On the Distributional Effect of Carbon Tax in Developing Countries: The Case of Indonesia[1]

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This paper analyses the distributional impact of carbon tax in Indonesia, one of the largest carbon emitter developing countries. Using a Computable General Equilibrium (CGE) model with disaggregated households, the result suggests that in contrast to most studies from industrialised countries, the introduction of carbon tax in Indonesia is not necessarily regressive. Its structural change and resource reallocation effect, following the carbon tax, is in favor of factors endowed more proportionately by rural, and lower income households. In addition, the expenditure of lower income households, especially in rural area, are less sensitive to the prices of energy-related commodities. Revenue-recycling through uniform reduction in commodity tax rate may reduce the adverse aggregate output effect, whereas uniform lumpsum transfers may enhance the progressivity. This study demonstrates an example, that encouraging developing countries to reduce carbon emission, may not only increase the efficiency of carbon abatement globally, but also have desirable distributional implication in the developing countries themselves.

Key Words: Carbon Tax, Climate Change, Distribution, CGE, Indonesia
JEL Classification: D30; D58; Q40; Q48; Q54; Q56; Q58

1. BACKGROUND

The problem of global warming has increasingly become more alarming over time, and scientific studies now are more conclusive in that human is responsible for the damage[3]. In the famous report, Stern (2006) suggests that scientists are now able to attach probabilities to the temperature outcomes and impacts on the natural environment associated with different levels of greenhouse gasses stabilisations. The report, for example, suggest that without any apropriate actions, there is at least 50% chance of exceeding 5^0C global average temperature change during the following decades, and such change would transform the physical geography of the world, with catastrophic and irreseversible consequences.

However, despite those concern, multilateral actions for greenhouse gases stabilisation, such as under Kyoto Protocol has been less promising. The main reason, is its associated high cost of that action, in terms of the economic growth. This argument has been used by the U.S. and Australian government not to ratify Kyoto Protocol, which then emphasis their belief that economic and environmental objectives can not go hand in hand.

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[3] As reported by by the recent fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), published in February, 2007 (source: The Economist, February 8^{th} 2007, 'Climate change: Heating Up'.)

The linkage between economic, environmental, and social dimension of sustainable development had been stressed since 1987 in the so-called 'Brundtland report'. More recently they were also emphasized as the three pillars of sustainable development in 2002 Johannesburg World Summit. Most of us are aware and accept that those 'three pillars' are inter-linked, but some of us, morever, believe that they are often conflicting each others: one of the best example is on the issue of climate change.

In the global climate change policy, equity issue can not be separated either. This include, how, the responsibility of actions are distributed accross nations. This was the reason why in the 1992 United Nations Framework Convention of Climate Change (UNFCC), the responsibility of actions accross nations should follow the principle of 'common but differentiated responsibilities'. Sharing the burden equally, will be regarded as unfair because of developing countries' low trace of historical greenhouse gas emission. However, for the U.S,. for example, the lack of formal commitment of developing countries in Kyoto Protocol, has been used as the argument againts its ratification.

Participation of developing countries to curb global greenhouse gases emission is crucial and could be the important driver needed to resume to the 'halting' progress of multilateral efforts[4]. Even though the per-capita carbon emission in developing countries, is still a lot lower than that of developed countries, developing countries are increasingly contributing to the accumulation of greenhouse gases. Developing countries already account for half of annual greenhouse gas emission, and in the future, emission growth will come mainly from developing countries (Jotzo 2004).

Even for developing countries themselves, there are many reasons to justify more active participation in the global carbon stabilisation. The impacts of climate change tends to hurt the poorest countries more, and this include Indonesia. Developing regions, for example, are already warmer, and suffer from high rainfall variability, heavily dependent on agriculture, and lack of adequate health provision and low-quality of public services. Being low income countries, with low budget constraint, adaptation to adverse effect of climate change will be more difficult (Stern 2006).

As the fourth largest country in terms of population, Indonesia is important in global climate change policy. Even though among developing countries, Indonesia, rank 7^{th} in the total CO_2 emission from fossil fuel, in 2000, Indonesia rank 2^{nd}, after China if CO_2 emission from land use change (mainly deforestation) is included[5]. Overall, including industrialised countries, Indonesia is in fact, a member of the biggest 20 carbon emitting nation in 2002, and its emission grow rapidly for around 6.6% anually.

The changing composition of Indonesian energy mix has also caused some concern about Indonesian contribution to the global climate problem. Although, emissions from the consumption of liquid petroleum products is still dominant, amounting to 49% of Indonesia's 2002 fossil-fuel CO_2 emissions, emissions from natural gas consumption and coal usage, although quite variable, have risen steadily since the early 1970s and account for 15% and 24% of Indonesia's 2002 total emissions. The future priority of coal as fuel for electric power generation has become Indonesia's future agenda as Indonesia is running out of oil. When currently Indonesia has become a net oil importer, coal reserves with current production capacity will still last for 50 years (Tanujaya 2005). In addition, with a population exceeding 210 million people, although, Indonesia's per capita emission rate of 0.39 metric tons of carbon in 2002 is well below the global average, it has

[4] Especially due to the rejection of the U.S. to ratify the Kyoto Protocol.
[5] Source: World Resource Institute Online Database.

grown ten-fold since the early 1950s (Marland et al. 2005)[6].

Discussion on the formal commitment of carbon emission stabilisation in developing countries, as well as in Indonesia, perhaps, is still at its infancy. However, the above concern has gain a lot more attention, even in Indonesia itself. Indonesia recently ratified Kyoto Protocol[7]. One of the obligation as a party of the Convention is to communicate actions taken to mitigate climate change and also to establish the National Committee on Climate Change. By ratifying the protocol, the issue of reducing GHG emissions will have more priority in the public discourse.

Environmentally-motivated policy, such as carbon abatement policy, also carry distributional effect within the country that implements it. If the distributional effect of such policy is not desirable, for example, because it has the potential to increase poverty and inequality, it may be perceived as potentially do more harm to the society. If there is expectation of such adverse distributive effect, it will even prevent the policy to be implemented at the first place. Social protest has always been part of fuel subsidy reduction in Indonesia. This happen as well in Europe, for example, 'the social protest that followed the oil price increase of 2000 prompted reductions in environmentally-motivated taxes on oil products in countries such as France, Italy, or Australia, and the postponement of planned tax increases in others, like the United Kingdom or Germany delayed planned tax increases' (OECD 2004, p.79).

It is very natural that environmental policy must have distributional impact. Because the essential purpose of environmental policy is to change consumptions and production patterns. Therefore it is inevitable that there will be winners and losers among households and firms (Kristörm 2003).

Complete picture of the distributional impact of environmental policies in general, or climate change policy, has to consider two distinct but inseparable issues (OECD 1994). First, the concerns related to the distribution of environmental benefit of the policy, i.e, the question on who gain more and who gain less; and, secondly, those associated to the distribution of financial effects of the policies, i.e., who pay more and who pay less.

On the issue of global warming, the distribution of the gain focuses, for example, on who will be affected more by rising global temperature, to which part of the country, and hence, the population that live there, the rise in sea level, will mostly have effects;, or to what sectors in the economy, the global warming has more potential to adversely affect their productivity. In short, it is more about the benefit of reducing global warming.

Distribution of financial effects, on the other hands, refers to how the cost of compliance or the cost of implementation of the policy are distributed accross households. The implementation cost of environmental policies can be socially regressive, that is, lower-income groups may be subject to a disproportionately higher share of environmental compliance costs. This paper is intended to cover this part of distributional story.

The confict between enviroment and equity objectives in the case of carbon abatement policies has been prevalent, as literature from developed countries has suggested[8]. From those empirical literature, carbon tax, for example has mostly found to be regressive, i.e., its cost is borne more by lower income households, rather than higher income households.

Despite the increasing relevance of developing countries' role in global climate change policy, this paper is mainly motivated by the empirical regularities from developed countries' studies that carbon abatement policies is regressive. In summary, the objectives of this research is mainly motivated by the lack of emphasis in the literature on the distributional aspect of environmental

[6] see figure 1.
[7] in July 2004 (Jotzo 2004).
[8] Next section will elaborate this point.

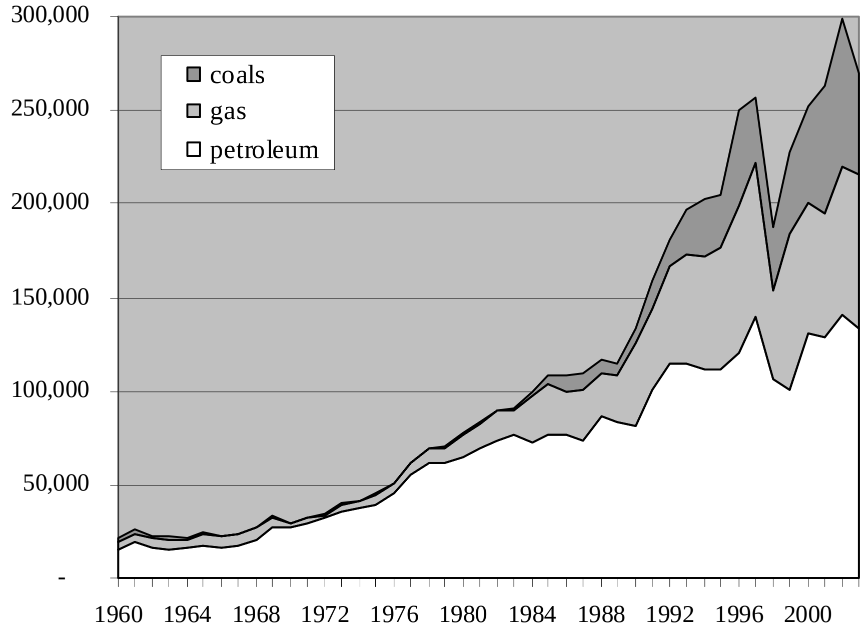

FIG. 1 Trend of Indonesian CO_2 emission by sources 1960 − 2003 (thousand tonnes)

policies especially in developing countries. While efficiency gain of environmental policies has been widely researched, it is hard to find studies that assess its distributional impact outside industrialized countries. Given the general tendency in the literature, it will be interesting and relevant to know whether similar conclusion could be drawn from developing countries. It has also been pointed out, for example, by Shah and Larsen (1992), there are many possible developing-countries' characteristics that may lead to a conclusion that those sort of policies may not be regressive. Despite yet a few of empirical evidences, in their survey OECD (1995, p. 25) even conjectures that "the net effect of adding carbon tax in developing countries may well be proportional to income, or even progressive". This study is an examination on whether or not and to some extent this expectation can be empirically shown which in turn give more this paper more relevance.

In Indonesia, as well as some other developing countries, although manufacturing sectors, which are relatively more energy-intensive, has increasingly more dominant in the economy's output, the large share of labor forces are still employed in agricultural sectors and to some extent services sectors. Carbon abatement policy will most likely hit energy-intensive sectors which typically is also capital intensive. The returns to factors that are more intensively employed in those sectors, such as capital, skilled-labor, formal, and urban workers, will be more under pressure than factors that are more intensively employed in less energy intensive sectors (such as agriculture and some services sector). Those factors are land, unskilled, and rural agricultural workers. The owner of such factors are most likely the lower income households. Therefore, this could drive the distributional impact of carbon abatement policy to be more progressive instead of regressive.

Moreover, unlike in developed countries, the expenditure pattern of lower income households will be likely to be less energy-intensive. In tropical countries like Indonesia, for example, domestic heating, is definetely not part of everyday's consumption like in Europe. Vehicle ownership is still a luxury for the larger part of the population, and dominant electricity consumption, including energy-consuming household appliances are still not considered necessity, especially in rural area, where most Indonesian live.

If these typical characteristics of developing countries, do drive the distributive effect of carbon abatement policy to be more progressive, it may have important policy implication at the local and global level. First, because encouraging developing countries to more actively participate in global multilateral effort for GHG stabilisation has increasingly become necessary, understanding that it would not cause adverse distributive effect would lessen the resistance in its implementation. Secondly, understanding that carbon abatement policies tend to be regressive in developed countries, but potentially tend to be progressive in developing countries may add more benefit, in terms of distributional implication, when the location of carbon abatement is partially shifted from the developed countries to developing countries.

2. EMPIRICAL REGULARITIES IN THE DISTRIBUTIVE EFFECT OF CARBON ABATEMENT POLICIES

Most of the studies on the distributional impact of carbon tax are from developed countries. This is confirmed for example by Baranzini et al. (2000) which observe: "Unfortunately, there are few studies on the distributional effects of a carbon tax in developing countries or countries with economies in transition (p. 405)". The lack of the studies from developing countries, to some extent, widen the relevance of the research in this paper.

Poterba (1991) analyses the distributional effect or carbon tax by examining the expenditure pattern of households, especially the pattern of energy spending. The policy proposed in the paper, is $100 per ton of carbon implemented in 1990. Using data from U.S. Consumer's Expenditure Survey. Poterba (1991) assumes that the $100/ton carbon tax is fully translated into purchaser's price[9] of various energy related products, and combined these with the data on energy expenditure pattern to estimate the distributional burden of the carbon tax. The result suggest that a carbon tax is regressive, and if it were adopted without any offsetting changes in other tax or transfer programs, the burden would fall more heavily on low-income than well-off households[10].

Another earlier work is a study by Pearson and Smith (1991) using more or less similar method with Poterba (1991). This study examines the distributive effect of carbon tax in European countries. For U.K. households, the result suggest, for example that, the poorest quintile pay 2.4% of their spending, while, the richest quintile pay only 0.8%. Pearson and Smith (1991, p. 42), concludes that 'the burden of the tax in relation to household spending being higher for the poor than for the rich'.

The study for Canada was conducted by Hamilton and Cameron (1994), estimating the distributional impact of meeting the Rio target, stabilising CO_2 emission at 1990 level by the year 2000. The methodology used is a combination of a Computable General Equilibrium (CGE), and micro-simulation model. The study suggest that carbon tax in Canada is mildly regressive[11].

[9] Producer's price is not affected.

[10] The source of the regressivity, apparently, are that the share of income which low-income households devote to heating fuel, electricity, and gasoline is significantly higher than that of better-off households. In other words, that energy-related commodity for American households, was in fact a necessity. Poterba (1991), for example reported: "Total energy outlays for households at the 25th percentile of the income distribution are approximately 16% of income, compared with only 7% for households at the 75th percentile of the distribution (p. 8).

[11] The distributional consequences of the simulated tax are moderately regressive: decrease in consumable income for the lowest quintile of households are from 1.1 to 1.2 percent larger than for the highest quintile (p. 394).

Cornwell and Creedy (1996) investigates the distributional implication of meeting the Toronto target for Australia, a reduction in emissions of 20% per cent of 1988 levels by 2005. The methodology used is the combination of Input-Output analysis and household demand system. The general conclusion suggest that the distributive effect is regressive. The simulation for example, increase Gini coefficient from 0.2778 to 0.2838[12].

Barker and Köhler (1998) examines the distributional effects of imposing additional excise duties on energy product according to carbon content, which is essentially, a carbon tax. The countries studied are quite comprehensive, i.e., members of the European Union. The methodology used in this study is called the energy-environment-economy model for Europe (E3ME), a sectoral, regionalised, econometric model. The policy scenario is the increase in excise duties on energy products, such that it escalates from 1999 to 2010 and achieve levels reducing CO_2 emission by 10 per cent below baseline by 2010 for 11 EU member states. The results, without revenue recycling suggests that the excise duties is regressive, but progressive if revenue from the additional excise duties is recycling as lump-sum transfers[13].

Symons et al. (2000) examines the likely immediate impact of pollution tax on the tax burden of households in a number of European countries. Although a number of pollutants are examined, this paper focus on CO_2. The method is basically similar to many other studies, such as Labandeira and Labeaga (1999) and Cornwell and Creedy (1996), where input-output framework is used to assess the likely impact of pollution/energy taxes, via increases in the costs of using fossil fuels, upon the prices of consumer goods. The policy scenarios used in the study are a CO_2 tax of 0.1ECU per kg emission of CO_2 and an energy tax that raises the same revenues at the CO_2 tax. Revenue recycling is not included in the analysis because as Symons et al. (2000, p. 7) states "we need to know the extent of the regressivity of the tax without any additional effects". The results suggest that both CO_2 tax and energy tax are regressive in Germany, where for CO_2, lowest income groups pay 8% of expenditure, while the highest income group pay just above 5%. The tax is also regressive for France and slightly regressive for Spain. The result for Spain is slightly different with the study by Labandeira and Labeaga (1999), in which they found the neutrality of a carbon tax. In Italy however, the result is neutral, and U.K., in contrast to other studies, is progressive.

Jacobsen et al. (2003) analyses the distributional implications of environmental taxation in Denmark. The taxes that are examined in the paper are various individual taxes, as well as the combination of all these taxes and duties related to environmental concerns. The distributional impact is examined by looking at tax payments relative to disposable income for each income deciles. Comparing the pattern of the tax payments, Jacobsen et al. (2003, p. 495) concludes, that "the distributional effects varies a great deal between different environmental taxes, with transport-related taxes reducing after-tax inequality, and green taxes [including CO_2 tax] increasing inequality".

Bork (2003) studies the impact of ecological tax reform in Germany. The ecological tax reform is referred to energy taxation combined with the reduced social insurance contributions. The reform was launched in 1999 with the aim to reduce energy consumption and emissions and to promote the development of environmentally sound production and technologies. The methodology used is a combination of macroeconomic models and micro-simulation model. Bork (2003) concludes households with lower incomes will bear a somewhat heavier burden as a share

[12] Table 3 of Cornwell and Creedy (1996, p. 31)

[13] Barker and Köhler (1998) for example concludes that "the package of measures that is examined here is regressive across expenditure groups ..." (p. 399). It is also suggested that the results are dominated by the effects of domestic energy taxes, which are weakly regressive.

of net household income[14]. In other words, the study by Bork (2003, p. 167) suggests that ecological tax reform in Germany is regressive. The introduction of fuel tax, which mostly used for transportation purpose, as also shared by other studies, tend to be progressive.

Brannlund and Nordstrom (2004) analyse consumer response due to changes in energy or environmental policy in Sweden. The policy simulation is to illustrate response and distributional impact of non-marginal changes of the CO_2 tax. It appears that the distributional impact is regressive, where household with lowest income quintile pay 0.52 per cent of their disposable income, and household with highest income quintile pay only 0.33 per cent. Brannlund and Nordstrom (2004, p. 225), conclude that 'relative to disposable income the welfare loss will be greater for low income household indicating that the tax is regressive.

Wier et al. (2005), examine whether carbon tax is regressive in Denmark. The methodology used is a combination of Input-Output model and household survey data. The results suggests that carbon tax payment in Denmark is regressive. Wier et al. (2005, p. 245), for example, report that "as income rises, a falling share going to environmental taxes indicate a regressive tax".

To summarise, although not all of the studies reviewed above conclude the regressivity of environmental policy related to energy and carbon emission, the literature generally suggests that environmental policy in the form of carbon tax or energy tax is regressive. The burden is borne more proportionately by lower income households compared to richer households. Similar conclusion is also shared by some other studies that survey more or less similar literature. The survey by Baranzini et al. (2000), OECD (1994), OECD (1996), Kristörm (2003), and Boyce et al. (2005) confirm this general tendency.

Baranzini et al. (2000), for example, in their evaluation of carbon taxes with regard to their competitiveness, distributional and environmental impact, suggest the tendency toward regressivity. In its survey on the distributive effect of carbon tax, OECD (1995), for example, concludes,

> With regard to income distributional effects, empirical studies suggest that a national carbon tax or trading programme would be at least mildly regressive (i.e., would impose greater percentage burdens on the lower income groups) in many OECD countries, although there is some evidence that such programmes might actually be progressive in developing countries (p.57).

More recent review by Kristörm (2003, p. 44) also conclude that 'Empirical evidence tends, on balance, to suggest that environmental policy is regressive (on a gross basis) Meanwhile, Boyce et al. (2005, p. 3), after reviewing studies on distributional impact of carbon tax in developed countries, concludes that 'studies in [European] and other industrialised countries generally have concluded that carbon charges are regressive'.

In other words, the general tendency of literature from developed countries suggests that environmental policies (in the form of energy-related policies, or climate change policy) tend to be regressive.

As suggested earlier, compared to numerous studies from industrialised countries, studies from developing countries that analyse the distributive effect of carbon abatement policies hardly exist. Among the few are early study by Shah and Larsen (1992), and very recent study by Boyce et al. (2005).

[14]The main reasons are the higher prices for electricity, heating oil and natural gas. By contrast, medium-income households will bear the greater burden as regard to the increased fuel taxes (p. 167).

In their analysis Shah and Larsen (1992) the case for carbon taxes is examined in terms of their revenue potential, efficiency, and distributional implications. A small fossil fuel carbon tax of the order of $10/ton is selected. However, the distributional implication is only analysed for Pakistan case. The illustration for Pakistan use four different cases. For the first case of 'full forward shifting' where the price increase is perfectly translated into final consumer's prices, Shah and Larsen (1992, p. 8) shows that "the carbon tax burden falls with income, thereby yielding a regressive pattern of incidence. Such regressivity, nevertheless less pronounced with respect to household expenditure". However, with only partial forward shifting the results suggest "roughly proportional incidence of carbon taxes .. and a progressive incidence pattern. Shah and Larsen (1992, p. 10) then conclude that "the ... analysis suggests that the regressivity of carbon taxes should be less of a concern in developing countries than in developed countries".

Another studies from developing countries found in the literature is a study for China by Boyce et al. (2005). In this study, Boyce et al. (2005) analyse the distributional impacts of carbon charges and revenue recycling in China. The study use the data of a nationally representative household income and expenditure survey for the year 1995. They separate household spending into six categories, and apply a carbon loading factor to each of the categories to estimate the carbon usage embodied in these different types of household consumption.

The policy simulated is a charge of 300 yuan per metric ton of carbon. The result suggest that even without revenue recycling the effect of carbon charge would be progressive[15].

Boyce et al. (2005) then conclude that the results is primarily driven by differences between urban and rural expenditure pattern, and also conjecture that 'a similar pattern may exist in other developing countries'

3. METHODOLOGY: COMPUTABLE GENERAL EQULIBRIUM MODEL

3.1. Model Structure

The CGE model is built based on ORANI-G model, an applied general equilibrium model of the Australian economy. Its theoretical structure is typical of a static general equilibrium model which consists of equations describing (1) producers' demands for produced inputs and primary factors; (2) producers' supplies of commodities; (3) demands for inputs to capital formation; (4) household's demand system; (5) export demands; (6) government demands; (7) the relationship of basic values to production costs and to purchasers' prices; (8) market-clearing conditions for commodities and primary factors; and (9) numerous macroeconomic variables and price indices (Horridge 2000).

Demand and supply equations for private-sector agents are derived from the solutions to the optimisation problems (cost minimisation and utility maximisation) which are assumed to underlie the behaviour of the agents in conventional neoclassical microeconomics. The agents are assumed to be price-takers, with producers operating in competitive markets with zero profit conditions. For more detail about the specification of the model, please see Appendix. The important feature of the model, that also involve important modification to the standard ORANI-G model are the following.

The first modification is to allow substitution among energy commodities, and also between primary factors (capital, labor, and land) and energy because the standard model treats energy

[15] As Boyce et al. (2005) report: 'The lowest decile pays 2.1% of their total expenditures ..., and the highest decile pays 3.2%. This reflects the fact that the mix of products that relatively rich people buy is, on average, more carbon intensive than what relatively poor people buy. This contrast with results from studies in other [industrialised] countries. ... Our results call into question the generality of this conclusion (pp. 9-10).

commodity as among intermediate inputs under Leontief production function, therefore, it does not allow price-induced energy substitution[16]. In this respect, this model has 38 industries, and 43 commodities with detail energy sectors. Energy commodity include coals, natural gas, gasoline, automotive diesel oil, industrial diesel oil, kerosene, LPG, and other fuels.

Secondly, The model incorporate carbon (CO_2) emission accounting, and carbon taxation mechanism[17]. In this study, only CO_2 emission from fossil-fuels burning are included. It means, it excludes other source of CO_2 emission such as land-use change or deforestation. Data on detail emission by sector and by type-of fuel for Indonesia is not available. However, Statistics of Indonesian Energy Balance, report detail consumption of fossil-fuel by type of energy (natural gas, coal, gasoline, diesel, kerosene, LPG, others) in energy unit[18]. From data on energy consumption measured in unit of energy (e.g. BOE), we can calculate the amount of CO_2 emission. Later on, by assuming that all users of energy face the same prices[19], using the Social Accounting Matrix data with detail consumption of energy by various industries and households and by type of energy, we can distribute the emission and produce a matrix of CO_2 emission by fuel type, and by users (industry and households) or $E_{f,u}$. More specifically,

$$E_{f,u} = \frac{44}{12} \cdot \varpi_f \cdot CC_f \cdot \phi \cdot Q^E_{f,u}$$

where $E_{f,u}$ is CO_2 emission by energy type f, used by user u, in ton; $Q^E_{f,u}$ is quantity of energy consumption by energy type f, used by user u, in energy unit (Barrel of Oil Equivalent/BOE); ϕ is a factor to convert BOE to Giga-Joule; CC_f is carbon content of energy type f in ton of carbon per Giga-Joule (tC/GJ), ϖ_f is oxidation factor by energy type i.e. fraction of carbon oxidized. Q^E_f data is from Statistics of Indonesian energy balance 2003, whereas ϖ_f, CC_f, ϕ are from database of International Panel on Climate Change (IPCC).

Following Adams et al. (2000), Government revenue from CO_2 (R) tax can be calculated as,

$$R = \tau \cdot \sum_f \sum_u E_{f,u}$$

where τ is specific tax on CO_2 (in Rupiahs per ton of CO_2), and $E_{f,u}$ is the quantity (tones) of emission of CO_2 by energy type f and by user u. Since, the emission tax will be imposed as ad-valorem energy/fuel tax, R will be equivalent to

$$R = \sum_f \sum_u \frac{t_{f,u}}{100} P_f Q_{f,u}$$

where t_f is ad-valorem tax rate, P_f is price, and $Q_{f,u}$ is quantity of energy consumed by user u. and for every energy type and user, specific emission tax can be translated into ad-valorem fuel/energy tax as follow,

$$t_{f,u} = \tau \frac{100 \cdot E_{f,u}}{P_f \cdot Q_{f,u}}$$

The last bit of the equation i.e., $\frac{E_{f,u}}{P_f Q_{f,u}}$ can be defined as emission intensity per Rupiah use of energy. For any specific price of carbon (or carbon tax) the impact on ad-valorem tax rate on each energy, then not only depend on technical, or chemical matter such as its carbon content,

[16] This modification is more or less similar to the modification in the INDOCEEM (Indonesian Comprehensive Economic and Energy Model) model, another ORANI-G based model built by Monash University and Indonesian Ministry of Energy.

[17] This modification, follow closely the treatment in MMRF-Green model, as described in Adams et al. (2000).

[18] In this case, Barrel of Oil Equivalent (BOE).

[19] After taking into account different price paid by households and industries due to fuel subsidy.

but also on economic variable or market condition such as its prices.

Thirdly, multi-household feature is added to the standard model which only has single household. The multi-household feature is not only added to the expenditure or demand side of the model[20], but also from the income side of the households[21].

3.2. Social Accounting Matrix

Indonesian Social Accounting Matrix 2003 serves as the core database to the CGE model. The distributional impact of policies analyzed in the CGE modelling framework have been constrained in part by the absence of a Social Accounting Matrix (SAM) with disaggregated households. Since Indonesian official SAM does not distinguish households by income or expenditure size, it has prevented accurate assessment for the distributional impact, such as calculation of inequality or poverty incidence. The SAM used in this paper, is a specially-constructed SAM representing Indonesian economy for the year 2003, with 181 industries, 181 commodities, and 200 households (100 urban and 100 rural households grouped by expenditure per capita centiles) was constructed. The SAM (with the size of 768x768 accounts) constitutes the most disaggregated SAM for Indonesia at both the sectoral and household level.

The construction of the SAM is a lengthy process and consumed a lot of research resources, such as fieldwork and data collection, hence it will not covered in this paper. The nature of constructing specifically-designed SAM with distributional emphasis not only require large-scale household survey data but also involved reconciliation of various different data sources. Interested readers can refer to Yusuf (2006). The structure of the SAM can be seen from table 1.

[20] Such as done for some of other ORANI-G version.

[21] More or less similar modification to ORANI-G model has been made to the very popular WAYANG model, an ORANI-G based Indonesian CGE model.

TABLE 1
Structure of 768×768 Indonesian SAM

		Activities 1⋯181	Commodity Domestic 1⋯181	Commodity Imported 1⋯181	Factor labour 1⋯16	Factor Capital	Ind. Tax	S-I	Households 1⋯200	Transfers	Enterprises	Gov't	ROW	TOTAL
Activities	1 … 181		MAKE Matrix											Industry Sales
Domestic Commo-dities	1 … 181	Domestic Intermedi-ate Input						Domestic Invest-ment	Domestic Hou. Con-sumption			Domestic Gov't Con-sumption	Export	Total Dom. Demand
Imported Commo-dities	1 … 181	Imported Intermedi-ate Input						Imported Invest-ment	Imported Hou. Con-sumption			Imported Gov't Con-sumption		Total Import
labour	1 … 16	Salary and Wages											labour used abroad	Total labour Demand
Capital		Non-labour											Cap. used abroad	Capital Demand
Ind. Tax		Tax/ Subsidy		Tariff										Ind. Tax Reven.
Urban HH	1 … 100				labour Income: Urban	Capital Income: Urban				Inter-Hous. Transfer			ROW transfer to HH	Total Hous. Income
Rural HH	1 … 100				labour Income: Rural	Capital Income: Rural				Inter-House. Transfer			ROW transfer to HH	Total Hous. Income
Transfer									Transfer to HH					Int. Hou. Transfer
S-I									Household Saving		Enterprise Saving	Gov't Saving		Total Saving
Govern-ment							Ind.Tax Revenue		Direct Tax		Ent. Trans. to Gov't	Inter G Transfer	ROW Tans. to Gov't	Govt Revenue
Enter-prises						Enter-Capital					Inter Ent. Trans.		ROW Trans. to Enter.	Ente. Income
ROW				Import	Foreign labour	Foreign Capital			HH Transfer to abroad		Ent Trans. to abroad	G. Transfer to abroad		Forex Outflow
TOTAL		Industry Costs	Dom. Supply	Import Supply	labour Supply	Capital Supply	Ind. Tax Revenue	Total Invest.	Household Spending	Int. Hou. Transfer	Enter. Spending	Govern. Spending	Forex Inflow	

The detail SAM used in this model not only provide detail household disaggregation, but also detail labor classification acknowledging the typical characteristics of labor market in developing countries like Indonesia. The Social Accounting Matrix distinguishes 16 classifications of labour. It recognises 4 skills types (agricultural, non-agricultural unskilled, clerical and services, and professional workers), urban-rural distinction, and formal and informal (unpaid) workers. Together, it distinguishes 16 labor categories.

Standard official SAM relies on the Input-Output table. However, the Input-Output table, only distinguishes a single type of labour recorded in the wage bills of industrial costs. Gross operating surplus is then calculated as residuals. In developing countries, where a significant portion of industry does not officially record all payments to labour, this practice, may lead to misleading information.

First, the economy will appear to be highly endowed with capital, which is unlikely to be the case for developing countries like Indonesia. For example, from the Input-Output table, compensation of employees in Indonesia only accounts for around 35% of value added, whereas in the European Union, for example, the number is around 65%[22].

Second implication, is that certain industries which are supposed to be relatively labour intensive (e.g., agriculture compared with manufacturing) will instead appear to be capital intensive. Factor intensity is a very important driver of behaviour in the CGE model. For example, the parameters of most production functions used in the CGE model are function of factor shares. The reliability of some CGE models which rely purely on Input-Output table with understatement of labour, will be in question[23]. Understatement of labour compensation is quite common in a developing country Input-Output table. Cororaton (2003), for example shows the case for the Philippines.

The SAM constructed for this research has incorporated the above overlooked aspects utilizing both nation-wide data, as well as detail information from large-scale household survey data.

3.3. Closure

There are at least three consideration, in this study, in specifying closures for the simulations. First, closures have to be able to accommodate the research questions specified. For example, when we would like to know the aggregate welfare impacts of the shocks, aggregate real consumption, as indicator of welfare, has to be one of the endogenous variables. As Horridge (2000), for example, stated, the choice of closure is affected by the needs of a particular simulation. Secondly, closure should also be able to minimise the weakness due to realism that can not be explained by the model. For example, because the model used is a static model, to avoid inter-temporal allocation of welfare impact, at the expenditure side real investment and trade balance is better treated as exogenous. Finally, closure is associated with the idea of the simulation timescale, the period of time which would be needed to adjust to new equilibrium (Horridge 2000). The objective is to specify the closure as realistic as possible, representing the particular economy, under the environment we would like to investigate.

In specifying macroeconomic closure, at the aggregate demand side, aggregate real investment, aggregate real government consumption, and trade balance (in real terms) are treated as exogenous, whereas aggregate real consumption is endogenous hence can be interpreted as aggregate index of welfare. This prevents, for example, inter-temporal allocation of welfare im-

[22] Source: GTAP Database.

[23] Standard WAYANG model, for example, is based mainly on Indonesian Input-Output table which records around 34.36% of the aggregate labor share (source: Wayang 2002 database).

pact, for example, due to capital accumulation that may increase welfare in the future. Nominal exchange rate is the numeraire.

In the factor market closure, capital is specific, can not mobile across sectors, and the industry-specific price of capital is the equilibrating variable. Labor is mobile across industries, however, aggregate employment is exogenous, a typical neoclassical closure with full employment.

3.4. Method for Analyzing Distributional Impact

There are a few approaches for dealing with income distribution analysis in a CGE model. The traditional one is the representative household method, where it is assumed income or expenditure of households follows a certain functional form of distribution[24]. Distribution is assumed to remain constant before and after the shock, and usually the behaviour of the group is also dominated by the richest. There has been growing evidences to suggest, that variation within the one single household-category is important and can significantly affect the results of the analysis (Decaluwé et al. 1999). Household-specific shocks, such as transfers to targeted household groups, are also impossible to carry out with approach. Studies by Indonesia by Sugema et al. (2005) and Oktaviani et al. (2005), among others, belong to this type of approach.

The most common studies for Indonesia are CGE studies that use the official household classification of the SAM, i.e., 10 socioeconomic classes. The distributional impact is only analyzed by comparing the impact of policies among these socioeconomic classes. Studies by Resosudarmo (2003), Azis (2000), and Azis (2006), among others, follow this approach.

Another approach is a top-down method, where price changes produced by the CGE model are transferred to a separate micro-simulation model, such as a demand system model or an income-generation model. Price changes are exogenous in this micro-model, hence endogeneity of prices is ignored. Studies for Indonesia by Bourguignon et al. (2003) and Ikhsan et al. (2005) are among this type of approach. Some attempt has been made to improve this approach by providing feedback from the micro-model to the CGE model. Belonging to this category among others are studies by Filho and Horridge (2004) for Brazil, and Savard (2003) for the Philippines.

The most recent approach is multiplying the number of households into as many as households available in the household level data. Increasing computation capacity allows a large number of households to be included in the model. It allows the model to take into account the full detail information from household-level data, and avoids pre-judgment about aggregating households into categories. All prices are endogenously determined by the model, and no prior assumption of parameter distribution is necessary. Difficult data reconciliation and that the size of the model can become a constraint are among the drawbacks of this approach. This integrated-microsimulation-CGE model has been implemented in various studies including Annabi et al. (2005) for Senegal, Plumb (2001) for U.K., Cororaton and Cockburn (2005) and, Cororaton and Cockburn (2006) for the Philippines.

The last approach, to be used in this paper, is disaggregating or increasing the number of household categories by the size of expenditure or income per capita. If the categories is detailed enough, such as centiles, the distributional impact such as poverty incidences or standard inequality indicators can be estimated more precisely. For example, Warr (2006) used this approach for Laos in assessing the poverty impact of large scale irrigation investment.

The ideal approach in distributional analysis where disaggregated households are integrated in the CGE model is when all observations in the household survey are integrated in the model like in the Micro-simulation CGE models. It turns out that using only 100 representative household

[24] Of which the most popular one is log-normal distribution.

classified by centile for expenditure per capita, the calculation of poverty and inequality indicator could be fairly accurate[25].

In this study, poverty incidence, for example, is simply calculated using the following formula. Let y_c is real expenditure per capita of household of the c-th centile where $c = 1, \ldots, n$, and $n = 100$. Poverty incidence then is calculated using

$$P(y_c, y_P) = \max\{c | y_c < y_P\} + \frac{y_P - \max\{y_c | y_c < y_P\}}{\min\{y_c | y_c > y_P\} - \max\{y_c | y_c < y_P\}}$$

where y_P is the poverty line. The first term is simply the centile of of which expenditure per capita is the closest from the origin (the left) to the poverty line. The second term is the linear approximation of the decimal point of the poverty incidence.

The change in poverty incidence after a policy shock (simulation) is calculated as

$$\Delta P = P(y_c', y_P) - P(y_c, y_P)$$

where

$$y_c' = \left(1 + \frac{\hat{y}_c}{100}\right) \cdot y_c$$

where $\hat{y}_c$ is the percentage change in *real* per capita expenditure of household of the centile c produced from the simulation of the CGE model. The change in the real expenditure per capita across household will be used to investigate ex-ante distribution (before the policy change) and ex-post distribution (after the policy change).

4. SCENARIO AND SIMULATION STRATEGY

Unlike the developed countries who have a legal commitment under Kyoto Protocol to cut their CO_2 emission, Indonesia do not yet have to follow certain scenario of emission reduction.In this study, a carbon tax of Rp. 280,000 per ton of CO_2 emission[26] is introduced with three different scenario of revenue-recycling. [27]

In the first scenario (SIM 1), carbon tax will be implemented without revenue recycling, that is the revenue from the carbon tax is assumed to be used for fiscal adjustment, allowing government to run a budget surplus. This is intended to see the direction of the distributional cost, had the tax revenue is not returned to the economy or not used for compensation.

Two options will be considered for revenue-recycling, in order for the carbon tax policy to be "revenue-neutral". In the second scenario (SIM 2), the implementation of the carbon tax will be accompanied by a reduction in a uniform general advalorem sales tax rate for all commodity, such that extra government revenue is disappeared. To do this, a uniform sales tax shifter is endogenised while government saving is exogenised. The other relevant scenario for the revenue-recycling mechanism is to give uniform lump-sum transfer to all households. This will be the third scenario (SIM 3).

Another option is the reduction in the income tax rate, which is widely discussed in the 'double-dividend-hypothesis' literature. This alternative option is not implemented in this exercise for at least two reasons. First, for the double divident hypothesis to work, it is necessary

[25] Calculation of Gini coefficient is carried out for the whole 29,278 sample of urban households from SUSENAS and using only 100 households grouped by centile of expenditure per capita. The results are almost identical.

[26] Around US$ 32.6.

[27] The carbon tax of this amount is chosen, to reduce emission by 6.6%, Indonesian historical growth rate of emission. So, essentially, this is a scenario of emission stabilisation. We can always set arbitrary carbon tax, such as the social cost of carbon from the literature, or any level of tax, but the direction of distributional result, which is the focus of this paper, will not significantly change.

to have endogenous labor supply, which is not specified in the CGE model. Secondly, income (especially labor income) tax rate collection in Indonesia is quite low in terms of its population coverage, and therefore the likelihood of reducing the tax rate is less feasible.

5. RESULTS AND DISCUSSION

5.1. Macroeconomic and industry results

The summary of macroeconomic, emission, and factor market result is shown in table 2, whereas table 3 shows the results on industry output and prices of several relevant commodities. Systematic Sensitivty Analysis is conducted and reported in the Appendix.

GDP, as well as consumption expenditure, which can be treated as indicator of aggregate welfare, fall slightly, in all three scenarios of revenue-recycling. However, the simulation suggests that SIM 2 in which revenue from carbon tax is returned to the economy as the uniform reduction in commodity tax rate, produces the lowest decline in welfare effect, where real aggregate consumption falls by only 0.03 percent. Reduction in commodity tax rate, minimises the impact on prices of commodities following carbon tax implementation, as can be seen by the lowest percentage increase in the consumer's price index (0.58%). This has expansionary effect on the economy because of the increase in demand and output for commodities. Uniform cash transfers to all households perform less in generating expansionary pressure on the domestic economy compared to the reduction in commodity tax, although it may have better distributional outcome.

The immediate effect of introducing carbon tax is the increase in the price of energy products because carbon tax is implemented through the increase in advalorem tax of energy commodities, of which its magnitude depend among others on their carbon content. Price of coal rises the most of more than 100%, followed by other energy and its closely-associated products such as electricity and transportation.

Industry which are hurt the most are obviously energy related sectors. In SIM 1, for example, output of petroleum refinery and coal mining fall by 3.9% and 2.9% respectively. Other related sectors which experience significant contraction are among others natural gas, LNG, electricity, water and gas, road and other transportation sectors.

In terms of factor reallocation, in general, the simulations, suggests that by introducing carbon tax, energy and capital intensive manufactaring sectors tend to contract while agriculture, less energy-intensive manufacturing and service sectors experience slight expansion. It indicates that economic resources have been reallocated from energy sectors, most non-food manufacturing industries, and utility sectors, to agriculturally-based sectors (such as paddy, other crops, and wood sectors), some other manufacturing sectors and services sectors (such as hotel and restaurants).

Table 4, for example, suggests that industries which experience significant decline in their output are industries which are relatively highly energy intensive. Other than energy sectors (petroleum refinery, coals, crude oil, and natural gas), those industries are, among others, LNG, chemical product, pulp and paper, Non-ferous metal, electricity, water and gas, construction, and transportation. As table 4 also reveals, most of those industries are capital intensive industries. This structural change will affect the functional distributional of income, by the tendency to reduce return to capital more than to others factors, and in turns will tend to hurt households who are endowed with capital more proportionately.

The changes in the returns to factors as shown in table 2, clarify the points. The adjustment

TABLE 2
Simulated Macroeconomic, Emission, and Factor Market Results of Carbon Tax

	SIM 1 No-revenue recycling	SIM 2 Uniform cut on com. tax rate	SIM 3 Uniform transfers
Macroeconomics			
GDP	-0.04	-0.02	-0.03
Consumption expenditure	-0.06	-0.03	-0.04
CPI	1.32	0.58	1.75
Export	-0.11	0.67	-0.12
Import	-0.16	0.93	-0.16
CO_2 emission	-6.55	-6.39	-6.52
Real wage			
Agriculture, rural, formal	-0.58	1.62	1.28
Agriculture, urban, formal	-0.54	1.78	1.48
Agriculture, rural, informal	-0.48	1.63	1.61
Agriculture, urban, informal	-0.49	1.70	1.63
Production, rural, formal	-2.68	2.03	-2.73
Production, urban, formal	-4.65	0.56	-5.21
Production, rural, informal	-2.23	2.25	-2.55
Production, urban, informal	-2.24	2.22	-2.98
Clerical, rural, formal	-2.17	1.49	-2.92
Clerical, urban, formal	-3.12	0.66	-4.10
Clerical, rural, informal	-1.76	2.11	-1.64
Clerical, urban, informal	-1.78	2.05	-1.93
Professional, rural, formal	-3.19	0.50	-4.32
Professional, urban, formal	-3.55	0.54	-4.63
Professional, rural, informal	-2.19	1.49	-2.72
Professional, urban, informal	-2.06	2.46	-3.45
Average return to capital	-5.77	-1.86	-6.23
Average return to land	-0.41	1.81	1.78

in the production sectors affect prices of factors in the factor market. In general, capital owner is hurt more compared to other factors. Return to capital decline the most, followed by real wages, and return to land. In all scenarios, returns to capital fall. In the labor market, for SIM 1, for example, real average return to capital fall the most by -5.77%, while return to land falls by onley 0.41%, and the falls in real wage vary depending on its skills, but a lot less than the fall in return to capital. Real wage fall more for urban and formal skilled labor reflecting the contraction in the industry which employ more intensively those type of labors. The real wage of urban formal production workers, which is mostly employed in manufacturing sectors, urban formal clerical workers, and urban formal professional workers falls the most by 4.6%, 3.1%, and 3.5% respectively. On the other hand, agricultural labor only experience slight fall in their real wages. This adjustment in the factor market will have important impact in the distributional effect, because it can drive the distributional effect of carbon tax to be more progressive from the income side.

As far as macroeconomic impact or aggregate welfare's concern, lump-sum transfers as revenue recycling mechanism perform less than commodity tax cut, given the same neutrality of government budget. Being a lump-sum cash transfers, the real purchasing power to richer households is a lot less than to poorer households. Even though, the lump-sum transfer for rural household is more like of a windfall, the economy is more driven by the spending of the richer households. Therefore, a uniform tax rate cut to all commodities has a lot more expansionary effect through demand for commodities.

TABLE 3
Simulated Industry and Prices Impact of Carbon Tax

	SIM 1 No-revenue recycling	SIM 2 Uniform cut on com. tax rate	SIM 3 Uniform transfers
Output of industries			
Paddy	0.09	0.09	0.29
Other food crops	0.05	-0.09	0.09
Estate crops	-0.13	-0.08	-0.38
Livestock	0.13	0.14	0.35
Wood and forests	0.09	0.15	0.05
Fish	-0.08	-0.03	-0.02
Coal	-2.94	-2.88	-2.95
Crude oil	-0.29	-0.30	-0.28
Natural gas	-0.69	-0.69	-0.69
Other mining	-0.10	-0.23	-0.08
Rice	0.10	0.10	0.31
Other food (manufactured)	0.15	0.18	0.58
Clothing	0.41	0.96	0.64
Wood products	0.23	0.33	0.04
Pulp and paper	-0.07	0.17	-0.14
Chemical product	-0.66	-0.27	-0.41
Petroleum refinery	-3.87	-4.01	-3.83
LNG	-2.89	-2.83	-2.89
Rubber and products	-0.20	0.54	-0.51
Plastic and products	-0.05	0.46	0.07
Nonferrous metal	-1.61	-1.93	-1.49
Other metal	-0.37	-0.12	-0.28
Machineries	-0.50	2.45	-0.22
Automotive industries	0.35	-0.08	-0.47
Other manufacturing	0.20	0.38	0.76
Electricity	-1.44	-1.32	-1.29
Water and gas	-2.24	-2.13	-2.68
Construction	-0.01	-0.01	-0.02
Trade	0.05	0.09	0.29
Hotel and restaurants	0.30	0.10	0.24
Road transportation	-0.66	-0.67	-0.58
Other transportation	-1.44	-1.29	-1.43
Banking and finance	0.23	0.02	0.10
General government	0.00	0.00	0.00
Education	0.11	0.06	0.04
Health	0.31	0.17	0.49
Entertainment	0.60	0.49	0.23
Other services	0.29	0.04	-0.25
Prices of commodities			
Coal	131.80	131.95	132.47
Natural gas	26.35	27.27	26.50
Gasoline	24.61	24.72	24.59
Diesel (Automotive)	45.31	45.56	45.44
Diesel (Industries)	43.48	43.83	43.67
Kerosene	29.30	29.54	29.93
LPG	25.62	26.28	24.71
Other fuels	21.37	21.90	21.46
Electricity	16.93	16.97	17.38
Water and gas	12.38	12.13	12.16
Road transportation	1.77	1.30	1.58
Other transportation	2.36	1.00	2.31
CPI	1.32	0.58	1.75

TABLE 4
Cost Share of Industries and Change in Output

	Share of total input					Change in
	Labor	Capital	Land	Energy	Oth. Int	Output
Paddy	51.40	16.56	14.50	0.00	17.54	0.09
Other food crops	57.36	17.35	15.20	0.01	10.09	0.05
Estate crops	52.73	11.21	8.88	0.29	26.89	-0.13
Livestock	42.39	8.08	3.41	0.03	46.08	0.13
Wood and forests	36.37	21.78	21.34	0.42	20.09	0.09
Fish	38.96	8.77	27.19	1.98	23.09	-0.08
Coal	8.09	72.01		13.17	6.73	-2.94
Crude oil	5.80	80.74		6.41	7.06	-0.29
Natural gas	5.81	80.97		6.44	6.77	-0.69
Other mining	26.38	47.48		2.16	23.98	-0.10
Rice	6.17	8.32		0.02	85.49	0.10
Other food (manufactured)	15.23	18.59		0.84	65.34	0.15
Clothing	14.58	19.10		0.83	65.48	0.41
Wood products	18.24	25.36		1.05	55.35	0.23
Pulp and paper	13.92	22.79		1.51	61.79	-0.07
Chemical product	11.88	14.70		3.56	69.86	-0.66
Petroleum refinery	7.54	57.83		8.04	26.60	-3.87
LNG	1.66	51.77		40.05	6.51	-2.89
Rubber and products	15.80	14.82		1.82	67.56	-0.20
Plastic and products	7.81	20.26		0.82	71.11	-0.05
Non-ferous metal	20.40	34.71		6.82	38.07	-1.61
Other metal	9.90	14.06		1.79	74.26	-0.37
Machineries	9.35	13.31		0.63	76.71	-0.50
Automotive industries	15.67	29.73		0.80	53.80	0.35
Other manufacturing	14.06	26.56		1.40	57.98	0.20
Electricity	5.92	50.14		19.33	24.62	-1.44
Water and gas	17.27	26.37		13.42	42.93	-2.24
Construction	23.09	9.55		4.76	62.60	-0.01
Trade	35.27	26.83		1.48	36.42	0.05
Hotel and restaurants	36.93	10.99		0.04	52.04	0.30
Road transportation	21.40	22.11		8.31	48.17	-0.66
Other transportation	12.48	18.17		10.33	59.01	-1.44
Banking and finance	18.90	53.47		0.25	27.38	0.23
General government	53.98	5.62		2.14	38.26	0.00
Education	43.72	8.54		1.10	46.65	0.11
Health	54.50	9.02		0.19	36.29	0.31
Entertaintment	17.24	18.11		0.10	64.55	0.60
Other services	25.06	34.83		0.31	39.79	0.29

TABLE 5
Simulated Distributional Effect of Carbon Tax

	SIM 1 No-revenue recycling	SIM 2 Uniform cut on com. tax rate	SIM 3 Uniform transfers
Urban			
Ex-ante Poverty Incidence	13.600	13.600	13.600
Ex-post Poverty Incidence	13.768	13.613	12.915
Change in Poverty Incidence	0.168	0.013	-0.685
Rural			
Ex-ante Poverty Incidence	20.200	20.200	20.200
Ex-post Poverty Incidence	19.430	19.743	16.198
Change in Poverty Incidence	-0.770	-0.457	-4.002
Urban + Rural			
Ex-ante Poverty Incidence	17.194	17.194	17.194
Ex-post Poverty Incidence	16.852	16.951	14.703
Change in Poverty Incidence	-0.343	-0.243	-2.492
Urban			
Ex-ante Gini Coefficient	0.347	0.347	0.347
Ex-post Gini Coefficient	0.347	0.347	0.337
Change in Gini Coefficient	0.000	0.000	-0.010
Rural			
Ex-ante Gini Coefficient	0.277	0.277	0.277
Ex-post Gini Coefficient	0.274	0.275	0.260
Change in Gini Coefficient	-0.003	-0.002	-0.017
Urban + Rural			
Ex-ante Gini Coefficient	0.350	0.350	0.350
Ex-post Gini Coefficient	0.347	0.348	0.333
Change in Gini Coefficient	-0.003	-0.002	-0.017

5.2. Distributional results

Table 5 shows the summary of distributional effect of carbon tax for all 3 scenarios. In the table, both poverty effect, indicated by the change in head count poverty incidence, and inequality effect, indicated by change in Gini coefficients are shown for urban, rural, and urban + rural households. Figure2 illustrate in greater detail how each simulation affect household income, household specific CPI, and household real expenditure across urban, rural, and expenditure classes.

In general, the simulations suggest that the introduction of carbon tax in Indonesia, hurt urban households more than rural households. In rural area its impact is progressive, which means the poor gain relatively more than the rich, whereas in urban area its distributional direction depend on how the revenue from carbon tax is recycled. It is relatively neutral for the case of no-recycling and tax rate reduction, but obviously progressive for the case of uniform lump-sum transfers. Nation-wide, its overall net-impact is progressive for all scenarios, as can be seen from the reduction in the Gini coefficients.

General results from the simulations also suggest, that almost all rural households experience welfare gain as their real expenditure percapita rise. These gains, as can be seen from figure 2 are distributed progressively, as poorer households gain more percentage change in welfare compare to richer households. However, in all simulation 1 and simulation 2 almost all urban households are worse-off, and the cost are distributed relatively neutral, while in simulation 3, the lowest 20% are better off, and the distributive effect is progressive.

The driving forces of these results are closely related to the impact of carbon tax on both

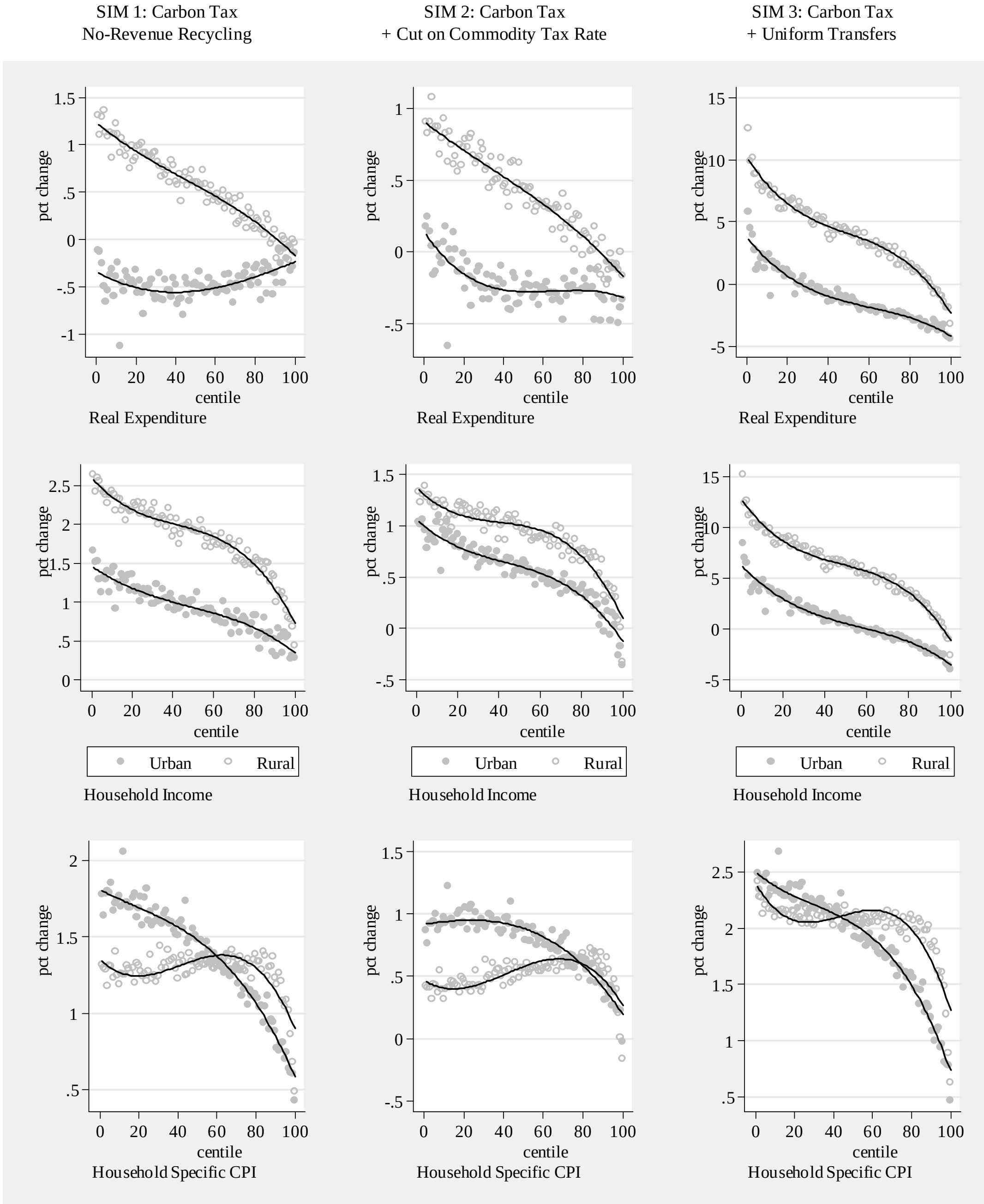

FIG. 2 Simulated impact on households' real expenditure, income, and households' specific CPI

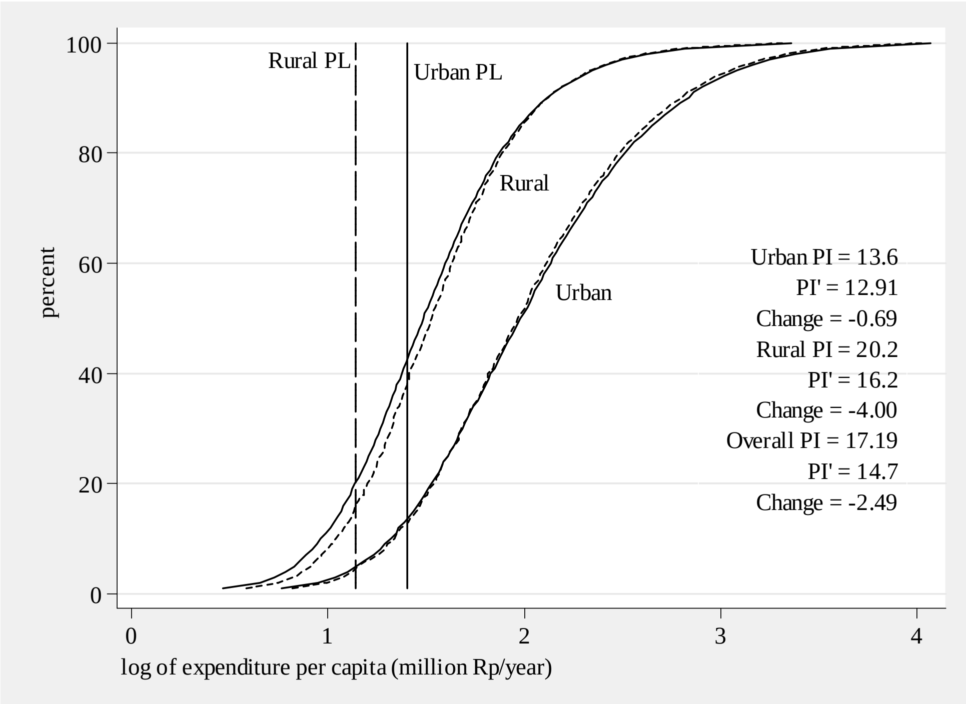

FIG. 3 Simulated Poverty Impact of Carbon Tax (SIM 3)

commodity prices and factor prices, in which each household has distinct pattern of consumption and factor endowments. From the simulations, rural households and poorer households (both in urban and rural area) tend to gain or to 'loose less' compared to urban and richer households.

One of the contributing feature of the CGE model with full-integration of disaggregated households is that we can look at what cause the distributive effect from two side of the coins. Unlike partial equilibrium analysis, which only look at the demand side from expenditure pattern of the households or even a CGE model with separate top-down micro-simulation model, the CGE model used in this study is able to offer deeper analysis on its distributive effect from the income side. From the story of the industry results, factor reallocation which is happening in the economy are biased against capital and skilled labor, and in favor of agriculture and services sectors, and hence agricultural, unskilled, and informal workers. This explains why the distributive effect is progressive from the income side of the households. As can be seen from the pictures, in all scenarios, the percentage change in household incomes are clearly declining (suggesting progressivity) both in rural and urban area, with rural household's income overall increase more than urban household's income.

This results is more or less could be explained by the typical characteristic of developing country's economy, where abundant unskilled labor, and prevalently rural, are employed in less energy and capital intensive sectors. In a general equilibrium 'mechanics' there will be factor reallocation from energy-intensive sectors (which mostly also capital intensive) into less energy and less capital intensive sectors such as agriculture. Expansion in these sectors will have favorable distributional consequences in a developing country like Indonesia. It is shown before, for example, that land return, and return to informal, unskilled, rural, agricultural workers rise relative to return to capital or return to formal skilled workers. This drive the favorable distributional impact from the income side, as also illustrated by declining trend of percentage change in income over expenditure centile both in urban and rural area. It may be expected that in more developed countries, the characteristics of the economy is different, in which most of the sectors are energy-intensive, capital intensive and less agricultural. This may explain, for example, why distributive effect of carbon tax in developed countries as reported in various studies are mostly regressive. This study shows, that in developing countries, the distributive effect of carbon tax may not necessarily the same, even if we just look from typical factor market feature in developing countries and from the income side pattern of the households.

Moreover, from the other side of the story, the consumption basket of poorer households in Indonesia is less energy intensive. Electricity usage, not to mention car or vehicle ownership, for example, is not as common as in richer countries. So, there is expectation that progressivity may be originated from the expenditure side as well.

However, the result suggests that the impact is less clear. As illustrated in bottom panel of figure 2, progressivity from the expenditure side could be determined if household specific CPI is increasing over centile, suggesting the price paid for its total consumption bundle increase more for richer household and less for poorer households. This may be true, as shown in those figures, for rural household from the poorest to the 80^{th} centile. Starting from the 80^{th} centile, its pattern is declining. Hence, from the expenditure side, it is only progressive on the lowest tail of the distribution.

In urban area, the story is rather different, poorer urban households are under pressure from the expenditure side. Household specific CPI are declining over expenditure centile in urban area, suggesting the price paid by poorer household for their consumption basket increase more than richer households. It means that urban households' consumption are more sensitive to the price of energy-related products compared to rural households. These commodities, among others, are vehicle fuels, electricity, and transportations. What drive the regressivity from the expenditure side in urban area is in fact lower-income household's dependence on domestic fuel (i.e., kerosene). The regressivity from the expenditure side, and the progressivity from the income side, in turn, drive the neutrality of distributive effect of carbon tax in urban area. Another important issue to be mentioned here, is the role of heavy subsidy on domestic fuel that make poor household especially in urban area are heavily dependent on kerosene. Overall nation-wide distributional impact, however, is still progressive, despite the regressivity from the expenditure side in urban area.

With regard to the poverty impact, since rural households (especially lower income ones) experience increase in real-expenditure, poverty in rural area falls in all scenarios. As expected, rural poverty falls the most (by 4%) when the revenue from carbon tax is returned to households as uniform lump-sum transfers. Figure 3 illustrate the poverty reduction potential of carbon-tax plus lump-sum transfers as revenue recycling scheme. Because rural population is a lot larger than urban population, declining poverty incidence in rural area help nation-wide poverty incidence fall in all simulation, despite slightly increasing poverty incidence in urban area (for SIM 1 and SIM 2).

Comparing alternative revenue-recycling mechanism, it suggests that uniform reduction in general commodity tax rate has favorable aggregate welfare impact (in terms of aggregate real consumption and GDP). GDP fall the least in SIM 2, with the magnitude half of the SIM 1. However, in terms of equity objectives, uniform lump-sum transfers produce a lot more favorable distributional impact. Inequality nation-wide fall the most. Gini coefficient fall, significantly by 0.017 compared to only 0.002 with the uniform sales tax cut. The poverty impact of uniform lump-sum transfers is also the most favorable where poverty nation-wide fall by 2.5%, which is contributed mostly by the fall in rural poverty incidence by 4%, as shown in figure 3.

However, uniform reduction in the rate of commodity tax, clearly has more favorable macroeconomic impact because of its potential for boosting consumption spending, as shown in the discussion of the macroeconomic impact in the earlier section. Moreover, uniform cash transfers is not a common instrument of redistribution, and is difficult in its implementation.

It should also be noted, however, that introducing uniform reduction in commodity tax, may affect the direction of the initial distributive effect of carbon tax i.e., its effect when the carbon tax revenue is not recycled. First, the reduction in inequality (in terms of the reduction in Gini coefficient) is lower in SIM 2 (with tax-cut) compared to SIM 1 (no-recycling). Because the pattern of the change in household specific CPI, over centile, of both simulation seems to be similar (except its overall magnitude), it is less likely that commodity price rises contribute to the different result. It is understandable because the reduction in commodity tax is uniform across commodities, hence will more or less have similar impact on their prices. The pattern of change in household income however is relatively different between the two simulations. Comparing only urban and rural households, the figures show that the gap between change in household income of urban and rural households are narrower in SIM 2 (tax-cut) compared to SIM 1 (no-recycling). Therefore, it may suggests that what is happening in the factor market has driven the different distributional result.

Table 2 may again, help explain this result. Output of industries which fall under SIM 1 tend to fall with less magnitude in SIM 2, simply because of increasing demand due to reduced prices brought about by uniform sales tax-cut. The increase in demand for commodities offset the decline in demand for labor by industries that would have happened without the tax-cut, and real wages form all type of labor rise instead of fall, and return to capital fall a lot less in SIM 2 compared to SIM 1. Some industries (such as pulp and paper, rubber, plastics, and machineries) manage to avoid contraction and some other contract a lot less. Most of these industries are capital intensive, and employ more intensively urban-formal production workers. These may contribute to mitigate the distributive effect of carbon tax from too much of urban-biased. However, despite these factors, carbon tax with revenue recycled through the uniform reduction in general sales tax is still progressive, reducing inequality, adding to its preferability because of its favorable macroeconomic effects.

6. CONCLUDING REMARKS

This study attempts to touch three important inter-linked issues i.e., development, environment, and equity, with the emphasis on the last two. In many cases, those three objectives could be conflicting, and it may be true as well between environment, and equity goals. This study, then attempts to answer, using the case study on carbon abatement policy, an increasingly more widely-discussed and topical global issue.

This study also offers a methodological contribution. It demonstrates that with households disaggregated by centile of expenditure per capita (made possible by constructing highly disaggregated Social Accounting Matrix), fully-integrated into a CGE model, it does not only allow for taking into account simultaneously both income pattern and expenditure pattern as inseparable driving forces into distributional story in an economy-wide framework, but also allows for more direct and accurate calculation of inequality indicators and poverty incidences.

Analysing the carbon abatement policy via the introduction of carbon tax in Indonesia, the result from various simulations suggests, that in contrast to most studies from developed countries, the distributive effect of carbon tax in Indonesia is not necessarily regressive. It is strongly progressive, and robust to various alternative recycling-scheme in rural area; and either neutral or slightly progressive in urban area. Its overall distributive effect nation-wide is progressive.

A closer look on what may contribute to the favorable distributive effect of the carbon tax, reveals that the progressivity is driven from both the income pattern of the expenditure pattern of households. The resource reallocation in the economy due to the introduction of carbon tax is in favor of factors endowed more proportionally by rural, and lower income class households, as shown, for example, by the contraction of the energy intensive manufacturing sectors and the expansion of agriculture and service sectors. The typical expenditure pattern in developing countries, which is less-energy-sensitive, also helps drive the progressivity of the result especially in rural area.

To conclude, this study shows that there is not necessarily a conflict between environment and equity objectives especially when the policies or reforms in order to achieve environmental goals are carefully designed. The result from the case study of carbon abatement policy, moreover, may have important global policy implication. Encouraging developing countries to reduce carbon emission, not only increase the efficiency of carbon abatement globally, but also may have favorable distributional implication in the developing countries themselves, in contrast to less preferable distributional impact in developed countries. Wheras global "efficiency gain" from shifting the location of carbon abatement from industrialised to developing countries has been widely acknowledged, this study introduces the notion of its 'global equity gain'.

REFERENCES

Adams, P., J. Horridge, and B. Parmenter (2000). MMRF-GREEN: A dynamic, multi-sectoral, multi-regional model of australia. Technical report, CoPS, Monash University. Centre of Policy Studies/IMPACT Centre Working Papers no. op-94.

Annabi, N., F. Cissé, J. Cockburn, and B. Decaluwé (2005). Trade liberalisation, growth and poverty in Senegal: a dynamic microsimulation CGE model analysis. Cahiers de recherche 0512, CIRPEE. available at http://ideas.repec.org/p/lvl/lacicr/0512.html.

Arndt, C. (1996). An introduction to systematic sensitivity analysis via gaussian quadrature. Technical Report 305, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.

Azis, I. J. (2000). Simulating economy-wide models to capture the transition from financial crisis to social crisis. *Annals Regional Science 34*(2), 251–278.

Azis, I. J. (2006). A drastic reduction of fuel subsidies confuses ends and means. *ASEAN Economic Bulletin 23*(1), 114–136.

Baranzini, A., J. Goldemberg, and S. Speck (2000). A future for carbon taxes. *Ecological Economics 32*(3), 395–412.

Barker, T. and J. Köhler (1998, November). Equity and ecotax reform in the eu: achieving a 10 per cent reduction in co2 emissions using excise duties. *Fiscal Studies 19*(4), 375–402. available at http://ideas.repec.org/a/ifs/fistud/v19y1998i4p375-402.html.

Bork, C. (2003). Distributional effects of the ecological tax reform in Germany- an evaluation with a micro-simulation model. paper prepared for the OECD Workshop on the Distribution of Benefits and Costs of Environmental Policies, 4-5 March 2003.

Bourguignon, F., A.-S. Robilliard, and S. Robinson (2003). Representative versus real households in the macro-economic modeling of inequality. Working paper DT 2003-10, DIAL.

Boyce, J., M. Riddle, and M. D. Brenner (2005). A chinese sky trust? distributional impacts of carbon charges and revenue recycling in china. Working papers, Political Economy

Research Institute, University of Massachusetts at Amherst.

Brannlund, R. and J. Nordstrom (2004, February). Carbon tax simulations using a household demand model. *European Economic Review 48*(1), 211–233. available at http://ideas.repec.org/a/eee/eecrev/v48y2004i1p211-233.html.

Cornwell, A. and J. Creedy (1996, August). Carbon taxation, prices and inequality in australia. *Fiscal Studies 17*(3), 21–38. available at http://ideas.repec.org/a/ifs/fistud/v17y1996i3p21-38.html.

Cororaton, C. B. (2003). Construction of philippine SAM for the use of CGE-microsimulation analysis. mimeo, Philippine Institute for Development Studies, http://www.pep-net.org.

Cororaton, C. B. and J. Cockburn (2005). Trade reform and poverty in the philippines: a computable general equilibrium microsimulation analysis. Cahiers de recherche 0513, CIRPEE. available at http://ideas.repec.org/p/lvl/lacicr/0513.html.

Cororaton, C. B. and J. Cockburn (2006). WTO, trade liberalization, and rural poverty in the Philippines: Is rice special ? *Rev. Agr. Econ. 28*(3), 370–377.

Decaluwé, B., J. C. Dumont, and L. Savard (1999). How to measure poverty and inequality in general equilibrium framework. CREFA Working Paper no. 9920. Laval University.

Filho, J. and M. Horridge (2004). Economic integration, poverty and regional inequality in Brazil. Centre of Policy Studies/IMPACT Centre Working Papers g-149, Monash University, Centre of Policy Studies/IMPACT Centre. available at http://ideas.repec.org/p/cop/wpaper/g-149.html.

Hamilton, K. and G. Cameron (1994, December). Simulating the distributional effects of a canadian carbon tax. *Canadian Public Policy 20*(4), 385–399. available at http://ideas.repec.org/a/cpp/issued/v20y1994i4p385-399.html.

Hertel, T., D. Hummels, M. Ivanic, and R. Keeney (2003). How confident can we be in cge-based assessments of free trade agreements? GTAP Working Papers 1324, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.

Horridge, M. (2000). ORANI-G: A general equilibrium model of the Australian economy. Centre of Policy Studies/IMPACT Centre Working Papers op-93, Monash University, Centre of Policy Studies/IMPACT Centre. available at http://ideas.repec.org/p/cop/wpaper/op-93.html.

Ikhsan, M., T. Dartanto, Usman, and H. Sulistyo (2005, April). Kajian dampak kenaikan harga BBM 2005 terhadap kemiskinan. LPEM Working Paper http://www.lpem.org.

Jacobsen, H. K., K. Birr-Pedersen, and M. Wier (2003, December). Distributional implications of environmental taxation in denmark. *Fiscal Studies 24*(4), 477–499. available at http://ideas.repec.org/a/ifs/fistud/v24y2003i4p477-499.html.

Jotzo, F. (2004). Developing countries and the future of the kyoto protocol. Economics and Environment Network Working Papers 0406, Australian National University, Economics and Environment Network. available at http://ideas.repec.org/p/anu/eenwps/0406.html.

Kristörm, B. (2003). Framework for assessing the distribution of financial effects of environmental policies. paper prepared for the OECD Workshop on the Distribution of Benefits and Costs of Environmental Policies, Paris 4-5 March 2003.

Labandeira, X. and J. Labeaga (1999). Combining input-output analysis and micro-simulation to assess the effects of carbon taxation on spanish households. *Fiscal Studies 20*(3), 305–320.

Lluch, C., A. Powell, and R. Williams (1977). *Patterns in Household Demand and Savings.* Oxford University Press, London.

Marland, G., T. Boden, and R. Andres. (2005). *Global, Regional, and National CO2 Emissions. In Trends: A Compendium of Data on Global Change.* Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A.

OECD (1994). *The Distributive Effects of Economic Instruments for Environmental Policy.* OECD, Paris.

OECD (1995). *Climate change, economic instruments and income distribution.* OECD, Paris.

OECD (1996). *Implementation Strategies for Environmental Taxes.* OECD, Paris.

OECD (2004). Environment and distributional issues: analysis, evidence and policy implication. Technical Report JT00165943, Organisation for Economic Co-operation and Development. Final Report, Working Party on National Environmental Policy.

Oktaviani, R., D. Hakim, S. Sahara, and H. Siregar (2005, May). The impact of fiscal policy on Indonesian macroeconomic performance, agricultural sector and poverty incidences (a dynamic computable general equilibrium analysis. Report to the Poverty and Economic Policy (PEP) Network http://www.pep-net.org/.

Pearson, K. and C. Arndt (2000). Implementing systematic sensitivity analysis using gempack. GTAP Technical Papers 474, Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University.

Pearson, M. and S. Smith (1991). The european carbon tax: An assessment of the european commission's proposals. London: The Institute for Fiscal Studies, 1991.

Plumb, M. (2001). An integrated microsimulation and applied general equilibrium approach to modelling fiscal reform. mimeo.

Poterba, J. M. (1991). Is the gasoline tax regressive? NBER Working Papers no 3578.

Resosudarmo, B. (2003). Computable general equilibrium model on air pollution abatement policies with indonesia as a case study. *Economic Record 79*(0), 63–73.

Savard, L. (2003). Poverty and income distribution in a cge-household micro-simulation model: Top-down/bottom up approach. Cahiers de recherche 0343, CIRPEE. available at http://ideas.repec.org/p/lvl/lacicr/0343.html.

Shah, A. and B. Larsen (1992, August). Carbon taxes, the greenhouse effect, and developing countries. Policy Research Working Paper Series 957, The World Bank.

Stern, N. (2006). *The Economics of Climate Change: The Stern Review.* Cambridge Univ. Press.

Sugema, I., M. Hasan, R. Oktaviani, Aviliani, and H. Ritonga (2005). Dampak kenaikan harga BBM dan efektivitas program kompensasi. INDEF Working Paper http://www.indef.or.id/download/pubs/BBM.PDF.

Symons, E. J., S. Speck, and J. L. R. Proops (2000). The effects of pollution and energy taxes across the european income distribution. Keele Department of Economics Discussion Papers (1995-2001) 2000/05, Department of Economics, Keele University. available at http://ideas.repec.org/p/kee/keeldp/2000-05.html.

Tanujaya, O. (2005). Indonesia beyond 2012: How to emit less and grow more at the same time. In A. P. Sari (Ed.), *Kyoto Protocol: Beyond 2012.* Pelangi.

Warr, P. (2006). The Gregory thesis visits the tropics. *Econ. Record 82*(257), 177–194.

Wier, M., K. Birr-Pedersen, H. K. Jacobsen, and J. Klok (2005, January). Are co2 taxes regressive? evidence from the danish experience. *Ecological Economics 52*(2), 239–251. available at http://ideas.repec.org/a/eee/ecolec/v52y2005i2p239-251.html.

Yusuf, A. A. (2006, November). Constructing indonesian social accounting matrix for distributional analysis in the cge modelling framework. Working Papers in Economics and Development Studies 200604, Department of Economics, Padjadjaran University. available at http://ideas.repec.org/p/unp/wpaper/200604.html.

APPENDIX A: DESCRIPTION OF THE CGE MODEL

A.1. Production Sectors

The structure of the nested production function for each industry is illustrated in figure 4. At the very bottom part, industry choose how many each type of labor demanded and determine the number of labor composite according to Constant Elasticity of Substitution aggregation function. More formally, every industry solve the following optimisation problem,

$$\min \sum_o w_o L_o \text{ s.t. } \tilde{L} = \text{ CES}\left(L_1, L_2, \ldots, L_O\right)$$

where w_o is wage of each of the occupational type, L_o is the number of labor for each occupation type, and $\tilde{L}$ is labor composite, and $o = 1, \ldots, O$. In this model, the classification of the labor type is fairly detail and also represent the higher degree of dualistic nature of informality in the labor market, typical in developing countries. Therefore in this model, formal and informal labor, for example, are not perfect substitutes, and paid with different wages. This typical informality is often neglected in many others CGE model.

At the next stage, the optimisation problem for each of the industry is,

$$\min P^K K + P^N N + \tilde{w}\tilde{L} \text{ s.t. } V = \text{ CES}\left(K, N, \tilde{L}\right)$$

where K and P^K are capital and price of capital respectively, N and P^N are land and price of land respectively, and $\tilde{L}$ and $\tilde{w}$ are labor composite and its price respectively, whereas V is value added or primary factor composite.

At the other end, for every energy commodity, each industry optimise to choose the source of the commodity from either local or imported commodity, or

$$\min P_e^D E_e^D + P_e^M E_e^M \text{ s.t. } \tilde{E}_e = \text{ CES}\left(E_e^D, E_e^M\right)$$

where P_e^D and E_e^D are price of domestic energy e and quantity of domestic energy e respectively, where P_e^M and E_e^M are price of imported energy e and quantity of imported energy e respectively, whereas $\tilde{E}_e$ is domestic-imported composite of energy e.

The industry, then, choose the composition of energy type for every energy composite that they need,

$$\min \sum_e \tilde{P}_e \tilde{E}_e \text{ s.t. } E^C = \text{ CES}\left(\tilde{E}_1, \tilde{E}_2, \ldots, \tilde{E}_E\right)$$

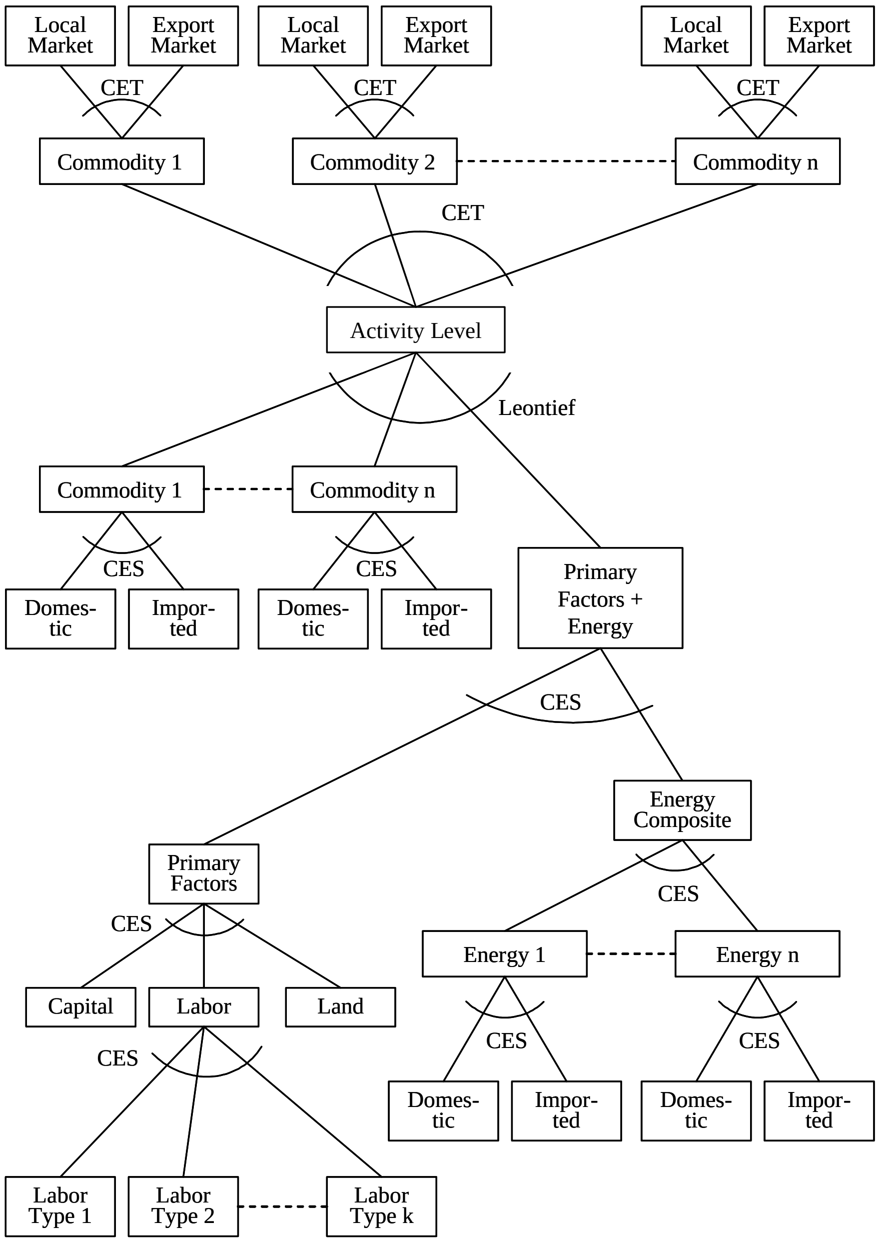

FIG. 4 Structure of Production

where $\tilde{P}_e$ and $\tilde{X}_e$ are price and quantity of domestic-imported composite energy e, respectively, while E^C is the energy composite.

Industries are allowed to substitute between energy and primary factors, so they are solving the following optimization problem

$$\min P^E E^C + P^V V \text{ s.t. } VE = \text{ CES}\left(V, E^C\right)$$

where P^E is the price of energy composite, and P^V is the price of primary factor composite, while VE is value-added and energy composite.

At the top of the production nest, each industry minimises cost of purchasing intermediate costs and primary-factor-energy composite to produce output of the activity level using Leontief production function, or

$$\min \sum_c P_c X_c + P^{VE} VE \text{ s.t. } A = \min\left(X_1, X_2, \ldots, X_C, VE\right).$$

where P_c and X_c are price and quantity of intermediate commodity c respectively, where A is activity level or total output of industry.

In this model, each industry is allowed to produce multiple commodities[28], such that

$$\max \sum_c P_c X_c \text{ s.t. } A = \text{ CET}\left(X_1, X_2, \ldots, X_C\right)$$

where CET refer to Constant Elasticity of Transformation function. And finally, industry can choose to sell either in local or export market such that the optimisation problem is

$$\max \sum P_c^D X_c^D + P_c^E X_c^D \text{ s.t. } X_c = \text{ CET}\left(X_c^D, X_c^E\right)$$

where P_c^D and X_c^D are price and quantity of commodity sold to local/domestic market, whereas where P_c^E and X_c^E are price and quantity of commodity supplied to export market.

The model has 38 number of sectors and 43 number of commodities. All industry producing single commodity except petroleum refinery sector where it produces 6 type of commodities i.e., gasoline, kerosene, automotive diesel oil, industrial diesel oil, other fuels, and LPG. This is the aggregation from 181 sectors/commodities in the Social Accounting Matrix, as discussed in the earlier section. Since fuel commodities is disaggregated in detail, it can capture accurately how the October 2005 package was implemented, because the rise in the fuel prices are different across fuel commodities.

A.2. Households

Household maximise Stone-Geary Utility function (in log form),

$$U = \sum_i \beta_i \log\left(x_i - \gamma_i\right)$$

where x_i is consumption of good i, γ_i is subsistence consumption of good i, $x_i > \gamma_i$, $0 \leq \beta_i \leq 1$, and $\sum_i \beta_i = 1$,

subject to

$$y = \sum_i p_i x_i.$$

[28]Although in the model, it will only applies to a single refinery industry that allow to produce multiple type of fuels.

This will yield the following demand system in expenditure form, which is called Linear Expenditure System (LES).

$$p_i x_i = p_i \gamma_i + \beta_i \left(y - \sum_j p_j \gamma_j \right)$$

Compared to Cobb-Douglas and CES demand system, LES is richer for distributional effect analysis, because income elasticity is not constant, hence the impact on the same percentage shock on each household income, would generate different behavioral responses by each households. The natural reason that income elasticity of households are different is that marginal utility of income vary with level of income. Poor households will have higher marginal utility of income, while rich household will have lower. In the LES, this is captured by Frisch parameter that varies with income level.

A.3. Model Database and Parameters

The database for the model is built based on the Social Accounting Matrix 2003 specifically constructed for this research, as described in detail in the earlier section. For the purpose of the case studies the industry is aggregated into 38 sectors and the commodity is aggregated into 43 sectors.

There are some sets of parameters of which their values have to be estimated or borrowed from literature or other models. Those set of parameters are: (1) Armington elasticity between domestic and imported commodities; (2) Export elasticity; (3) Elasticity of substitution among labor types (or skills); (4) Elasticity of substitution among primary factors; (5) CET transformation for industries with multiple commodities; (6) Elasticity of substitution among energy types; (7) Elasticity of substitution between energy composite and primary factor; (8) Expenditure elasticity for LES household demand system, and; (8) Frisch parameter, elasticity of marginal utility of income.

Parameter 1 to 5 are taken from GTAP database. Parameter 6 and 7 is borrowed from INDOCEEM[29] model. Here, the elasticity of substitution among fossil-fuel energy is set moderately 0.25, while the elasticity of substitution between energy composite and primary factors of production is set to be 0.1. All of the parameters which are borrowed from literature or other model are subject to sensitivity analysis as discussed in the next section.

Expenditure elasticity parameter are estimated econometrically, and Frisch parameter is calculated based on the study by Lluch et al. (1977).

APPENDIX B: SYSTEMATIC SENSITIVITY ANALYSIS

In a CGE exercise, because some of the parameters are taken from other sources such as others studies, models, or literature. It is necessary to examine the reliability of the results with respects to uncertainty in the parameters. In a standard or 'ad-hoc' sensitivity analysis, the model is solved for one or two different sets of parameters, and then the sensitivity of the change in endogenous variables are examined. However, since there are many parameters are imputed into the model, this approach is difficult or less practical to be implemented when we want to examine the sensitivity of the results on the independent uncertainty about the values of several parameters. In this model, for example, for Armington elasticity alone, because the model has 38 different commodities, the sensitivity analysis to each of the parameters would be

[29] A model developed by Monash University and Indonesian Ministry of Energy.

computationally burdensome.

Recent advances in the literature on sensitivity analysis offer a rather convenient approach, i.e., systematic sensitivity analysis[30]. The question to be asked in this sensitivity analysis is, how reliable is the results if we vary 'all' the parameters in the model, let's say by 50%. Hence, if for example, the Armington elasticity of commodity A is 5, then we allow it to vary between 2.5 and 7.5. We will do it for all the parameters. The popular approach is a typical Monte Carlo simulation, where we draw independently enough number from each of the range value of the parameters, and do that in a sufficiently large draw such that the result is statistically accurate. However, with this kind of approach, time and computational constraint will prevent the accuracy of the estimates.

The new approach is the so-called Systematic Sensitivity Analysis (SSA) via Gaussian Quadrature. This is a type of programming or optimisation method. Given the distribution of M parameters, what is the best possible choice of parameters in N simulations if we want to estimate means and standard deviations for all endogenous variables. A procedure for choosing the N parameters made in this way is often referred to a Gaussian quadrature. However, this assumes (1) the simulation results are well approximated by a third-order polynomial in the varying parameters; (2) that parameters which vary all have a symmetric distribution[31]; (3) the parameters vary quite independently (zero correlation). Arndt (1996) for example demonstrates that the results are often surprisingly accurate, given the relatively modest number of times the model is solved.

The confidence interval for each endogenous variables is calculated by employing the Chebyshev's inequality. Suppose that we have an endogenous variable y with mean μ and standard deviation σ. Chebyshev's inequality says that, whatever the distribution of the variable in question, for each positive real number k, the probability that the value of y does not lie within k standard deviations of the mean $\mu$is no more than $\frac{1}{k^2}$. The confidence interval is calculated as $\mu \pm k \cdot \sigma$, where $k = 3.16$ for 90% confidence interval, and $k = 4.47$ for the 95%. In this SSA, all parameters are assumed to vary by 50%, and the SSA is implemented in Gempack (Pearson and Arndt 2000).Table 6 shows the result of systematic sensitivity analysis for carbon tax simulation (SIM 1, no-recycled revenue), assuming triangular distribution in the parameters, with 50% variation from the mean, and applied using Gaussian Quadrature approach. In general, the result suggests, that the result is robust to variation in the extraneous parameters, as shown by low standard deviation of most endogenous variables.

However, some macroeconomic variables tend to be more sensitive to parameters. Statistically speaking, for example, we can not 90% confident, that GDP or aggregate consumption fall, because its upper confidence interval is non-negative. However, CPI is relatively insensitive, but CO_2 emission seems to have very wide confidence interval.

For factor price variables, some real wages such as for agricultural labor are relatively more sensitive, but for real wage of other type of labor is relatively less sensitive to variation in parameters. However, the qualitative direction is robust with even 95% confidence level. Moreover, the pattern on which relative real wage change[32], which has implication in the distributional story, is also robust to sensitivity analysis.

Looking at the confidence interval in real household expenditure by centiles, it also suggests that distributional impact of carbon tax is less likely to be sensitive to parameter variation. It

[30] See Arndt (1996), Pearson and Arndt (2000), and its implementation among others in Hertel et al. (2003), and Plumb (2001).

[31] The SSA carried out in this paper, the parameters are assumed to have triangular distribution.

[32] For example, the percentage change on the real wage of formal urban production workers, compared to the real wage of informal, rural, agricultural workers.

TABLE 6
SSA of SIM 1: Carbon Tax (50 percent Variation in All Parameters)

	mean	s.d.	Con. Interval (90%) lower	Con. Interval (90%) upper	Con Interval (95%) lower	Con Interval (95%) upper
Macroeconomics						
GDP	-0.040	0.013	-0.081	0.001	-0.098	0.018
Aggregate consumption	-0.061	0.020	-0.122	0.001	-0.148	0.027
CPI	1.324	0.033	1.218	1.430	1.174	1.473
CO2 emission	-6.535	0.656	-8.609	-4.461	-9.468	-3.602
Real wage						
Agriculture, rural, formal	-0.587	0.127	-0.988	-0.187	-1.154	-0.021
Agriculture, urban, formal	-0.548	0.118	-0.922	-0.175	-1.077	-0.020
Agriculture, rural, informal	-0.478	0.120	-0.858	-0.099	-1.015	0.059
Agriculture, urban, informal	-0.497	0.111	-0.849	-0.144	-0.995	0.002
Production, rural, formal	-2.691	0.178	-3.254	-2.128	-3.487	-1.894
Production, urban, formal	-4.647	0.190	-5.248	-4.047	-5.497	-3.798
Production, rural, informal	-2.236	0.195	-2.851	-1.620	-3.106	-1.365
Production, urban, informal	-2.245	0.202	-2.883	-1.606	-3.148	-1.342
Clerical, rural, formal	-2.178	0.069	-2.397	-1.959	-2.487	-1.869
Clerical, urban, formal	-3.126	0.111	-3.479	-2.774	-3.625	-2.628
Clerical, rural, informal	-1.763	0.114	-2.124	-1.402	-2.274	-1.253
Clerical, urban, informal	-1.786	0.112	-2.139	-1.433	-2.285	-1.287
Professional, rural, formal	-3.183	0.134	-3.606	-2.761	-3.781	-2.586
Professional, urban, formal	-3.551	0.115	-3.915	-3.188	-4.065	-3.037
Professional, rural, informal	-2.198	0.184	-2.780	-1.616	-3.021	-1.375
Professional, urban, informal	-2.070	0.114	-2.431	-1.708	-2.581	-1.558
Average price of capital	-4.447	0.082	-4.705	-4.189	-4.813	-4.082
Average price of land	0.919	0.116	0.553	1.284	0.401	1.436
Output						
Coal	-2.933	0.454	-4.370	-1.496	-4.965	-0.901
Natural gas	-0.687	0.139	-1.128	-0.247	-1.310	-0.064
Refinery	-3.837	0.447	-5.252	-2.423	-5.838	-1.837
Electricity	-1.436	0.090	-1.722	-1.151	-1.841	-1.032
Water and gas	-2.238	0.066	-2.448	-2.028	-2.535	-1.941
Road transportation	-0.663	0.077	-0.906	-0.419	-1.007	-0.318
Other transportation	-1.430	0.172	-1.974	-0.885	-2.200	-0.659
Prices						
Coal	131.877	1.574	126.901	136.853	124.840	138.914
Natural gas	26.561	1.542	21.684	31.439	19.663	33.459
Gasoline	24.626	0.294	23.696	25.555	23.311	25.940
Diesel (Automotive)	45.251	0.828	42.634	47.868	41.550	48.952
Diesel (Industries)	43.442	0.786	40.957	45.927	39.928	46.956
Kerosene	29.305	0.534	27.615	30.995	26.915	31.695
LPG	25.714	1.293	21.626	29.802	19.932	31.495
Other fuels	21.389	0.696	19.187	23.591	18.275	24.503
Electricity	16.953	0.852	14.260	19.646	13.144	20.761
Water and gas	12.379	0.295	11.445	13.312	11.058	13.699
Road transportation	1.763	0.060	1.572	1.953	1.493	2.032
Other transportation	2.349	0.072	2.121	2.578	2.027	2.672
Real consumption						
Urban						
Centile 1	0.135	0.031	0.036	0.234	-0.005	0.275
Centile 2	0.083	0.031	-0.014	0.180	-0.054	0.220
Centile 3	0.060	0.030	-0.034	0.154	-0.072	0.193
Centile 4	-0.306	0.031	-0.403	-0.209	-0.443	-0.168
Centile 5	-0.514	0.039	-0.636	-0.393	-0.687	-0.342
Centile 13	-0.296	0.029	-0.386	-0.205	-0.423	-0.168
Centile 95	-0.247	0.028	-0.335	-0.159	-0.372	-0.123
Centile 96	-0.407	0.024	-0.482	-0.333	-0.513	-0.302
Centile 97	-0.223	0.026	-0.305	-0.141	-0.339	-0.107
Centile 98	-0.569	0.022	-0.640	-0.499	-0.669	-0.470
Centile 99	-0.509	0.020	-0.571	-0.447	-0.597	-0.421
Centile 100	-0.343	0.026	-0.424	-0.262	-0.458	-0.229
Rural						
Centile 1	1.657	0.070	1.434	1.880	1.342	1.972
Centile 2	1.546	0.068	1.331	1.760	1.242	1.849
Centile 3	1.625	0.077	1.381	1.869	1.280	1.970
Centile 4	1.711	0.063	1.511	1.911	1.428	1.994
Centile 5	1.453	0.063	1.254	1.652	1.171	1.735
Centile 20	1.157	0.058	0.974	1.339	0.899	1.415
Centile 95	0.002	0.040	-0.124	0.127	-0.176	0.179
Centile 96	-0.228	0.038	-0.347	-0.108	-0.396	-0.059
Centile 97	-0.251	0.035	-0.362	-0.139	-0.408	-0.093
Centile 98	-0.123	0.040	-0.250	0.004	-0.302	0.056
Centile 99	-0.049	0.049	-0.203	0.105	-0.267	0.169
Centile 100	-0.224	0.050	-0.383	-0.066	-0.448	0.000

can be interpreted for example, that we are 95% confident that in rural area, real expenditure of the poorest 1% household will rise not less than 1.342%, and that of the richest 1% household will not be better-off (0% rise in expenditure per capita). Therefore, the carbon tax tend to reduce inequality in rural area.

The direction of the poverty impact can also be looked at what happen to households near to the poverty line. In urban area, for example, that household is the centile 13th household. Since its 95% confidence interval is between -0.386 to -0.205, we can be 95% confident that poverty in urban area falls following the introduction of carbon tax.