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THE IMPACTS OF IMPLEMENTING THE CARBON TAX ON FOSSIL FUELS: A HYBRID CGE ANALYSIS FOR INDONESIA

DAMPAK DARI PENERAPAN PAJAK EMISI UNTUK ENERGI FOSIL: ANALISIS CGE HIBRIDA UNTUK INDONESIA

Herbert Wibert Victor Hasudungan
Secretariat General of National Energy Council of the Republic of Indonesia
Jl. Jenderal Gatot Subroto Kav. 49 Jakarta Selatan 12950 Indonesia. Telephone: 021-52921621,
Faxsimile: 021-52920190. E-mail: herbertwvh@gmail.com

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ABSTRAK

Penelitian ini menginvestigasi dampak ekonomi dan lingkungan dari penerapan pajak CO_2 bahan bakar berbasis karbon dengan menggunakan model CGE yang detil pada disagregasi energi-ekonomi-lingkungan. Hingga saat ini pajak karbon belum diterapkan di Indonesia, namun demikian, instrumen ini telah dipertimbangkan dalam laporan Kementerian Keuangan sebagai salah satu strategi kerangka kerja fiskal untuk sumber dana untuk membiayai rencana kerja Indonesia dalam komitmen untuk menurunkan emisi gas rumah kaca nasional. Kami mengasumsikan bahwa pemerintah menerapkan pajak karbon sebesar Rp. 100,000/ton CO_2e dengan dua skenario revenue-recycling yang memungkinkan: tambahan pendapatan negara yang diperoleh dari penerapan pajak karbon akan dikompensasi dengan mengurangi pajak penghasilan atau meningkatkan pengeluaran pemerintah. Untuk perbandingan, kami juga menerapkan suatu skenario non-kompensasi dimana tambahan pendapatan dari pajak karbon dianggap sebagai budget surplus. Secara keseluruhan, hasilnya menujukkan bahwa pajak karbon dapat menurunkan tingkat emisi nasional, namun menambah beban biaya ke dalam perekonomian sehingga PDB menurun. Terkait dengan distribusi pendapatan, pajak karbon cenderung progresif untuk semua skenario. Namun jika skenario non-kompensasi diterapkan, pajak karbon cenderung regresif - rumah tangga yang miskin menanggung beban pajak karbon lebih tinggi dibandingkan dengan rumah tangga yang kaya.

***Kata Kunci**: pajak karbon, energi fosil, gas rumah kaca (GRK), ketimpangan dan kesejahteraan rumah tangga, model CGE hibrida, Indonesia.*

ABSTRACT

This paper investigates the environmental and economic impacts of introducing the CO_2 taxation on carbon-based fuels using a detailed disaggregation of energy-economy-environmental CGE model for Indonesia. The carbon tax has yet to be implemented in Indonesia. However, this instrument has been considered in the Ministry of Finance report as one of the government's fiscal strategic framework to finance the country's action plan in commitments to reduce the GHG emissions. Suppose that the government levies the tax of Rp. 100,000/ton CO_2e under two possible revenue-recycling scenarios: the carbon tax revenue is recycled through a reduction of labour income tax rate or an increase of government spending on commodities. For comparison purpose, we also implement the non-compensated scenario of which the additional revenue from carbon tax is kept as government savings to run budget surplus. Overall, the results suggested that the carbon tax reduces the national emissions but adding more costs to the economy, resulting a fall in GDP. In terms of income distribution, the carbon tax tends to be progressive in both scenarios of revenue-recycling. However, when there is no compensating mechanism, the carbon tax tends to be regressive - the poorer households carry a higher share of the carbon tax burden.

Keywords: carbon tax, fossil fuels, Greenhouse Gas (GHG) emissions, households' welfare and inequality, hybrid CGE model, Indonesia.

I. INTRODUCTION

In recent decades, the threat of global warming – that is primarily caused by the atmospheric greenhouse gas emissions – has become a central issue in the world's political and scientific arena. The global average temperature has increased by 0.6^{0}C over the last century, whilst the CO_2 concentration could rise between 75% - 350% above preindustrial level by the end of the twenty-first century (IPCC 2010). If the CO_2 emissions are not mitigated, the global temperature could rise by between 1.4 – 5.8^{0}C by 2100 (IEA 2009; and Baumert et al. 2005). As a consequence, the climate change can lead to severe problems for the world's population, especially in developing countries, such as sea level rise, extreme weather, flooding, a drop in biodiversity, a lack of water resources, and diseases (Lackner et al. 2012; and Baumert et al. 2005).

As a group member of non-Annex 1, Indonesia ratified the UNFCCC and adopted the Kyoto Protocol in order to seriously mitigate the climate change (Ministry of Finance 2008). Under the Copenhagen Accord, the Indonesia's government has voluntarily made a commitment to reduce their national greenhouse gas (GHG) emissions by 26% in year 2020 of which the GHG emissions shares from energy utilization are targeted to be reduced by about 1% (NCCC 2009). Despite the fact that Indonesia has a huge potential of renewable energy sources, their utilizations are still very low (NCCC 2009). Therefore, Indonesia is expected to scaling up this clean energy production in order to lowering the national emissions (NCCC,2009; Ardiansyah et al. 2012).

Until date, Indonesia still faces great challenges to reach the target of an evenly distributed energy development. Indonesia's energy supply has been strongly dominated by fossil fuels (96%), while only 4% energy supply from zero emission (renewable) sources – mostly from hydro and geothermal (National Energy Council, 2014). Total GHG emissions from the energy sector are suspected to grow rapidly, from 598 million tCO_2e (28% of total national emissions) in 2014 to about 2,900 million tCO_2e in 2050 in the base scenario, or about 3,829 million tCO_2e in the high scenario[1] (BPPT, 2016). The largest emissions contributor is the high rate of fossil fuels combustion in industrial activities that reached around 5.1% on growth rate average per year, with coal accounting for 56% of total fuel consumption. Ministry of Finance (2012) argued that by reducing fossil fuels dependence, the emissions from electricity industry are most likely to be reduced by 26%. If this is achieved, the total national emissions can be cut by around 14% or about 104 million tCO_2e in year 2020. This target, however, requires additional funding at least one third of the total budget either through some joint financing schemes or fiscal compensations.

Imposing carbon taxes – carbon pricing instrument[2] – can be used as alternative schemes in mitigating the climate change (Bhattacharyya, 2011 Carbon tax is an explicit tax – in terms of the price per tCO_2e – imposed on the carbon content of the polluter, i.e. the 'dirty' fuels (Hoeller and Wallin, 1991). It is a Pigouvian tax aiming to internalize the externality of climate change (Bhattacharyya, 2011). Pittel et al. (2012) point out that a carbon tax increases the price of polluter commodities, such that there are incentives to reduce the utilization of such commodities. However, carbon tax may bear some disadvantages, i.e. it increases the energy costs which in turn reduces the domestic consumption (and production) (Orlov 2012). However, a carbon tax has some disadvantages. It increases the energy costs which in turn reduces the domestic consumption (and production) (Orlov 2012). It might also be regressive towards income distribution; as 'dirty' fuels are normal goods, thus, imposing carbon taxes to these polluters might disproportionately harm low-income households instead of rich households (Ditya and Resosudarmo 2016; and Callan et al. 2009). Carbon pricing might also create a "rebound effect", in that it triggers a higher level of GHG emissions instead of reducing it (Ditya and Resosudarmo 2016). A rebound effect may occur from two channels. First, the increased price of CO_2-related fuels leads to a higher energy efficiency which in turn increases the energy consumption that offsets the energy saving (Sorrel and Dimitropoulos 2008; and Sorrel 2009). Second, the additional revenue gained from carbon

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[1] *Based on BPPT (2016), the energy projections until 2050 are estimated on two different scenarios: base scenario and high scenario. In base (high) scenario, the Indonesian GDP between 2014 – 2050 is assumed to be increased at average growth rate 6% (7%) per year. GDP growth in year 2014 (5.02%) is projected to be increased by 7% (8%) in year 2025 and then slowly reduces until 5% (6%) in year 2050. These projection trends are in line to the projections given in the national development plan (RPJMN) 2015-2019.*

[2] *Based on the World Bank (2015), carbon pricing can be introduced in several ways, i.e. the implementation of Emission Trading System (ETS), carbon taxes, offset mechanisms, results-based finance (RBF), and internal carbon prices set by companies.*

tax could also increase the institutions' demand for energy (Ditya and Resosudarmo 2016).

In Indonesia, the carbon tax has yet to be implemented. A carbon tax was considered in the Ministry of Finance (2009) report as one of the government's fiscal strategic framework to finance the country's action plan to reduce the GHG emissions – regulated in the Presidential Regulation no. 61/2011. The report identified the strategy including "working towards a carbon tax or levy on fossil fuel in parallel with removal over time of energy subsidies and with access to international carbon markets" (Ministry of Finance, 2012). The report argued that a carbon tax can lower the carbon emissions in electricity generation supply and industrial activities as well future investment decisions (Ministry of Finance, 2009).

This study aims to investigate the implications of implementing the carbon tax on Indonesian economy. The term of 'carbon' refers only to CO_2 emissions of fossil fuels and its refined fuels; we exclude the emissions generated from other activities, i.e. land use in agriculture and deforestation. We analyze the effects of this policy instrument, within the context of general equilibrium analysis, on Indonesia's macroeconomic and examine how different institutions and sectors in the economy are affected. We carry out a number of scenarios which are principally related to the ways of fiscal schemes in recycling the carbon tax.

We assume that the Indonesia's government levies a tax of Rp. 100,000/ton CO_2e with two possible revenue-recycling schemes. In the first simulation, we allow the revenue neutralizing scheme by which the revenue raised from carbon tax is neutralize through a reduction in income (labour) tax rates. In other words, the income (labour) tax rate is allowed to adjust so that the government net receipts are in balance. In the second simulation, we allow the government to adjust their spending on goods proportionally in response to the revenue raised from carbon tax. A higher public expenditure is expected to increase the equilibrium output. For comparison, in the third simulation, we assume endogenous government saving, without any revenue recycling, to allow a budget surplus.

The rests of this chapter are organized as follows: Section 2 discusses the literature studies. Section 3 discusses the theoretical model and identification of scenarios. Section 4 discusses simulation results and sensitivity analysis. Finally, Section 5 presents the conclusions.

II. METHODOLOGY

A. Previous Literature

A carbon tax usually aims to improve the environment and to reduce tax distortion although the magnitude of its benefit highly depends on the economy's structure and strategies in recycling the revenue (Orlov 2012). According to the literature, carbon taxes tend to be regressive in developed countries; and neutral or progressive in developing countries. These distributional implications are considered to be the most important issue on the carbon taxes political agenda (Baranzini et al. 2000).

A study for Russia was done by Orlov and Grethe (2012), who investigated the distributional effects of carbon tax under perfect and imperfect competition (Cournot oligopoly), in the context of Computable General Equilibrium (CGE) model. The authors simulated the implementation of a carbon tax on fossil fuels combustion to meet the national emissions reduction target by 10%, where the revenue is recycled through the reduction of labour taxes under two market conditions: perfect competition and Cournot oligopoly. A carbon tax is found to be regressive; however, lower labour taxes can compensate the lower-income households so that the regressive effect can be prevented. Under perfect competition, the revenue recycling of carbon tax through reduction of labour taxes can obtain a strong double dividend – although the magnitude of the welfare highly depends on the labour supply elasticity and the elasticity of substitution among production factors and energy. Welfare, measured by the EV, is improved by 0.23%; household income increases due to higher return to land via the increasing land supply and improvement of labour income via lower labour taxes and an increased labour supply. Under Cournot oligopoly, carbon tax increases mark-ups. which leads to welfare losses – measured as EV. The domestic supply is already sub-optimal under imperfect competition, thus a further reduction in domestic demand will lead to higher dead-weight losses. Specifically, the introduction of a carbon tax increases the market power of the gas sector due to the increasing shares of gas demand in the market. The mark-ups of chemical products and metals increase due to less competition; in contrast, the mark-ups of mineral products and petroleum products are declined, thus the pre-existing distortions arising in these markets are partially alleviated. In conclusion, the welfare costs of imposing the carbon tax under Cournot oligopoly is higher than that of the perfect competition.

Mahmood and Marpaung (2014) investigated the effects of implementing the simultaneous carbon energy taxes and energy efficiency improvement on Pakistan's economy. By employing a recursive CGE model, they simulated two main scenarios: (i) the shock of carbon tax (at different levels ranging from \$20 - \$80/ton CO_2) with two alternatives of revenue-recycling, which are either adjusting the government spending on public goods or lump-sum transfers to households; and (ii) the shock of simultaneous carbon tax (\$50) and energy efficiency (at different levels) with increase of government spending on public goods to recycle the tax revenue. The findings revealed that all scenarios lead to a GDP contraction and a large reduction of GHG emissions (CO_2, CH_4, N_2O, and SO_2). In scenario (i), the carbon tax of \$80/ ton CO_2e will decrease GDP by 3.59% in year 2050; the primary energy consumption dropped largely by 27.92% and CO_2 20.83%. A lower carbon tax (\$10/ton CO_2) the GDP (and other macroeconomic variables excluding government consumption) reduction is much smaller. In a variant of scenario (i), the results indicated a less contraction to GDP due to the increased investment (or a higher marginal propensity to save) which in turn increases final consumption; nonetheless, the effects on CO_2 emissions and sectoral changes are quite similar to that of the first case. In contrast, scenario (ii) has positive implications for the economy in which the GDP is improving while energy consumption and pollutant emissions decline more than that of both cases in scenario (i). The authors argued that this is induced by the effects of energy efficiency improvement which identical to a higher volume of energy inputs but reduction of their prices, which in turn, it gradually offset the adverse effects of carbon taxation. This study, does not examine the impacts on income distribution since it is only based on a single representative household.

Nurdianto and Resosudarmo (2016) analysed the economic benefits and losses of implementing carbon tax across ASEAN countries (Indonesia, Malaysia, the Philippines, Singapore, and Thailand) using the Inter-Regional System of Analysis for ASEAN (IRSA-ASEAN) model – a multi-region CGE model. The study simulated a uniform carbon tax (US\$ 10/ ton CO_2) under three different scenarios of recycling scheme. Overall, the results suggested that the carbon tax, in short run, can reduce the national emissions in an effective way without a rebound effect. However, a double-dividend might not be always achieved through a combination of the carbon taxation and its revenue-recycling scheme among ASEAN countries. The introduction of a carbon tax would likely result in a fall in GDP. The carbon tax tends to be progressive for all countries, excluding Singapore. In terms of income distribution, the carbon tax tends to be progressive for all countries except Singapore. The carbon tax can also lead to more poverty; however, poverty can be reduced if the government directly compensates the poor households through cash transfers.

B. The Hybrid CGE Model

We specifically develop a hybrid CGE model that incorporates energy technologies – particularly power plants. This will enable us to identify the magnitude of the impact of different level of carbon taxes on fossil fuel on Indonesia's economy. We also distinguish the nested structure between energy and non-energy producing sectors by which we allow substitution between energy and production factors as well as substitution among energy types. The carbon emission is generated from consumption on final energy goods such as household types and government as well as industries (used as the intermediate inputs or factor inputs).

a. The Output Production

For non-energy sectors, we allow two possibilities of energy substitution: inter-fuel substitution and fuel-factor substitution (between the energy composite and production factors). We allow a fixed factor of natural resources of each type of fossil fuel, i.e. oil resources factor for oil sector, coal resources for coal mining, and natural gas resources for gas mining. These factors characterize the resource constraints due to the fact that fossil output production is highly dependent on the availability of these resource stocks (RTI 2008).

For refinery industry, the nested production structure is identical to that of fossil fuel industries (Fig. 1). However, there are some differences. The refinery industry depends strongly on crude oil input – generated from oil mining industry – to produce petroleum products which cannot be replaced by other types of intermediate inputs. However, it is not dependent on the fixed factor of oil resources (RTI 2008). Due to this principle, we modify the top stage of nested structure for fossil industries by excluding the fixed factor of natural resources input. But we are allowing the intermediate input of crude oil commodity – as the most essential input – in fixed proportion to produce petroleum products. Furthermore, because refinery industry produces

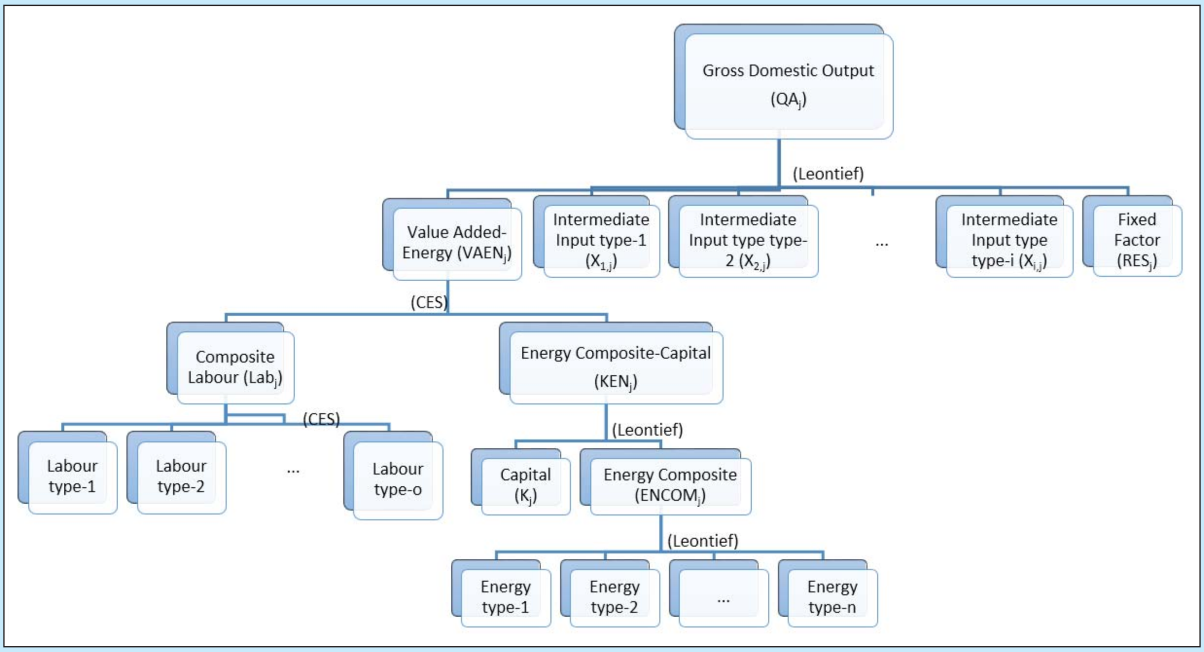

Figure 1
The nested structure for fossil fuel producing Sectors.

several types of petroleum products, hence we characterize a one-to-multiple relationship between activity output (and price) and its commodity supply (and price). Figure 2 illustrates the relationship between refinery's industry output and its petroleum products.

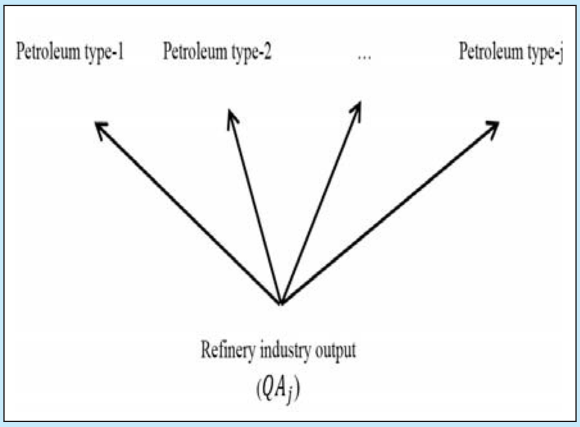

Figure 2
Structure of petroleum products.

In electricity sector, we employ a hybrid modeling approach – integrating top-down macroeconomic models and bottom-up engineering models – in which we disaggregate the electricity sector into activities of transmission (and distribution) and electricity technologies: conventional fossil, geothermal and hydro power plant[3]. Figure 3 illustrates the production process of -th electricity industry to generate the homogenous electricity supply.

The electricity supply is determined from the fixed shares of transmission (and distribution) and generation composite output. Whilst, the generation composite output is defined by three arguments of Cobb-Douglas function over conventional, geothermal, and hydro power plants. Since the activities of transmission and distribution are related only to non-energy services, we assume that the production structure is similar to that of non-energy producing sectors. Therefore, the specifications for all stages (top – bottom stage) of this activity are identical to the non-energy producing structures. While, the production structures of conventional (aggregated fossil fuels) generation is illustrated in Figure 4. The production structures for renewables generation are similar to that of the conventional activity. The differences, however, are by which we allow the fixed factor of natural resources of each type of renewable generation, i.e. geological hot dry

[3] We do not include other generation technologies such as solar, nuclear, wind, and so on because these generations were not existed in the base year data set.

rock for geothermal generation, and topographically-determined hydrostatic potential for hydro generation (Wing 2006). Because the SAM data set does not record these factors explicitly, we follow Wing (2006) approximation by which these are estimated as roughly 20% shares of capital input. In addition, we eliminate the specification for the energy composite at the bottom stage since this composite is not required to generate renewable energy.

For non-energy sectors, we allow two possibilities of energy substitution: inter-fuel substitution and fuel-factor substitution (between the energy composite and production factors).

b. Calculating the Carbon Tax

To specify the CO_2 emission and its taxation, we assume that utilizations (absorptions) of fossil and its refinery (petroleum) products emit CO_2 due to their combustion. Following Allan et al. (2008), we do not take into account the pollutants from non-CO_2 emissions – i.e. methane, sulphuric acid, carbon monoxide emissions – due to the complexity of identifications that are strongly related to combustion conditions and technology. These absorptions cover: the fossil (and petroleum) input in the production process across industries and the final fossil (and petroleum) consumption by households and government. Because of limited information,

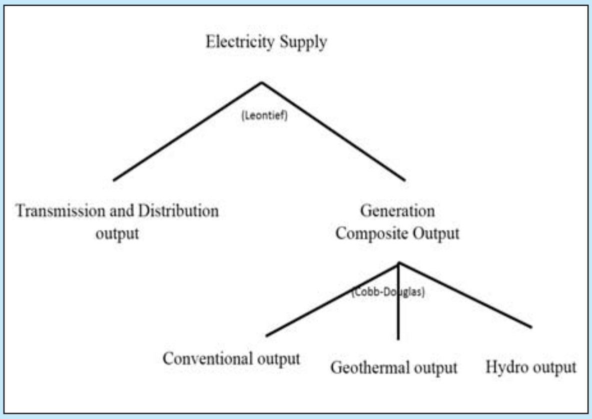

Figure 3
Structure of electricity sector.

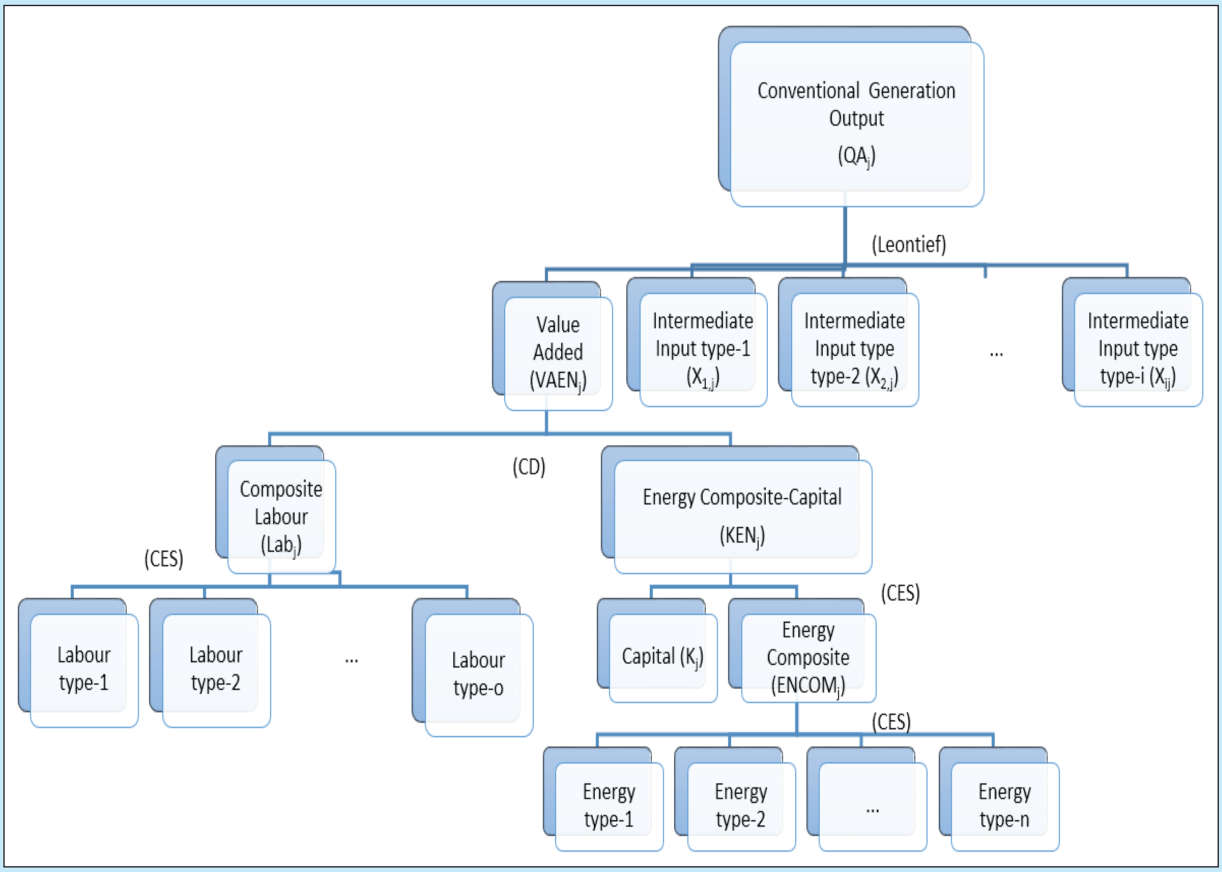

Figure 4
Structure of conventional generation activity.

however, we exclude the emissions generated by agriculture – i.e. land use change – and deforestation.

1. CO_2 emissions accounting

Suppose the intermediate fuel inputs (fossils and refineries inputs), denoted as $i \in \{fuel\ types\} \subset energyc \subset C$, used by the j-th industry in the production processes are specified as X_{ij}. Hence, the total CO_2 emissions, expressed in tons, generated from fuels combustion in each industry ($CO2FIRM_j$), is obtained by the multiplication of X_{ij} and their emission factor $CO2FAC_i$ as follows:

$$CO2FIRM_j = \sum_{i \in \{fuel\ types\} \subset energyc \subset C} CO2FAC_i \, . X_{i,j} \, , \quad j \in A \quad (1)$$

The total CO_2 emission generated from fuel consumption by households and government are obtained as follows:

$$CO2INS = \sum_{i \in \{fuel\ types\} \subset energyc \subset C} CO2FAC_i \, . \left(\sum_{h \in H} CH_{i,h} + CG_i \right) \quad (2)$$

Where $CO2INS$ is the total CO_2 emission on final consumption; i is an element of the subset of fuel types (fossils and refineries) commodity; $\sum_{h \in H} CH_{i,h}$ and CG_i are the respective fuel consumption by the households' and government.

In the absence of detailed emission factors by fuel type for Indonesia, we use the available data based on the Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (2006). To estimate the total CO_2 emissions emitted in Indonesia in the year 2008, the quantity (volume) of fuel domestic consumption is required. We use the available data of domestic oil fuels sales (unit of kilo liters (kl)), crude oil (unit of thousand barrels), coal, natural gas, and LPG consumption (unit of Thousand Barrel Oil Equivalent (BOE) published in the Handbook of Energy and Economic Statistics of Indonesia, Ministry of Energy and Mineral Resources (2010). Table 1 shows the data of emission factors $\left({}^{TonCO_2}/_{TJ}\right)$ and oil fuels volume sales (TJ) for Indonesia in year of 2008[4].

Therefore, the overall CO_2 emissions generated from the economy transactions are the sum of the emissions arising from the fuel combustion of

Table 1
CO_2 emission factor and volume sales by fuel types

No.	Fuel Type	CO_2 emission Factor $\left({}^{TonCO_2}/_{TJ}\right)$	Volume Sales (Tera-joules (TJ))
1.	Bio-ethanol	70.80	7,096.72
2.	Bio-diesel	70.80	13,190.11
3.	Coal	94.60	458,466.31
4.	Crude Oil	73.30	2,187,141.07
5.	Kerosene	71.90	280,375.41
6.	Liquid Natural Gas (LNG)	64.20	1,394.87
7.	Natural Gas	56.10	208,771.97
8.	Non Subsidised Gasoline ('*Pertamax*')	69.30	10,571.66
9.	Non Subsidised Liquefied Petroleum Gases (LPG)	63.10	96,160.52
10.	Other Petroleum Products (Other Oils)	73.30	176,335.08
11.	Subsidised Bio-diesel	70.80	19,785.16
12.	Subsidised Bio-gasoline	70.80	1,560.05
13.	Subsidised Gasoline ('*Premium*')	69.30	682,208.69
14.	Subsidised Diesel Oil	74.10	931,479.67
15.	Subsidised Liquefied Petroleum Gases (LPG)	63.10	313,148.78

Source: IPCC (2006); and Ministry of Energy and Mineral Resources (2010).

[4] *We convert the unit of oil fuels volume (Kilo litters) to Tetra Joule (TJ) so that the total emissions can be calculated.*

industries, households and government:

$$CO2TOTAL = \sum_{j \in A} CO2FIRM_j + CO2INS$$
.

2. CO_2 Emission Taxation

The government revenue from a CO_2 emission tax (*IGCO2*) is obtained by multiplying the tax rate (*TAXCO2*) and total CO_2 emissions (*CO2TOTAL*): *IGCO2 = TAXCO2. CO2TOTAL*

$$= TAXCO2 \sum_{i \in \{fuel\ types\} \subset energyc \subset C} CO2FAC_i \left(\sum_{j \in A} X_{i,j} + \sum_{h \in H} CH_{i,h} + CG_i \right) \quad (3)$$

Where *IGCO2* is the government revenue collected from CO_2 emission tax; *TAXCO2* (in Rp / ton CO_2) is the specific CO_2 emission tax. This revenue is equivalent to the ad-valorem fuel tax imposed across users (industry, households, and government):

$$IGCO2 = \sum_{i \in \{fuel\ types\} \subset energyc \subset C} p_i^Z \left(\sum_j TAXFUEL_{i,j} X_{i,j} + \sum_{h \in H} TAXFUEL_{i,h} CH_{i,h} + TAXFUEL_{i,gov} CG_i \right) \quad (4)$$

Where p_i^Z denotes the market price index of each fuel and $TAXFUEL_{i,user}$ denotes the ad-valorem tax fuel for users that are *j*-th industry, *h*-th household, and government. The relationship between TAXCO2 and $TAXFUEL_{fuel,user}$ is then expressed as follows:

$$TAXFUEL_{i,j} = \frac{TAXCO2.\,CO2FIRM_{i,j}}{p_i^Z X_{i,j}}, i \in \{fuel\ types\} \subset energyc \subset C, \quad j \in A \quad (5)$$

$$TAXFUEL_{i,h} = \frac{TAXCO2.\,CO2H_{i,h}}{p_i^Z CH_{i,h}}, i \in \{fuel\ types\} \subset energyc \subset C, \quad h \in H \quad (6)$$

$$TAXFUEL_{i,gov} = \frac{TAXCO2.\,CO2G_i}{p_i^Z CG_i}, i \in \{fuel\ types\} \subset energyc \subset C, \ gov \in INS \quad (7)$$

Where *A* represents the activity (or industry) set; *H* represents the household set; and *INS* is the institution set. The above expressions imply that $TAXFUEL_{fuel,user}$ does not depend only from the carbon content of each fuel type, but also on economic variables such as fuel prices and volumes (Yusuf 2008).

Therefore, in the next step, we suppose that the government imposes an ad-valorem fuel tax on the utilization of energy input in the *j*-th industry production structure; and final fuel consumption by *h*-th households and government.

The solution software is General Algebraic Modelling System (GAMS) with the Mixed Complementarity Problem (MCP) solver, which has the advantage that it accommodates the complementarity slackness of a flexible mathematical representation of market conditions (Bohringer and Loschel 2006). The MCP solver is useful to solve the non-linier equation systems. It specifies complementarity boundary conditions clearly such that the model is solved normally and is calibrated to the initial values in the SAM (Dirkse 1994). By changing the exogenous variables, the MCP solves the model to obtain a new equilibrium.

c. Institution Block

The government earns income from total institutions' transfers and taxes on household income, enterprise income, output production, imports, and CO_2 emission. The revenues are then spent to purchase goods and services, transfer payments, and subsidies across industries and commodities. The household preferences on output bundles are described from their Cobb-Douglas utility function that is maximized subject to their budget income constraint. Households' disposable income is obtained from total income less income taxes, CO_2 emission tax due to their final consumption of 'dirty' fuel commodities, and transfer payments. The representative households' is motivated to save some portions of their disposable income according to the constant average propensities for savings. Rest of World (ROW) total outflow is generated from total import, institutions' income transfers to ROW, and ROW endowments of factors (labour and capital) supply to domestic. Whilst, the ROW total inflow is determined from total of exports, ROW transfers to institutions', payments to the labor and capital employed by ROW. ROW savings (balance of payments) is then determined equivalently from the current account deficit or residual between ROW outflow and inflow.

C. Data and Calibration

The model is calibrated to the energy-SAM for Indonesia including emission factors and population data. The energy-SAM is an extended version of the official

SAM for Indonesia in the year 2008[5]. To our knowledge, the Indonesian SAM 2008 is the most recent official SAM published. The extensions are as follows:

1. We disaggregate the specific energy accounts (both industries and commodities) from their aggregated account.
2. We characterize the activity-commodity relationship for each energy type, i.e. a refinery sector is permitted to produce multiple types of petroleum products, and multiple types of generation technologies produce a homogenous electricity commodity.
3. We disaggregate the natural resources factor from the capital account to represent the 'fixed factor' resources input such as water debits to generate hydro turbines, and hot dry rock to generate geothermal-based electricity.

To update the details of energy activity (and commodity) into the existing SAM, we employ the data source compiled by the National Energy Council. This data set is compiled by consolidating the information obtained from (a) Input-Output Table of 2008 and 2005, (b) Input-Output of Small and Middle Business Table 2003, (c) The Handbook of Energy and Economic Statistics of Indonesia 2008, (d) The State Expenditure Budget from the Ministry of Finance, (e) The National Statistics of Electricity, (f) The Statistics of City Gas given from the State-Owned Gas Company, (g) data of subsidized gasoline from the Ministry of Mineral and Energy Resources, (h) and other data sources which was obtained from the forum group discussion meetings or direct interview to the head of energy sector stakeholders.

D. Carbon Tax Scenarios and Results

a. Scenarios

At initial equilibrium, we introduce the exogenous injection of carbon tax by which the government collects the tax (*TAXCO2*) of Rp. 100,000/ ton CO_2e on dirty fuels with three possible revenue-recycling scenarios. In simulation 1, the labour income tax rates adjust to clear the government budget balance. The other tax and subsidy rates as well as government spending on goods and services remain unchanged. We suspect a double-dividend where both environmental improvement and reduction of the distorting tax system can be achieved. In simulation 2, the revenue raised from carbon tax is recycled through an expansion of government expenditures on commodities. In other word, the adjusted government expenditures across commodities is endogenous in order to clear the government budget balance; all tax and subsidy rates are fixed. In simulation 3, we assume within the condition if the additional revenue raised from carbon tax is not returned to the economy or not used for compensation. In other words, the tax revenue is kept as government saving to run a budget surplus. All taxes and subsidies as well as government expenditures on goods remain unchanged. Simulation 3 aims to investigate the impact of carbon tax on Indonesia's economy when there is no revenue-neutralizing mechanism.

III. RESULTS AND DISCUSSSION

A. Impacts on Macroeconomic Accounts

Table 2 summarizes the macroeconomic impacts of introducing the carbon tax. The results reveal that simulation 1 leads to improvement in all GDPs; in contrast, simulation 2 and simulation 3 reduce the GDPs. These imply that the increase of fuel prices due to a carbon tax is offset primarily by higher household income improvement via labour income tax rate reduction (simulation 1). Thus, it induces a higher domestic demand on goods and services due to improvement in their disposable income, which in turn, increases the aggregate output production. In simulation 2, the GDP at factor cost slightly falls by -0.01% which is related to the slight reduction of its component of total wage bills (-0.05%). However, the increase of public expenditure on commodities shifts up the aggregate demand which is indicated through the improvement in GDP at market prices – from income and expenditure side – by 0.60% and 0.29%, respectively. Compared to scenarios of a carbon tax with revenue recycling schemes (simulation 1 and simulation 2), the economy is more adversely affected: all GDPs contract – GDP at factor costs (-0.31%), GDP at market price from income side by -0.83%, GDP at market price from

[5] *In the official Indonesia's SAM in year 2008, all types of energy fossil sectors (oil, coal, and natural gas mining) are pooled together with geothermal and metal ores in a single account, namely: 'fossils and metal ores mining sector'. Refineries products are aggregated together in a single account, namely 'chemical, fertilizer, clays, and cements products'. Electricity is pooled together with other utilities such as drinkable water and city gas products. We put forward the argument that the set comprising 3 energy sectors in the existing SAM will not be sufficiently applicable to calibrate the hybrid-CGE model for specific energy analysis in Indonesia.*

Table 2
The impacts on national income account

Variables	% CHANGE		
	SIM-1	SIM-2	SIM-3
GDP at factor costs (GDPFC)	0.58	-0.01	-0.31
GDP at market prices from income side (GDPMP1)	1.56	0.60	-0.83
GDP at market prices from expenditure side (GDPMP2)	2.04	0.29	-0.87
Total private consumption	0.16	1.30	1.08
Total investment	0.22	-2.27	-3.81
Total real government consumption	1.64	2.54	2.69
Total export	-0.14	-0.07	-4.14
Total import	0.36	-0.30	-4.68
Net export	-5.11	-0.47	1.19
Net indirect tax (the total expenditures of all commodity taxes, including Import tariff, less subsidy on commodities (and activities)	74.30	1.34	-28.54
Total payment to all workers (WAGEBILL)	-3.24	15.01	-0.29
Total payment to capital (CAPBILL)	0.04	-0.05	-0.33
Emissions			
CO_2 emissions from Households	-7.52	-14.16	-12.53
CO_2 emissions from Industries	-0.14	-0.15	-0.99
CO_2 emissions from Government	-	-0.07	-
TOTAL CO_2	-0.64	-1.11	-1.77

expenditure side by -0.87%. The reduction of GDP at factor costs is related to a decline of its components of both total capital bills (-0.33%) and wage bills (-0.29%). The contraction of the GDP at market price from expenditure side is slightly higher than that of the GDP at factor costs due to a large decline in the net indirect tax (-28.54%). In other words, the equilibrium output tends to shift downward which in turn reduces the net indirect tax revenues. In terms of trade, both export and import indicate a strong contraction, which are -4.14% and -4.68%. The reason for this is clear: since the increased domestic price of energy products due to imposing the carbon tax is not compensated through a revenue-recycling scheme, the production costs rise. As a result, the contraction in aggregate demand is more pronounced in simulation 3 than that of simulation 1 and simulation 2.

In terms of emissions accounting, it is found that in all cases the national carbon emissions indicate a substantial drop especially in the households' fuels consumption. The largest decline of total CO_2 emissions is obtained in simulation 3. Therefore, these findings conclude that the emission reduction target from energy utilization by about 1% can be achieved through all scenarios.

B. Impacts on Industry's Output and Energy Composite

Table 3 presents the effects on industry's output and the required input of energy composite. It is revealed that simulation 1 does not necessarily lead to a decrease in energy composite among industries. The consumption pattern of energy composite in most of energy and energy-intensive industries indicate an expansion, although their output production tends to decline. Therefore, by looking at these trends, it can be suspected that there is an indication of 'local' rebound effect especially in energy-intensive industries, excluding chemical sector. In other words, instead of improving energy efficiency, the introduction of carbon tax on polluted fuels compensated by a reduction in labour income tax triggers a higher level of energy consumption thereby offsetting some of the energy savings achieved (Sorrel and Dimitropoulos 2008; and Sorrel 2009). Sorrel (2007) stated that the chosen recycling mechanism of carbon tax, i.e. compensating the carbon tax by lowering the distorted taxes, is very influential to create the incidence of rebound effect through demand responses. By reducing

Table 3
Impacts on industry's output and energy composite

Industry	Output			Energy Composite		
	SIM-1	SIM-2	SIM-3	SIM-1	SIM-2	SIM-3
	%Change					
Energy and Energy-Intensive Industry						
Coal Mining	0.00	-1.23	-1.89	-0.04	-0.68	-8.38
Natural Gas Mining	0.00	-0.24	-2.63	0.36	0.77	-1.47
Oil Mining	0.00	-0.08	-1.24	0.38	-1.76	-0.11
Conventional Power Plant	-94.38	-20.04	-63.07	7.01	-24.21	-100.00
Refineries	-1.04	-0.46	-2.47	0.13	-0.17	-1.84
Chemical	-5.93	-0.20	-7.83	-6.27	-1.57	51.41
Ores Mining	-7.48	-0.88	-11.76	-1.55	-17.69	-0.40
Land Transportation	-0.39	-0.29	-1.98	4.31	-0.32	-26.21
Construction	-0.01	0.09	-1.52	13.65	-10.22	15.69
Paper and Printing	-0.85	-0.02	-2.17	3.99	-3.59	44.34
Trade	-1.00	0.00	-0.07	13.90	-1.26	63.43
Textiles	1.07	-0.56	7.45	2.50	-13.34	6.62
Non-Energy Intensive Industry						
Agriculture Food Crops	-0.50	0.12	0.42	0.01	-49.76	-0.96
Air-Sea Transportation	15.29	-1.40	10.59	-0.95	-4.59	-9.81
Bank	-0.08	-0.06	-23.03	-0.02	-22.09	-1.39
Cattles	0.13	0.01	1.55	-0.17	-1.28	-1.06
City Gas	-13.83	-6.31	-5.19	0.50	9.21	-15.37
Real Estates	0.07	-1.29	0.29	0.25	21.75	0.41
Fishery	-0.01	-0.07	0.95	-0.85	-7.55	-3.46
Food	-0.44	0.04	0.17	2.12	-6.73	13.34
Forestry	0.18	-3.24	-40.83	-0.22	-10.16	-29.51
Geothermal Mining	-0.03	1.90	-1.60	-12.97	1.70	-1.85
Social Services	-1.86	0.27	-1.78	5.02	-3.61	3.66
Hotel	8.64	2.82	12.22	-0.13	4.03	-83.78
Hydro Generation	-0.04	0.39	935.41	na	na	na
Individual Services	0.95	0.39	-3.20	-8.77	1.78	3.25
Other Agriculture	-2.29	1.17	-4.56	-0.13	44.87	-3.74
Other Mining	-0.70	3.58	3.38	-2.18	-6.41	13.09
Geothermal Generation	-0.71	5.35	81.21	na	na	na
Restaurant	-0.17	-0.57	0.48	-0.24	-3.07	-1.32
Supporting Transportation	12.16	-3.35	34.83	-2.70	-102.16	45.31
Train Transportation	20.88	5.15	-11.55	-1.03	-19.89	-4.69
Transmission and Distribution	0.00	-0.69	-0.12	-1.98	-21.31	-1.99
Clean Water	13.52	13.52	-1.13	148.05	148.05	3.77
Wood	0.58	0.58	0.42	-20.34	-20.34	4.49

Table 4
Impacts on commodity

Commodity	Consumer Price			Domestic Consumption		
	SIM-1	SIM-2	SIM-3	SIM-1	SIM-2	SIM-3
	%Change					
Energy and Energy-Intensive Sector						
Coal	47.95	235.67	288.03	-0.09	-0.17	-2.96
Natural Gas	13.31	66.40	79.59	-0.12	-0.10	-1.71
Crude Oil	19.33	94.48	113.02	-0.13	-0.58	-0.12
Bioethanol	6.48	8.22	125.43	10.65	-1.00	-1.83
Biodiesel	1.32	9.16	7.41	-0.08	-0.66	-1.84
Kerosene	25.94	127.16	154.12	-0.19	-3.71	-1.67
LNG	1.43	7.58	127.63	2.12	-100.00	-441.35
Non-Subsidized Gasoline	73.86	361.95	438.82	-0.01	0.25	-1.16
Non-Subsidized LPG	27.90	140.55	168.10	11.36	-3.11	-1.79
Other Oil Products	12.03	56.32	69.59	0.75	-0.20	-0.87
Subsidized Biodiesel	21.74	105.97	125.85	0.17	-0.28	-0.81
Subsidized Biogas	22.79	114.15	140.16	-0.47	-0.46	-0.79
Subsidized Diesel	25.63	124.34	148.44	0.67	-0.93	-1.17
Subsidized Gasoline	24.69	119.71	141.79	-1.08	-0.37	-0.99
Subsidized LPG	13.48	56.35	65.83	2.47	-2.55	-0.75
Electricity	0.09	-1.69	-0.13	0.25	-0.44	-0.03
Chemical	3.19	-0.93	-7.21	-2.26	0.32	4.55
Metal Ores Mining	6.61	-0.65	-10.06	-2.97	-0.24	4.70
Land Transportation	-1.28	1.59	-1.99	-0.62	-1.34	2.08
Construction	0.43	-0.29	-1.52	-0.01	0.17	-0.11
Trade	0.19	-0.61	-0.07	-1.01	-0.01	1.23
Supporting Transportation	-8.47	-0.89	29.99	5.30	0.76	-5.31
Textiles	-0.31	-0.26	10.62	0.46	0.84	-5.24
Non-Energy Intensive Sector						
Agriculture Food Crops	0.53	0.17	0.26	-0.47	-0.07	-2.02
Air-Sea Transportation	-11.33	0.32	9.81	5.35	-2.11	-3.50
Bank	-0.15	-0.07	-11.10	-0.16	0.56	5.81
Cattles	-0.04	0.46	1.50	0.11	-0.29	-4.03
City Gas	11.40	0.15	-6.78	-14.30	-8.86	-0.07
Real Estates	-0.10	-1.55	0.00	-0.13	0.13	-0.14
Fishery	-0.07	0.64	0.98	-0.02	-0.31	-2.19
Food	0.47	0.15	0.58	-0.34	-0.09	-1.84
Forestry	0.02	-3.34	-13.76	-0.37	2.33	-28.97
Geothermal Mining	-0.11	3.09	-1.63	-0.05	-0.54	-1.87
Social Services	2.69	-0.61	-1.81	-1.51	0.33	2.46
Hotel	-6.71	0.63	16.64	-22.91	11.35	-12.57
Individual Services	-2.20	0.80	0.94	0.72	0.25	0.92
Other Agriculture	1.91	-0.08	-4.73	-1.69	0.19	2.12
Other Mining	0.06	1.02	3.10	-3.20	1.03	0.84
Paper products	0.50	-1.26	-2.26	-0.34	-0.01	0.90
Restaurant	0.08	0.10	0.48	-0.04	0.07	-0.49
Train Transportation	-14.63	1.81	-13.71	8.54	26.97	8.10
Clean Water	-9.11	-0.99	-1.13	5.36	-5.32	1.20
Wood	-0.38	-0.10	-4.75	0.14	0.11	3.30

the labour income tax, the household's purchasing power increases, which could induce a higher consumption of energy goods or other closely-associated products. In contrast, in simulation 2, a reduction in energy composite input is indicated in almost all sectors especially in energy-intensive industries. Conventional electricity generation hurts the most (-24.21%) followed by metal ores mining (-17.69%), textiles (-13.34%) and paper products (-10.22%) since their production is heavily relied on fossil fuel inputs. On the other hand, the output production from renewable electricity generation (hydro and geothermal) indicates an improvement which are 0.39% and 5.35%, respectively. This expansion is due to the technology switching effect from conventional (fossil fuels) generation to renewable (clean) generation. Whilst, without any compensation scheme (simulation 3), the price changes of energy composite across industries are substantially larger than those of simulation 1 and simulation 2results especially in the energy-intensive (utilities) sectors, i.e. conventional generation plant (90.62%) and land transportation sector (24.16%). This increase immediately leads to a sharp decline in their input volumes, in which conventional electricity generation hurts the most (-100%) followed by land transport (-26.21%), since their production is heavily relied on fossil fuel inputs. However, the simulation 3 results also revealed that some energy-intensive sectors tend to increase their energy composite input, which would induce a higher energy intensity. For non-energy intensive industries, the magnitude changes of energy aggregate input are prominently varied, although they do not necessarily in line to the changes of their output production. These results imply that simulation 3 leads to a greater uncertainty on the magnitude of energy consumption pattern across non-energy industries.

C. Impacts on Commodity

As shown in Table 4, the implementation of differentiated carbon tax on fossil fuel products – based on the level of their carbon content – immediately increases their consumer price. Overall, the increase of consumer prices among energy-intensive commodities is lower than those of energy commodities. The consumer price of electricity indicates a slight decline (negligible change) due to the technology switching from conventional to renewable (clean) generation resulting in a lower price of electricity commodity. This is because the commodity prices given in the model are based on relative price. Hence, introducing a carbon tax on polluting fuels increases the fuel prices higher than the renewable prices. In simulation 1, it can be seen that the implementation of carbon tax compensated by a reduction in labour (income) tax does not

Table 5
Impacts on income distribution and welfare

Household's Group	WELFARE			Inequality (% Change)		
	SIM-1	SIM-2	SIM-3	SIM-1	SIM-2	SIM-3
	(% Change)					
Rural households' - unclear occupations	-0.03	0.08	-0.438			
Rural households' - agricultural labors with low income	0.00	-0.13	-0.364			
Rural households' – non-agricultural labors with low income	-0.01	0.03	-0.128			
Rural households' – non-agricultural with high income	-0.05	-0.24	-0.162			
Rural Households' - Agricultural Employers	-0.03	0.06	-0.148			
Urban households' - unclear occupations	-0.01	0.20	-0.183			
Urban households' - low income	-0.02	-0.002	-0.159			
Urban households' - high income	0.12	-2.16	9.490			
Total	-0.036	-3.32	12.20	0.136	0.135	0.140

necessarily reduce the final energy consumption. However, in simulation 2 and simulation 3, domestic consumption tends to drop especially for energy and energy-intensive commodities.

D. Impacts on Income Distribution and Welfare

The inequality is measured from the Theil-L index, which belongs to the family of generalized entropy inequality measures; while the welfare is measured from the Equivalent Variation (EV). As presented in Table 5, it is revealed that the introduction of carbon tax in Indonesia compensated by lowering the labour (income) tax rates tends to be neutral (or slightly regressive) in both rural and urban areas. In other words, the impacts of simulation 1 on households' welfare are considerably negligible. However, in terms of aggregate welfare – measured as economy-wide EV – simulation 1 results in a slight welfare loss by -0.036%. In simulation 2, the results tend to be progressive. The higher income groups suffered a higher share of the carbon tax burden. On the other hand, without any compensation returned to the economy (simulation 3), the implementation of carbon tax tends to be regressive – in which the welfare losses on lower income households are more deteriorating than higher income households in both rural and urban areas. For simulation 1 and simulation 2, the result shows that inequality remains unchanged by 0.136 due to the negligible changes in households' welfare. However, in simulation 3, inequality increases from 0.136 to 0.140. This is because the welfare loss by poorer households increases the inequality gap among households.

IV. CONCLUSION

Aside from their achievement in reducing the national GHG's emissions, the results also revealed that all scenarios of carbon taxation would affect the economy's performances diversely in their magnitude of changes. Imposing carbon tax on fossil fuels immediately increases their consumer prices. In turn, these changes would lead to economy's contraction such as sectoral outputs, aggregate demand, as well as households' welfare. Nonetheless, these adverse effects can properly be addressed through the selected compensation (revenue-recycling) scenarios. Among other scenarios, it is suggested that compensating carbon tax by a reduction in labour (income) tax would likely be the most benefited scheme, of which a double dividend is gained. The increased price of fuels is offset through households' income improvement via labour tax income reduction. Hence, it would initiate a higher domestic demand due to improvement in their disposable income, which in turn, increases the aggregate outputs. The impacts on households' welfare are considerably negligible (neutral) in both rural and urban areas; and inequality remains unchanged. In the scenario of revenue-recycling through public spending improvement, the results found that the GDP at factor costs slightly falls but the GDP at market prices improves. The downward effects of carbon tax are offset by the expansion of public expenditure on commodities that would shift up the aggregate demand. The impacts on households' welfare tend to be progressive by which the welfare losses on higher income groups, especially urban households, are worse-off than those of lower income groups; thus, the inequality gap among households is slightly reduced. In contrast, the uncompensated scenario – where the additional revenue raised from carbon tax is kept as government savings to run budget surplus – generates the most disadvantages on economy's performance.

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