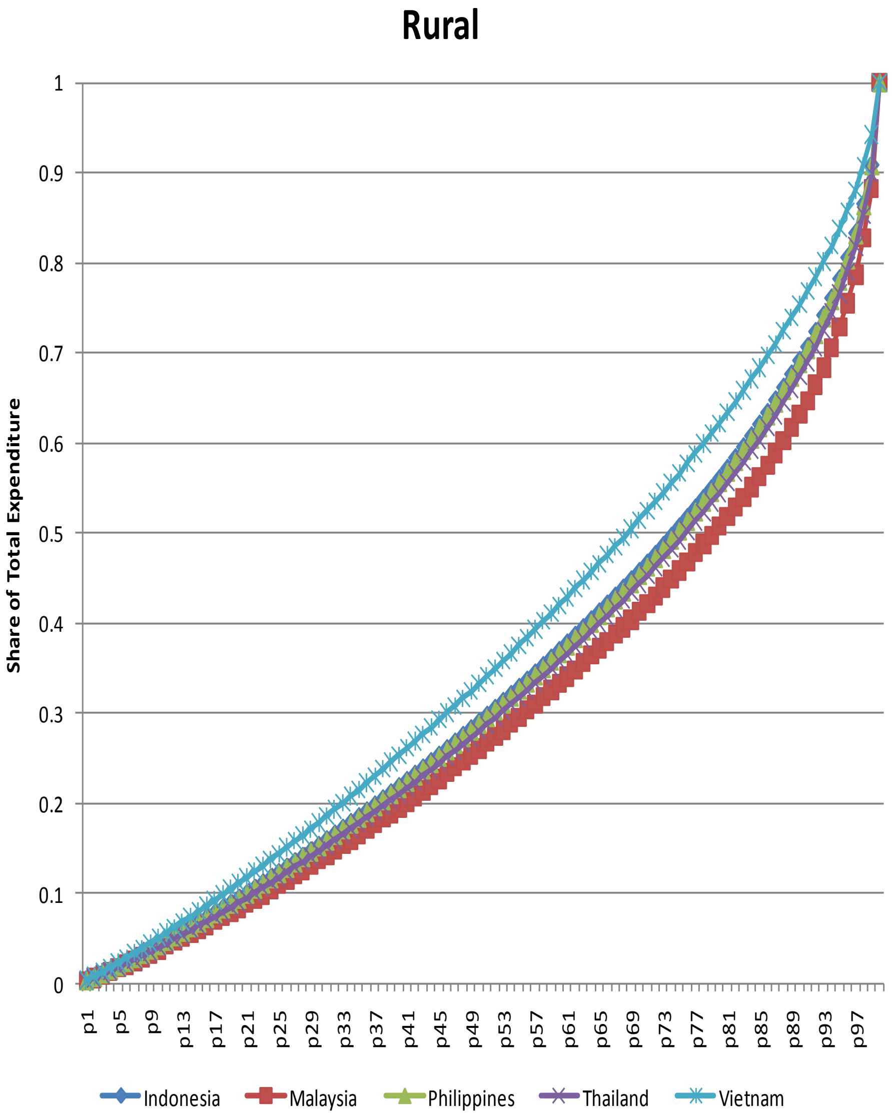
```
                   *(XHOU_S0(c,'HHURLOW',d)+XHOU_S0(c,'HHURHIGH',d)));

parameter
 RCONCAP(hx,p,d)  Real consumption per capita
 RCONCAP0(hx,p,d)  Real consumption per capita
;

 RCONCAP(hx,p,d)$RCON(hx,p,d) = (RCON(hx,p,d)*10**6)/POPP(hx,p,d);
 RCONCAP0(hx,p,d)$RCON(hx,p,d) = (RCON0(hx,p,d)*10**6)/POPP(hx,p,d);

display SHP, RCON, RCONCAP;

parameter
 RCONRURAL(p,d)
 RCONURBAN(p,d)
 RCONRURAL0(p,d)
 RCONURBAN0(p,d)
 RCONCAPRURAL(p,d)
 RCONCAPURBAN(p,d)
 RCONCAPRURAL0(p,d)
 RCONCAPURBAN0(p,d)
 LOGRCONCAPRURAL(p,d)
 LOGRCONCAPURBAN(p,d)
 dRCONCAPRURAL(p,d)
 dRCONCAPURBAN(p,d)
 RCONCHECK(d)
;

 RCONRURAL(p,d) = RCON('rural',p,d);
 RCONURBAN(p,d) = RCON('urban',p,d);
 RCONCAPRURAL(p,d) = RCONCAP('rural',p,d);
 RCONCAPURBAN(p,d) = RCONCAP('urban',p,d);
 RCONRURAL0(p,d) = RCON0('rural',p,d);
 RCONURBAN0(p,d) = RCON0('urban',p,d);
 RCONCAPRURAL0(p,d) = RCONCAP0('rural',p,d);
 RCONCAPURBAN0(p,d) = RCONCAP0('urban',p,d);
 LOGRCONCAPRURAL(p,d)$RCONCAP('rural',p,d) = LOG10(RCONCAP('rural',p,d));
 LOGRCONCAPURBAN(p,d)$RCONCAP('urban',p,d) = LOG10(RCONCAP('urban',p,d));

 dRCONCAPRURAL(p,d)$RCONCAPRURAL0(p,d) = (RCONCAPRURAL(p,d)-RCONCAPRURAL0(p,d))
                                        /RCONCAPRURAL0(p,d)*100;
 dRCONCAPURBAN(p,d)$RCONCAPURBAN0(p,d) = (RCONCAPURBAN(p,d)-RCONCAPURBAN0(p,d))
                                        /RCONCAPURBAN0(p,d)*100;

 RCONCHECK(d) = SUM((hx,p),RCON(hx,p,d))/SUM((c,h),XHOU_S.L(c,h,d));

display RCONCHECK;

$libinclude xldump RCONRURAL outputhhexpend.xls RCONRURAL
$libinclude xldump RCONURBAN outputhhexpend.xls RCONURBAN
$libinclude xldump RCONCAPRURAL outputhhexpend.xls RCONCAPRURAL
$libinclude xldump RCONCAPURBAN outputhhexpend.xls RCONCAPURBAN
$libinclude xldump LOGRCONCAPRURAL outputhhexpend.xls LOGRCONCAPRURAL
$libinclude xldump LOGRCONCAPURBAN outputhhexpend.xls LOGRCONCAPURBAN
$libinclude xldump RCONCAPRURAL0 outputhhexpend.xls RCONCAPRURAL0
$libinclude xldump RCONCAPURBAN0 outputhhexpend.xls RCONCAPURBAN0
$libinclude xldump dRCONCAPRURAL outputhhexpend.xls dRCONCAPRURAL
$libinclude xldump dRCONCAPURBAN outputhhexpend.xls dRCONCAPURBAN

parameter
chkhou_s1(d)
chkhou_s2(d)
chkhou_s3(hx,d)
chkhou_s10(d)
chkhou_s20(d)
chkhou_s30(hx,d)
dchkhou_s1(d)
dchkhou_s2(d)
dchkhou_s3(hx,d)
drconrural(p,d)
drconurban(p,d)
chkrural(p,d)
chkurban(p,d)
;

chkhou_s1(d) = sum(p,RCONRURAL(p,d));
chkhou_s2(d) = sum(p,RCONURBAN(p,d));
chkhou_s3('rural',d) = sum(c,XHOU_S.L(c,'HHRULOW',d)+XHOU_S.L(c,'HHRUHIGH',d));
```

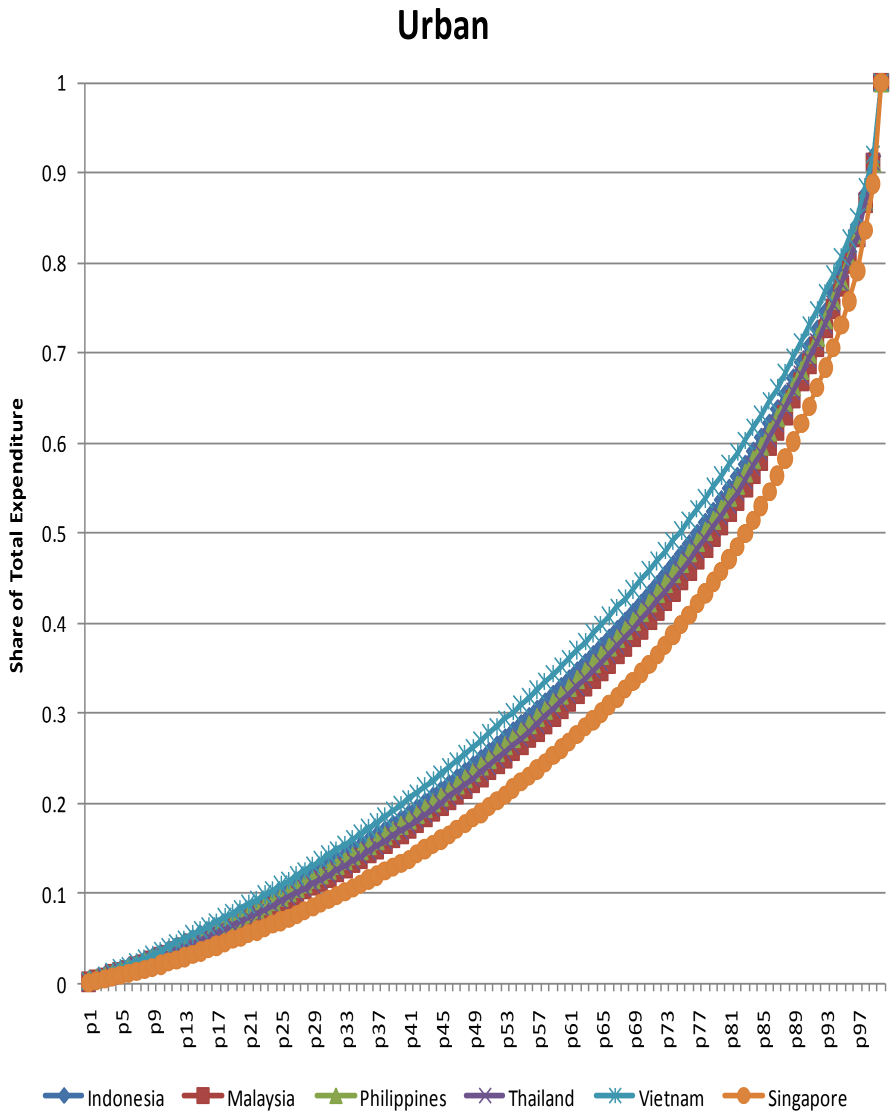
```
chkhou_s3('urban',d) = sum(c,XHOU_S.L(c,'HHURLOW',d)+XHOU_S.L(c,'HHURHIGH',d));

chkhou_s10(d) = sum(p,RCONRURAL0(p,d));
chkhou_s20(d) = sum(p,RCONURBAN0(p,d));
chkhou_s30('rural',d) = sum(c,XHOU_S0(c,'HHRULOW',d)+XHOU_S0(c,'HHRUHIGH',d));
chkhou_s30('urban',d) = sum(c,XHOU_S0(c,'HHURLOW',d)+XHOU_S0(c,'HHURHIGH',d));

 dRCONRURAL(p,d)$RCONRURAL0(p,d) = (RCONRURAL(p,d)-RCONRURAL0(p,d))
                                   /RCONRURAL0(p,d)*100;
 dRCONURBAN(p,d)$RCONURBAN0(p,d) = (RCONURBAN(p,d)-RCONURBAN0(p,d))
                                   /RCONURBAN0(p,d)*100;

chkrural(p,d)$dRCONCAPRURAL(p,d) = dRCONRURAL(p,d)/dRCONCAPRURAL(p,d);
chkurban(p,d)$dRCONCAPURBAN(p,d) = dRCONURBAN(p,d)/dRCONCAPURBAN(p,d);

dchkhou_s1(d)$chkhou_s10(d) = (chkhou_s1(d)-chkhou_s10(d))/chkhou_s10(d)*100;
dchkhou_s2(d)$chkhou_s20(d) = (chkhou_s2(d)-chkhou_s20(d))/chkhou_s20(d)*100;
dchkhou_s3('rural',d)$chkhou_s30('rural',d) = (chkhou_s3('rural',d)
                     -chkhou_s30('rural',d))/chkhou_s30('rural',d)*100;
dchkhou_s3('urban',d)$chkhou_s30('urban',d) = (chkhou_s3('urban',d)
                     -chkhou_s30('urban',d))/chkhou_s30('urban',d)*100;

display chkhou_s10, chkhou_s20, chkhou_s30, chkhou_s1, chkhou_s2, chkhou_s3,
        dchkhou_s1, dchkhou_s2, dchkhou_s3, chkrural, chkurban;
```

Appendix 2. Household Expenditure per Capita



Appendix 3. Household Expenditure Distribution





Appendix 4. Simulation Results of Scenario 2**

	CO_2	Real GDP	Real Sectoral Change (%)			Real Household Expenditure Change (%)			
	%	%	Agri.	Manuf.	Serv.	Rural-Low	Urban-Low	Rural-High	Urban-High
Government									
Indonesia	-3.66	0.25	-0.14	-0.29	0.73	-1.09	-1.26	-1.19	-0.20
Malaysia	0.01	*	*	*	*	*	*	*	*
Philippines	*	*	*	*	*	*	*	*	*
Singapore	-0.01	-0.01	*	-0.04	0.01		-0.03		-0.03
Thailand	*	*	*	*	*	*	*	*	*
Vietnam	*	*	*	*	*	-0.01	-0.01	-0.02	-0.01
Household									
Indonesia	-3.38	0.27	0.01	0.09	0.46	2.14	0.11	-1.32	-0.91
Malaysia	0.01	*	*	*	*	*	*	*	*
Philippines	*	*	*	*	*	*	*	*	*
Singapore	-0.01	-0.01	*	-0.04	*		-0.03		-0.02
Thailand	*	*	*	*	*	*	*	*	*
Vietnam	*	*	*	*	*	-0.01	-0.01	-0.01	-0.01
Industry									
Indonesia	-3.49	0.26	-0.04	0.44	0.21	-1.64	-1.72	-1.40	-0.17
Malaysia	0.01	*	*	*	*	*	*	*	*
Philippines	*	*	*	*	*	*	*	*	*
Singapore	-0.01	-0.01	*	-0.03	*		-0.03		-0.02
Thailand	*	*	*	*	*	*	*	*	*
Vietnam	*	*	*	*	*	-0.01	-0.01	-0.01	-0.01

* - Neglible Value

** - Asymmetric Carbon Tax at USD 10 per ton of CO_2 Emission with No Efficiency Gain

Appendix 5. Simulation Results of Scenario 3**

	CO_2	Real GDP	Real Sectoral Change (%)			Real Household Expenditure Change (%)			
	%	%	Agri.	Manuf.	Serv.	Rural-Low	Urban-Low	Rural-High	Urban-High
Government									
Indonesia	-4.51	0.29	-0.11	-0.27	0.79	-1.06	-1.23	-1.14	-0.12
Malaysia	-4.71	0.08	0.05	-0.14	0.51	-1.28	-1.46	-1.06	-1.27
Philippines	-4.14	*	-0.04	-0.40	0.31	-0.71	-0.63	-0.70	-0.65
Singapore	-0.95	-0.01	0.02	-0.35	0.12		-0.32		-0.33
Thailand	-2.99	-0.10	-0.16	-0.68	0.36	-0.82	-0.52	-1.03	-0.93
Vietnam	-7.73	-0.20	0.03	-0.97	0.98	-1.68	-1.66	-1.67	-1.42
Household									
Indonesia	-4.22	0.31	0.05	0.11	0.52	2.19	0.16	-1.27	-0.84
Malaysia	-4.40	0.10	0.20	0.10	0.08	7.17	-0.69	-1.29	-1.48
Philippines	-3.97	0.02	0.09	-0.16	0.14	5.83	0.48	-0.80	-0.82
Singapore	-0.88	-0.01	0.04	-0.26	0.09		0.46		-0.37
Thailand	-2.69	-0.04	0.03	-0.32	0.18	3.75	0.50	-1.21	-1.39
Vietnam	-7.22	-0.10	0.22	-0.51	0.44	2.53	0.39	-1.71	-1.67
Industry									
Indonesia	-4.16	0.30	0.02	0.60	0.17	-1.56	-1.61	-1.30	-0.26
Malaysia	-4.68	0.08	0.04	0.27	-0.27	-2.68	-2.53	-0.71	-0.91
Philippines	-4.49	*	-0.05	-0.25	0.19	-0.94	-0.56	-0.94	-0.53
Singapore	-0.94	-0.01	0.05	-0.10	0.02		-0.51		-0.22
Thailand	-3.10	-0.10	-0.10	-0.32	0.08	-2.49	-1.23	-2.14	-0.64
Vietnam	-5.17	-0.09	0.33	0.37	-1.05	-1.75	-2.46	-1.76	-2.51

* - Neglible Value

** - Symmetric Carbon Tax at USD 10 per ton of CO_2 Emission with 10% Energy Efficiency in Coal Use

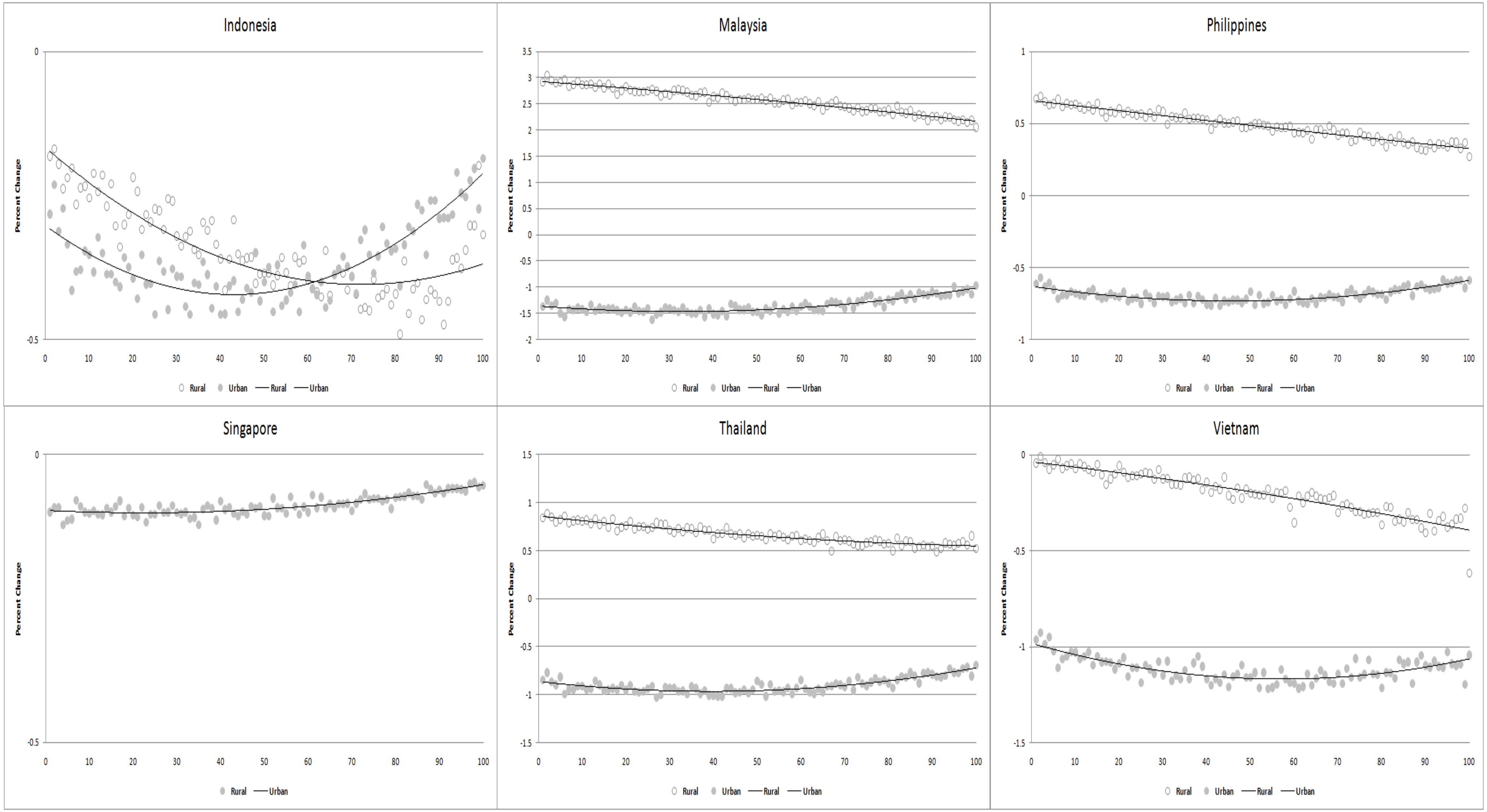
Appendix 6. Simulation Results of Scenario 4**

	CO_2	Real GDP	Real Sectoral Change (%)			Real Household Expenditure Change (%)			
	%	%	Agri.	Manuf.	Serv.	Rural-Low	Urban-Low	Rural-High	Urban-High
Government									
Indonesia	-6.36	0.75	0.31	0.03	1.38	-0.44	-0.64	-0.53	0.44
Malaysia	-6.76	0.44	0.36	0.07	1.16	-0.88	-1.04	-0.64	-0.84
Philippines	-5.97	0.19	0.13	-0.33	0.59	-0.56	-0.45	-0.51	-0.43
Singapore	-5.15	0.24	0.24	-0.07	0.36		-0.09		-0.04
Thailand	-5.20	0.59	0.50	-0.18	1.21	-0.33	0.14	-0.35	*
Vietnam	-8.15	0.08	0.28	-0.78	1.42	-1.35	-1.34	-1.34	-1.08
Household									
Indonesia	-6.07	0.77	0.46	0.40	1.11	2.75	0.71	-0.65	-0.26
Malaysia	-6.45	0.46	0.51	0.31	0.74	7.40	-0.28	-0.86	-1.04
Philippines	-5.81	0.21	0.26	-0.09	0.42	5.85	0.64	-0.61	-0.60
Singapore	-5.09	0.24	0.26	0.02	0.33		0.65		-0.08
Thailand	-4.91	0.65	0.68	0.17	1.03	4.14	1.14	-0.53	-0.45
Vietnam	-7.64	0.18	0.48	-0.32	0.88	2.85	0.70	-1.38	-1.33
Industry									
Indonesia	-6.03	0.76	0.43	0.87	0.78	-0.93	-1.02	-0.68	0.31
Malaysia	-6.73	0.44	0.35	0.47	0.40	-2.24	-2.08	-0.29	-0.49
Philippines	-6.31	0.18	0.12	-0.19	0.47	-0.77	-0.37	-0.74	-0.30
Singapore	-5.14	0.24	0.27	0.17	0.27		-0.27		0.06
Thailand	-5.31	0.59	0.56	0.17	0.93	-1.95	-0.55	-1.43	0.28
Vietnam	-5.57	0.20	0.59	0.56	-0.59	-1.42	-2.14	-1.43	-2.18

* - Neglible Value

** - Symmetric Carbon Tax at USD 10 per ton of CO_2 Emission with 5% Energy Efficiency in Oil Use

Appendix 7. Real Household Expenditure Changes in Percent with Second Recycling Revenue Mechanism



Appendix 8. Real Household Expenditure Changes in Percent with Third Recycling Revenue Mechanism