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Employing a CGE model in analysing the environmental and economy-wide impacts of CO_2 emission abatement policies in Malaysia

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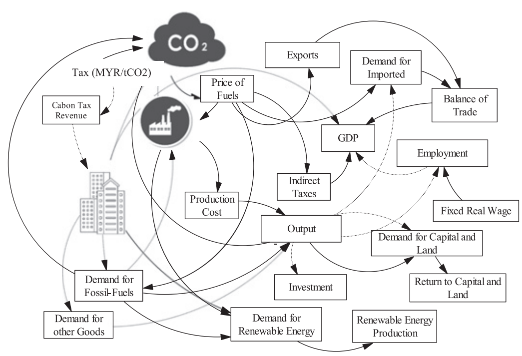
HIGHLIGHTS

- CO_2 abatement policies do not have substantial negative effects on Malaysia.
- A carbon tax with revenue-recycling is the most efficient carbon abatement policy.
- Emission standards cause mild contractions in the overall economy.
- Production of renewable energy would increase strongly under a carbon tax policy.
- Energy sectors affected substantially by the CO_2 abatement policies

GRAPHICAL ABSTRACT



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ABSTRACT

The impact of global warming has received much international attention in recent decades. To meet climate-change mitigation targets, environmental policy instruments have been designed to transform the way goods and services are produced as well as alter consumption patterns. The government of Malaysia is strongly committed to reducing CO_2 gas emissions as a proportion of GDP by 40% from 2005 levels by the year 2020. This study evaluates the economy-wide impacts of implementing two different types of CO_2 emission abatement policies in Malaysia using market-based (imposing a carbon tax) and command-and-control mechanism (sectoral emission standards). The policy simulations conducted involve the removal of the subsidy on petroleum products by the government. A carbon emission tax in conjunction with the revenue neutrality assumption is seen to be more effective than a command-and-control policy as it provides a double dividend. This is apparent as changes in consumption patterns lead to welfare enhancements while contributing to reductions in CO_2 emissions. The simulation results show that the production of renewable energies is stepped up when the imposition of carbon tax and removal of the subsidy is augmented by revenue recycling. This study provides an economy-wide assessment that compares two important tools for assisting environment policy makers evaluate carbon emission abatement initiatives in Malaysia.

1. Introduction

Many nations are seeking to reduce CO_2 emissions through various intergovernmental and country initiatives such as the United Nations Framework Convention on Climate Change (UNFCCC). Recently, the

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Table 1
CO_2 emissions among Southeast Asian countries.

	CO_2 emission ($MtCO_2$)	CO_2/TPES[a]	CO_2/GDP(ppp[b])	CO_2/POP	CO_2 emission ($MtCO_2$)	CO_2/TPES	CO_2/GDP(ppp)	CO_2/POP	CO_2 emission growth (%)
	2005				2013				
Indonesia	321.56	42.72	0.25	1.44	424.6	47.5	0.21	1.70	32.0
Malaysia	154.60	55.4	0.37	5.98	207.2	55.6	0.35	6.97	34.1
Myanmar	10.58	17.03	0.19	0.21	13.3	19.2	0.14	0.25	26.1
Philippines	71.48	43.94	0.19	0.83	89.6	48.0	0.16	0.91	25.4
Singapore	37.86	41.92	0.16	8.87	46.6	42.6	0.13	8.62	23.0
Thailand	200.20	48.30	0.31	3.05	247.4	44.1	0.30	3.69	23.6

Source: author's based on IEA (2015).
[a] Total primary energy supply.
[b] Purchasing power parities.

UNFCCC was adopted on December 2015 at COP21[1] in Paris as a means to mitigate greenhouse gas emissions (GHGs) through the adoption of various measures including financing beginning in 2020. By 2016, a total of 121 out of 197 parties (including Malaysia) had ratified the convention (UNFCCC, 2015).

Governments have sought to institute stronger measures to address the increasing concentrations of GHGs and their impact on natural resources, environment, and society. During COP15[2] in Copenhagen, Malaysia pledged to reduce CO_2-equivalent gas emissions as a proportion of its gross domestic product (GDP) by 40% by 2020 over 2005 levels (UNCCC, 2009). According to the Malaysia's second national communication (NC2) to the UNFCCC, the estimated total CO_2-eq[3] GHG in 2005 equalled 449.6 million tonnes while the emissions intensity of GDP stood at 0.62 tonnes of CO_2-eq/thousand Malaysian Ringgit in 2005. Based on the 40% target for 2020, the emission intensity should be reduced to 0.37 tonnes of CO_2-eq per thousand Malaysian Ringgit[4] unit of GDP. This can be achieved when GHG emissions in 2020 are reduced to 60% of 2005 levels. In other words, based on the estimated GDP of MYR906.6 billion in 2020, total emissions need to be limited to about 335 million tonnes of CO_2-eq (Ministry of Natural Resources and Environment, 2011). International Energy Agency (2015) data shows that compared to other Southeast Asian nations, Malaysia has relatively high CO_2 emissions growth per capita and per GDP rates at 6.97 (tonnes CO_2 per capita) and 0.35, respectively. Table 1 shows the indices related to CO_2 emissions for six Southeast Asian countries from 2005 to 2013 (IEA, 2015).

Rapid economic growth in Malaysia has raised concerns over the high intensity of CO_2 emissions (Begum et al., 2015), and unless strong mitigation actions are taken energy use and fossil fuel emissions will continue to increase along with GDP growth. Fig. 1 illustrates the positive correlation between the consumption of fossil fuels and the rate of economic growth in Malaysia from 1990 to 2014.

Malaysia's economic growth has led to a significant increase in the demand for energy especially for fossil fuels (Ang, 2008; Azlina and Mustapha, 2012; Begum et al., 2015). Further, in terms of energy-carbon intensity, the index shows that Malaysia recorded the highest level of CO_2 emission per unit of energy produced. The index shows a relatively high measure of as much as 55.6 tonnes of CO_2 per Tera joule of energy in 2013 (IEA, 2015). The rising trend in this index can be seen in the contribution of different types of fossil fuels in total CO_2 emissions as illustrated in Fig. 2. As shown, the rapid rise in CO_2 emissions is due to the high consumption of gas and oil energies and this, together with the huge increase in emissions from coal, especially from 2010 to 2012, placed Malaysia among the top CO_2 emitters in the region. Further, IEA (2015) data shows that about 47% (95.9 $MtCO_2$[5]) of Malaysia's total CO_2 emissions from fuel combustion in 2013 (207.2 $MtCO_2$) was generated by the power generation sector. Fig. 2 shows the rising trend in CO_2 emissions from coal due to the rapid rise in its consumption when it replaced natural gas in the power generation sector from 2011. The increasing trend for oil is also due to the increase in demand for this fuel by the transportation sector. Further, the contribution of gas in total CO_2 emissions is mainly due to its high demand by the power sector.

Fossil fuel combustion is a major factor to be considered in efforts to reduce GHG emissions. Providing subsidized fossil fuels increases their consumption leading to environmental pollution in terms of CO_2 emissions and significantly reduces Malaysia's oil reserves due to their high extraction and consumption rates, as noted by Othman and Jafari (2012). Therefore, the formulation and implementation of appropriate emission abatement policies to address environmental and natural resources depletion issues are among the key concerns facing Malaysia's macro-economic policy makers.

Malaysia's economy has been growing rapidly since the 1970s (Economic Planning Unit, 2010) and this has major implications for its sustainable development agenda. These issues include the rising levels of CO_2 emissions from fuel combustion, unsustainable energy supply owing to the domination of fossil resources in the country's energy mix, and low levels of renewable energy production and consumption. As noted in the literature on environmental economics, environmental instruments such as CO_2 tax and emission standards would effectively help to address the abovementioned issues. Imposing carbon taxation or implementing sectoral emission standards to reduce CO_2 emissions could have political and social implications. In addition, opinions vary on the impact of carbon taxation and emission standards on GDP growth and energy prices, and how conventional energy industries will be affected. It is important to explore how these instruments may affect the Malaysian economy as a whole.

The objective of this paper is to provide empirical analysis of alternative carbon abatement scenarios and discuss policy implications for Malaysia using a static CGE model with environment-energy-economy interactions. The analysis contributes to the current literature by examining the impact of introducing a carbon tax and implementing command-and-control measures together with removing petroleum product subsidies on energy consumption, estimating sectoral CO_2 emissions, renewable-energy production, and socio-economic factors such as household welfare.

Specifically, this paper has three main objectives, that is: i) to estimate the sectoral and total level of CO_2 emissions resulting from removing the subsidy for petroleum products, imposing CO_2 taxation with revenue-recycling and introducing sectoral emission limits; ii) to estimate the economy-wide impact of the above mentioned policies on economic variables including real GDP, employment, sectoral output, commodity prices and demand, returns to factors of production, sectoral employment, welfare consequences, and external trade measurements; and iii) to provide policy recommendations for formulating a comprehensive CO_2 abatement policy in Malaysia.

[1] 21th Conference on Parties.
[2] 15th Conference on Parties.
[3] Equivalent.
[4] Malaysian Ringgit or MYR (Malaysia's currency unit).
[5] Million tonnes of CO_2.

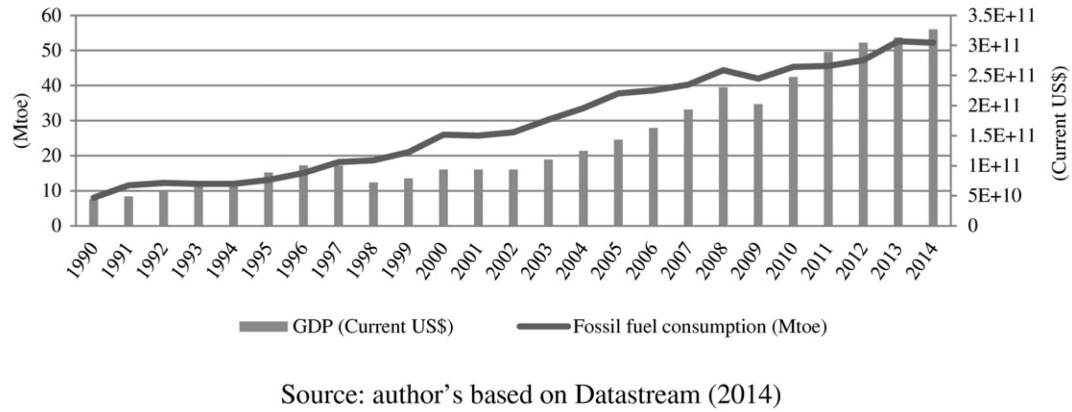

Fig. 1. Gross domestic product and total fossil fuel consumption (includes coal, crude oil and natural gas), Malaysia.
Source: author's based on Datastream (2014).

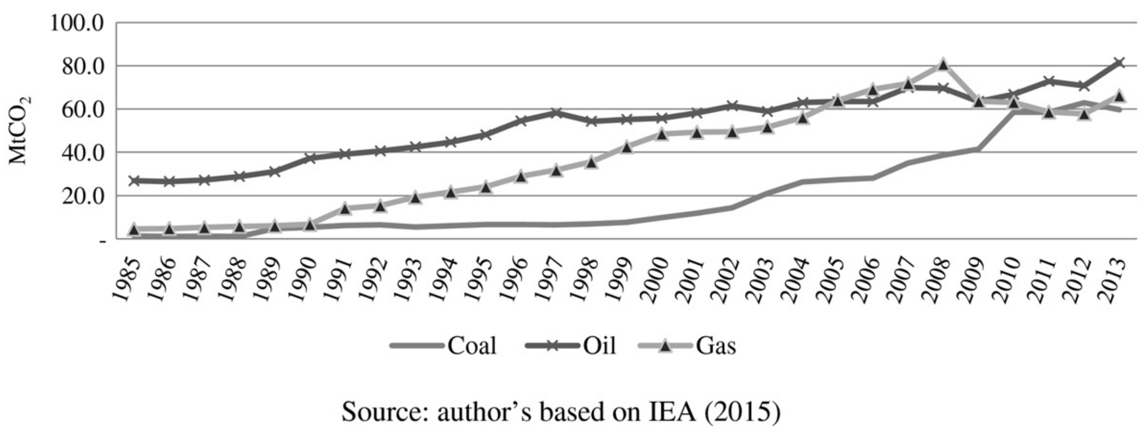

Fig. 2. CO_2 emissions from fuel combustion, Malaysia $MtCO_2$ (1985–2013).
Source: author's based on IEA (2015).

2. Literature review

There are various measures that are generally employed to control greenhouse gas (GHG) emissions with their effectiveness depending upon the circumstances under which they are implemented (OECD, 2007, 2009). These include market based instruments that focus on energy and carbon taxes, tradable emission permits, and command-and-control (CAC) initiatives which impose direct regulations for emission cuts and technological standards. Although many countries have utilized command-and-control measures to reduce emissions, the past few decades have seen environmental economists increasingly defending the use of economic instruments for that purpose. A review of studies comparing the two approaches can be seen in Hahn (2000). This section reviews the literature on environmental policy instruments, their impacts in the Malaysian context, and discusses the research questions addressed by this paper.

Most studies on climate change note that the introduction of economic instruments such as a carbon tax would decrease GHG emissions although how they affect the economy and variables related to equity issues remain unknown (Babiker et al., 2003; Bruvoll and Larsen, 2004; Callan et al., 2009). A major issue is whether any macroeconomic policy has a significant impact on attaining emission reduction targets. Many studies have been devoted to this issue. In terms of methodology, the general equilibrium approach is acknowledged as most suitable for analysing the indirect and direct economic effects of policy measures as it is able to simultaneously incorporate different sectors of the economy. Whalley and Wigle (1991) and Whalley (1992) are the pioneers in the field of carbon taxation in the CGE framework. Other related studies include those by Burniaux et al. (1992), Zhang (1998), and Hamilton and Cameron (1994). Bruvoll and Faehn (2006) show that after the introduction of a carbon tax, the costs on the economy will rise if the tax territory is changed from the global to the national level and, subsequently, environmental benefits will decline.

In a recent literature, Rausch et al. (2011) used a CGE model specifically designed for distributional effects to explore within-group equity impacts using various climate policy scenarios in the US economy. In the Australian context, Meng et al. (2013) used a modified CGE model based on an environmentally extended national Social Accounting Matrix (SAM) to determine that a A$23[6] per tonne carbon tax significantly reduced emissions and also slowed the economy. Using a revenue recycling scenario, they noted that a carbon tax plus a compensation policy would substantially help ease the negative effects of a carbon tax. In the Chinese context, Guo et al. (2014) note that a moderate carbon tax would reduce CO_2 emissions to a large extent but would slightly reduce economic growth.

Alternatively, studies show that command and control (CAC) methods, particularly emission standards are usually simple to be implemented under any situation and can be effective especially when a specific sector is targeted, although the costs of enforcing increase depending on the different sectors and sources of pollution involved (González-Eguino, 2011). Studies comparing the costs of economic instruments and CAC show that the former are more efficient in many circumstances but have significantly higher costs in terms of achieving

[6] Australian Dollar per tonne of carbon dioxide emissions.

environmental targets (Austin and Dinan, 2005; Goulder et al., 1999; Newell and Stavins, 2003; Parry and Williams, 1999). In comparing the two approaches within a comprehensive model covering different regions and pollution types, Tietenburg (2010) showed that using economic instruments reduces the costs of mitigation by about 40–95% compared with CAC. From the above literature, it can be concluded that market-based instruments seem to be more useful than CAC, if enforcement costs are not taken into account.

In the Malaysian context, Jaafar et al. (2010) concluded that carbon taxation in the form of an output tax for energy industries would reduce Malaysia's CO_2 emissions as well as GDP and trade performance. Nurdianto and Resosudarmo (2010) show that although a carbon tax helps to reduce CO_2 emissions it would also have negative macroeconomic impacts if not accompanied by a recycling mechanism. Moreover, Yahoo and Othman (2015) show that the negative impacts of economic instruments can be mitigated by channelling the revenue collected from environmental taxes to subsidise household purchases. Solaymani et al. (2015) assert that a carbon tax would not be beneficial for the Malaysia transportation sector as output and demand would be negatively affected.

Recently, Solaymani (2017) compared the impacts of two environmental tax policies, that is, carbon and equivalent energy taxes that took into account government revenue neutrality assumptions where revenues reverted to households through a lump sum transfer and a labour tax replacement. The author concluded that the carbon tax was more effective than the energy tax as the former resulted in an increase in household welfare. In addition, the author noted a linear relationship between the carbon tax and CO_2 reduction levels where a tax rate of $60 to $70 per ton of CO_2 would be needed to achieve a 40% reduction in carbon emissions from fuel combustion. Thus far, there has been little empirical evidence comparing the implementation of economic instruments and CAC[7] within a comprehensive model (covering detailed energy types and users) for Malaysia. This study addresses this by analysing the use of CAC (emission standards) and economic instruments (carbon tax with revenue recycling) in order to reduce CO_2 emissions from fuel combustion.

Regardless of the types of environmental instruments used, their impacts on the economy would be widespread. Reducing emissions entail transforming the production structure of industries, modifying wage and employment practices and, significantly, measuring the relative impact of fossil fuels. Generally, taxes on emissions can have both positive and negative effects. Ideally, they should reduce emissions while providing additional tax revenues to be allocated to address equity issues without upsetting the government's budgetary position.

A CAC policy on CO_2 emitting sectors can raise the production costs of other non-energy commodities as well as decrease real wages and incomes. Thus, this paper seeks to assess and compare how a carbon tax and CAC policy would contribute to lowering emissions in the Malaysian economy. It highlights equity impacts especially in relation to household utility. To achieve this objective, the model employs a single-country static Computable General Equilibrium (CGE) model together with an environment-based input-output table constructing data from the Malaysian Department of Statistics (2015) and other sources. The model applies explicit production substitution possibilities in renewable energy alternatives and for tax revenues thus garnered to be channeled towards improving household equity. To achieve this, the research questions applied are:

1. How would a carbon tax and petroleum subsidy removal (complemented with a compensation policy) differ from emission standards (and petroleum subsidy removal) on Malaysia's macroeconomic indices, sectoral outputs, prices, and household welfare?

2. Which instrument will generate greater structural changes in production technology towards employing more green energy sources in Malaysia?

This paper does not discuss emissions trading. The simulation results clarify the macroeconomic and environmental effects on Malaysia of any CO_2 emission abatement policy in the short run. The framework of the model and its database, policy scenarios, results and discussions of simulations, and concluding remarks are addressed in subsequent parts of the paper.

3. Methodology

Environmental policies indirectly impact economic variables such as economic growth, employment, and welfare. The complexity of the inter-linkages between these variables calls for economy-wide quantitative analysis in assessing the effectiveness of emission control policies. This study specifically extends and applies a detailed single-country, multiple-sector static CGE model of the Malaysian economy with special reference to energy and environment linkages. In addition, the study employs a Hicksian welfare criterion to establish the equity effects of shifts in tax revenues ensuing from any policy aimed at reducing carbon emissions.

3.1. The model and database

In the model used in this study it is assumed that emissions are linked directly to demand for the main energy sources within the economic core of the model.[8] Further, comparisons between the impacts of carbon tax and CAC are made in a uniform framework and the results appraised through a common macroeconomic environment. The model also includes the construction of a special module in analysing the use of greener energy inputs. While different emission reduction measures are designed to counteract any overestimation of the costs of mitigation, a detailed disaggregation of energy sectors in the extended model and database provides a more precise estimate of different impacts and costs of emission reduction policies. The model and database are used to perform a static economy-wide counterfactual analysis to compare the model simulations with and without alternative environmental policies, including a carbon tax scheme accompanied by compensating measures, and a CAC instrument in the form of emission standards. Moreover, in all model simulations, the subsidy for petroleum products is removed to reflect recent changes in Malaysia's energy policies. Appendix A shows the important variables, behavioral parameters, and the model equations corresponding to each block described in the following section.[9]

Basically, the model is structured along the one developed by Horridge (2006) for the Australian economy. Fig. B1 in supporting materials depicts the linkages between different institutions in the model of this paper. Production linkages in the benchmark-data use Malaysian input-output tables and further includes a representative household sector,[10] the government sector, foreign sector, different investment sectors, and changes to inventories together with the micro and macro-economic aspects, resource supplies, trade balances, and other market constraints.

[7] Based on the literature, environmental policies relate to two broad groups namely, economic or market-based instruments, such as a carbon tax and emissions trading and command-and-control means such as emission and performance standards. Then, one of the issues addressed by this study is to compare the impacts of these two instruments within a framework.

[8] A detailed sectoral CO_2 emission matrix is explicitly constructed and linked with the core economic part of the model.

[9] Appendix C in supporting materials presents the model description in more details and for other blocks.

[10] Although many of Malaysia's domestic economic policies focus on favouring the Bumiputra class of the total population, as depicted by Fig. B1, only one household sector is considered in this model since the revenue recycling scheme is through a uniform return to all households. Therefore, different household classifications in terms of various income classes (5-centile income group) or different ethnic groups (Bumiputra, Chinese, Indian and others) are not considered in this paper.

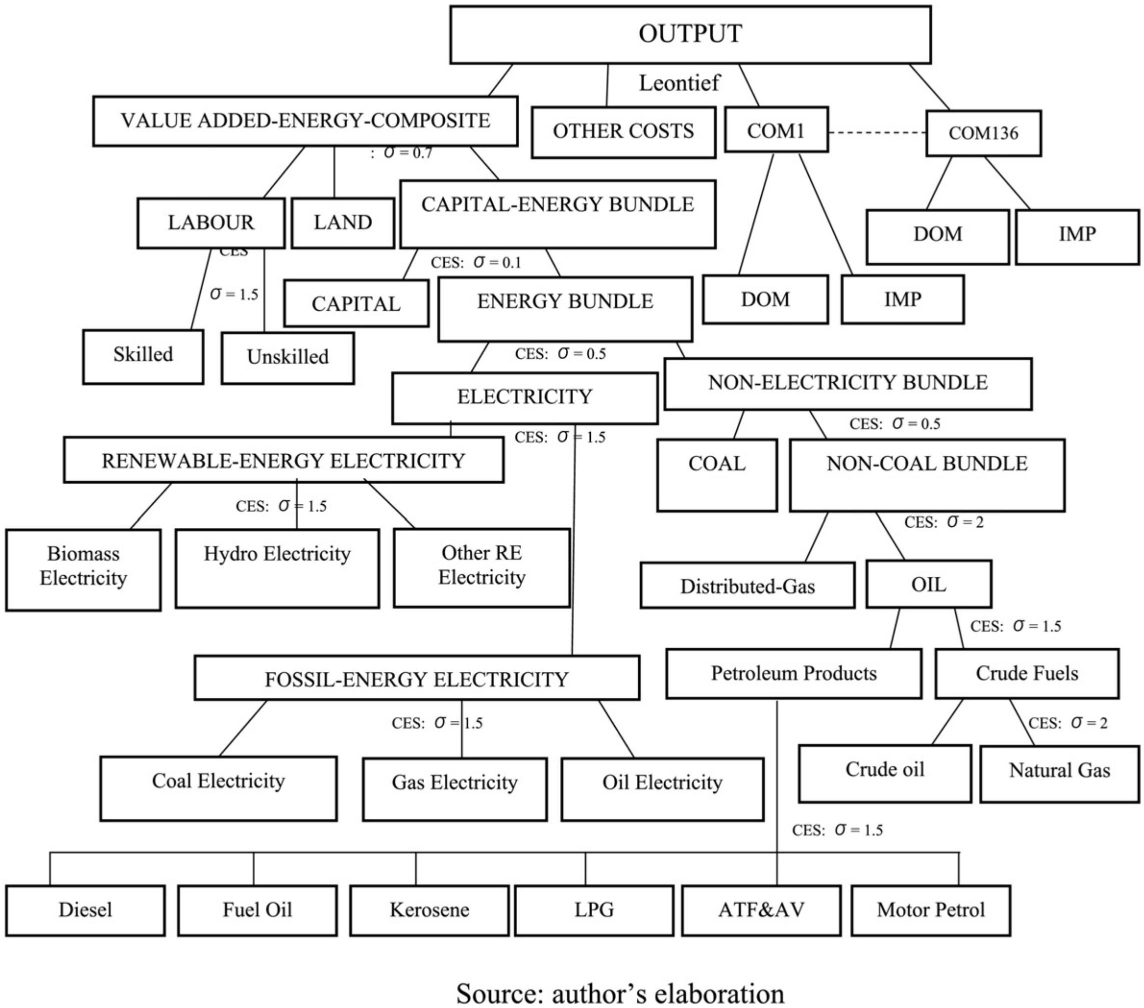

Fig. 3. Production nested (the values of key parameters used in the simulations are shown.
Source: author's elaboration.

To estimate the impacts of two policies more accurately, especially since Malaysia's Supply-Use tables (2015) combine the energy sectors comprising oil-natural gas, electricity-gas and petroleum refinery into one, the sectors were disaggregated using external data sources. Moreover, the decomposition of crude oil and natural gas, electricity, and the distributed gas is further indicated by including the sectoral data and shares obtained from the Department of Statistics (2015) and the national energy balance table from the Ministry of Energy Green Technology and Water (2010).[11]

Double-taxation is avoided by assuming that CO_2 is produced only by electricity generation and not its consumption. It is assumed that the technology for generating electricity is fuel-specific, for example, using oil for oil electricity generators. To cater to possible emissions reduction following the imposition of fossil fuel abatement policies, different substitutions will be allowed in the production structures of aggregated energy and capital, fossil and renewable-based ones, and between different energy commodities within each category. The parameters used in these simulations are shown in Fig. 3.

In the model, 131 industries and 136 commodities[12] (from 124 sectors in the original tables) represent the Malaysian economy. Energy and non-energy commodities flow between industries for use as intermediate commodities and are delivered to other demanders as final goods. Therefore, the model and its database include five types of margin commodities namely, four for transport and one for trade. The CO_2 emission module in the applied model is adapted from Adams et al. (2000) where emissions are linked to a production process that uses fossil fuels as intermediate goods and the final consumption of the household sector. It is noteworthy that the model and database only include CO_2 emissions from fossil-fuel combustion or burning, meaning that non-CO_2 emissions from fossil-fuel burning and CO_2 emissions from industrial processes, land-use change, or deforestation are excluded. Since data on CO_2 emissions based on detailed types of fossil fuels and sectors for Malaysia are not available and carbon taxes and emission standards are imposed based on the utilization of each fossil-fuel, a matrix of CO_2 emissions including different fuel types and users has been constructed in line with the objectives of this paper. The Tier 1[13] method as suggested in the IPCC (2006) Guidelines is used to estimate sectoral CO_2 emissions based on Malaysia's national energy balance data from the Ministry of Energy Green Technology, and Water (2010).

[11] Since the base year of the supply-use tables are 2010 and published by Department of Statistics Malaysia in 2015.

[12] In the disaggregated database, it is assumed that the petroleum refinery industry produces six petrochemical commodities.

[13] Since 1996, the Intergovernmental Panel on Climate Change (IPCC) has published a guide for estimating green-house gas inventories for reporting to the United Nations Framework Convention on Climate Change (UNFCCC). The panel has classified the methodological approaches in three different Tiers according to the quantity of information required, and the degree of analytical complexity.

As seen in Fig. 3, the production structure comprises an eight-layered utilization of CES (Constant Elasticity of Substitution) and Leontief functional form. Producers can substitute high carbon content fuels with low or non-carbon intensive ones as well as use different primary factors in their production mix. The CES function employs the Armington (1969)[14] assumption in combining domestic production and imports. For the supply side of the production equation, a CET (Constant Elasticity of Transformation) functional form is used showing options for producers in selecting either the domestic or foreign market depending on the price factor. Eqs. (1) and (14) respectively show the level equations for the Armington functions between domestically produced and imported goods on the demand side and between domestic consumption and export decisions on the supply side.

The optimal level of a carbon tax rate discussed in the literature, varies although Solaymani (2017) proposes an optimal carbon tax for Malaysia based on the linear relationship between tax rates and emissions reduction.[15] In this study, a CO_2 emission tax of MYR74[16] is considered in line with Marron and Toder (2014) who note that the mean social cost of carbon is about $25 per tonne of carbon dioxide, and that a lower tax should be imposed during the early stages of its implementation. The tax is levied on CO_2 levels emitted during the combustion of fuel for different uses. To ensure no double counting in the CO_2 tax base, crude oil used during the transformation process for producing petroleum products is exempted from the tax. This exemption also applies to electricity used when its production is subject to tax.

A short-run closure is assumed based on Horridge (2006). Moreover, from the income side, industrial capital stocks, land, and technical changes are fixed while aggregate employment (wage-bill weights) and indirect taxes are determined endogenously and can vary. These rules specify that this time period is inadequate to allow capital stocks to be installed or change and for technological improvements to occur. Labour movement among industries is assumed to be free while fixed real wages are deemed to be sticky and, as such, capital and labour markets are cleared by endogenous factor prices. Closure from the expenditure side is specified by treating total real investment expenditure, inventories, and government consumption as exogenous while the real trade balance and aggregate real household consumption are determined endogenously. As is assumed by most neoclassical models, relative prices are important and determining overall price levels require the introduction of a single exogenous price variable measured in local currency units. For this purpose, the numeraire of the model in all simulations is the consumer price index (CPI).

3.2. Policy scenarios

To highlight the contributions arising from the removal of the subsidy for petroleum products and the revenue-recycling components implemented within different simulations, the four scenarios were run as depicted by Table B2 in supporting materials. This study explored the contributions from the phasing out of the petroleum products subsidy based on the subsidy rationalization programme of the Ministry of Energy Green Technology and Water (2011), and that of the revenue-recycling component. In Scenario I the subsidy is removed and no carbon tax imposed, while under Scenario II the subsidy removal is complemented with a carbon tax and the revenue thus collected is not returned to the economy. Scenario III includes the carbon tax and subsidy removal coupled with a compensation plan, while Scenario IV simulates a command-and-control policy involving the introduction of emission standards. Both scenarios III and IV involve the complete removal of petroleum product subsidies. Finally, to enable a comparison between carbon tax and emission standards, the sectoral emission cuts in the carbon tax scenario (III) are used as sectoral standards/limits for each sector in Scenario IV.

Table 2
Results of key macroeconomic and environmental variables.[a]

Description/simulation	Scenario I	Scenario II	Scenario III	Scenario IV
Real GDP[b]	−1470.34	−4069.76	4975.31	−2807.87
Total carbon emissions[b]	−1.54	−13.01	−12.20	−12.20
Total carbon tax revenue[b]		11,626.44	11,818.41	
Compensating variation[b]	−1410.44	−3269.99	4994.52	−2027.42
Real GDP	−0.18	−0.4	0.60	−0.34
Total carbon emissions	−0.84	−7.14	−6.70	−6.70
Carbon intensity of GDP	−0.67	−6.68	−7.26	−6.38
Aggregate employment	−0.47	−1.10	1.54	−0.74
Import demand	−0.17	−0.61	0.24	−0.49
Exports supply	−0.13	−0.58	0.16	−0.49
Real exchange rate	−0.41	−1.01	0.91	−0.7
Household demand	−0.38	−0.89	1.35	−0.55
Primary factor costs	−1.10	−2.72	−0.14	−2.34
Domestic production	−0.42	−0.83	1.91	−0.41
Return to capital	−1.87	−5.06	−0.51	−4.41
Return to land	−0.84	−2.10	1.55	−1.50

Source: author's calculation.
[a] Except otherwise indicated, figures are percentage changes from base-run.
[b] Nominal change deviation from base-run: MYR (million) or Mt for carbon emissions.

4. Results and discussion

The main macroeconomic and total environmental impacts of each scenario are presented in Table 2.[17] It is clear that carbon emissions decrease under both policies (scenarios III and IV). The imposition of the carbon tax reduces total carbon emissions by 6.7% or about 12 million tonnes. The tax raises the cost of producing carbon intensive goods, and the ensuing decline in demand brings down emission levels. This reduction however would be offset by a household consumption compensation subsidy as it would restore demand for other goods and even for carbon intensive goods. The change in the carbon tax revenue variable shows that after refunding the revenues from the tax, the government nets about MYR12 billion. Since exogenous shocks to sectoral emission standards in Scenario IV are estimated based on the carbon tax in Scenario III (endogenous sectoral emissions deduction), the total level of emissions reduction is equal between the two scenarios.

Simulation results show that in regard to CO_2 emissions reduction, general economic indicators change only marginally as also shown by Meng et al. (2013) in the carbon tax experiment for Australia and in local studies such as by Solaymani et al. (2015) and Solaymani (2017). A carbon tax and compensation plan results in a 0.6% increase in real GDP as it generates higher demand for all commodities resulting from the compensation policy which stimulates domestic consumption and investment (Bor and Huang, 2010). Further, since the revenue recycling is accompanied by a complete removal of the petroleum subsidy, empirical evidence shows that the economy reacts through a higher incentive for investment (Morgan, 2007; Solaymani and Kari, 2014). Under the emission standards (scenario IV), real GDP decreases by about 0.35%

[14] In the general equilibrium literature, substitution elasticities between locally produced and imported sources of the same commodity are referred to Armington (1969) elasticities. Based on this, domestic and imported commodities are imperfect substitutes. Therefore, the outcome commodity from CES function and Armington assumptions will be a homogeneous Armington commodity.

[15] It should be noted that the estimated optimal carbon tax rate differs based on the assumptions used in the model and the emission's values in the base-run, and database itself that are used for calibration in the carbon tax literature. In terms of Malaysia, the estimated carbon tax rates in Solaymani (2017) for 5, 10, 15 and 20% deduction in CO_2 emissions differs from corresponding values estimated in Solaymani et al. (2015) while the benchmark database refers to the 2005 SAM tables for Malaysia in both studies. This highlights the importance of model assumptions and the database.

[16] Since the sectoral CO_2 emission data by fuel and by 132 users (131 producers plus one representative household) is added to the database and modelled explicitly, the MYR74 tax rate is imposed per ton of CO_2 emissions, which is close to Malaysia's optimal carbon tax in the literature.

[17] To address the main issue of the paper, although the results for four scenarios are presented, the discussion focuses on the results of the carbon tax and subsidy removal plus compensation and CAC scenarios (scenarios III and IV, respectively).

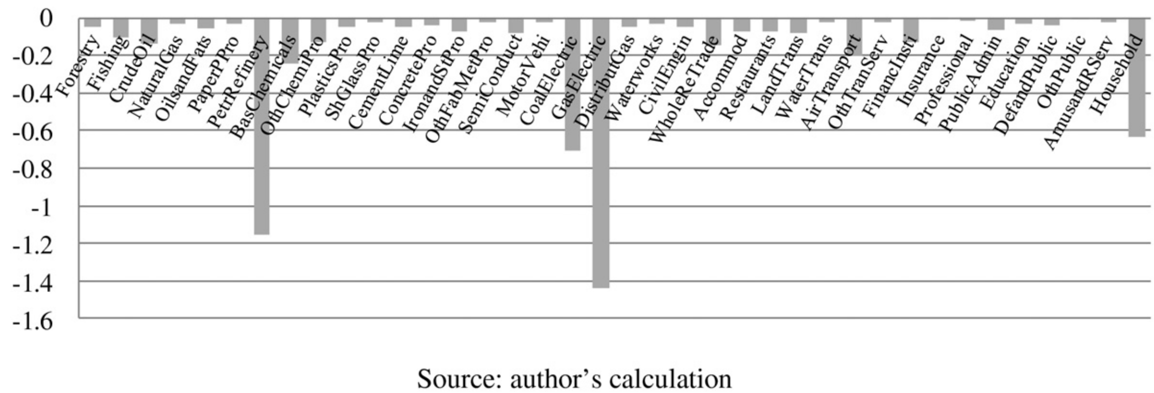

Fig. 4. Sectoral carbon emission reduction (% changes from base-run; since sectoral emission cuts in the carbon tax scenario are used as the standard in the second scenario, this figure shows an equal percentage point decline in emissions).
Source: author's calculation.

due to economic distortions. Closer observation shows that carbon dioxide emission policies would reduce the CO_2 emission intensity of GDP by about 7.26% and 6.38% under the scenarios III and IV, respectively.[18] It is worth mentioning that in terms of absolute changes in real GDP and total emissions, the larger reduction in this ratio as depicted by the carbon tax scenario is mainly primarily because the real GDP growth resulted from the compensation plan, since total emissions cut is equal across both scenarios. In other words, when the carbon tax plus revenue recycling scheme raises real GDP caused by higher household demand, and export and import levels (as confirmed by local studies such as Solaymani (2017)), in terms of percentage change as per Eq. (22)[19], the GDP intensity of the real GDP measure decreases at a greater magnitude with a carbon tax rather than with a CAC policy (see Table 2, the results for Scenario III).

In terms of employment, the carbon tax policy with a complementary plan will reduce distortions in the labour market due to the rise in production stimulated by the higher demand from the revenue recycling. Accordingly, as the revenue collected is channeled back into the economic system, it stimulates production and generates employment, as also noted by Bor and Huang (2010). Simulated results also show that removing petroleum energy subsidies and imposing a carbon tax leads to different demand for other primary factors with capital decreasing only marginally while the demand for land increases when revenues are recycled. Under an emissions standard policy, the demand for these factors decreases but at a higher rate since it forces producers to cut back on production (Dissou, 2005).

Under the carbon tax and subsidy removal scenario, the CV index shows that welfare is enhanced as household purchases are subsidized by revenues from a carbon tax. This is in line with local studies such as Solaymani et al. (2015). Households would be willing to pay up to MYR4.9 billion for the benefits of a carbon tax and energy subsidy removal policy that is accompanied by a consumption subsidy plan. Alternatively, welfare decreases following the imposition of emission standards due to reduced energy commodity production and the output for other commodities using energy as an intermediate input. The change of welfare in scenario IV shows that a minimum of MYR2 billion is needed to compensate households for the negative impacts of an emissions standard policy that is complemented with the petroleum products subsidy removal.

To evaluate the impacts of any policy, percentage changes in trade indices are important features for the demand side of a macro economy. As Table 2 shows, both exports and imports declined following the imposition of emission standards. For imports, the imposition of the industrial emissions standard results in a decline in demand for imported energy in tandem with a decline in their output. On the export side, the decline is due mainly to the reduction in industrial production as domestic demand for intermediate inputs decline (Solaymani et al., 2015). These results show the price changes affecting export-oriented industries after the introduction of emission abatement policies. In other words, imposing such a policy on CO_2-emission-intensive sectors will increase output prices in Malaysia. As mentioned, the imposition of emission standards will see a decline in the aggregate level of imports under the CAC scenario while under a carbon tax coupled with a compensation plan, it increases. Alternatively, the compensation scenario increases the purchasing power and consumption of imported commodities by Malaysian households resulting in higher imports (Solaymani et al., 2015). On the export side, when sectoral production increases due to the rise in demand for commodities, the supply of outputs to both domestic and foreign markets will accordingly increase (applied CET functional form for total supply in the model). As such, the export index (FOB-weighted-average) shows a positive percentage change. The impact on external trade from the carbon tax, subsidy removal, and revenue returning policy (Scenario III) leads to an increase in Malaysia's real exchange rate and total export and imports. These finding are also consistent with the studies on Malaysia such as by Solaymani (2017) and international studies such as Cabalu et al. (2015).

Fig. 4 shows the reduction in carbon emissions in various sectors resulted under scenario III and IV. As shown, fossil-fuel electricity generators, the petroleum refinery industry, the transport sector, and the chemical industry contribute significantly to CO_2 emission reduction efforts. The analysis of results across different types of fuels confirms the contribution of each fuel in Malaysia's electricity generation energy mix where gas has the highest share followed by coal and petroleum products (Ministry of Energy Green Technology and Water, 2010).

The relatively high reduction in CO_2 emissions by the petroleum refinery industry is also due to the decrease in its output (petroleum products) arising from the simultaneous effects of the subsidy removal and carbon tax policy. The contributions of the service-based and agricultural industries are proportionately small while that for other sectors such as renewable energy is zero. As discussed and as seen clearly in Fig. 4, emission levels decrease following the implementation of either a carbon tax with a revenue recycling plan and the emissions standard programme.

In addition to the impacts on macroeconomic variables, micro factors on output levels are also significant for many industries. Table 3 shows the percentage change in industrial outputs under scenarios III and IV where, among others, the energy sectors such as coal production, electricity generation, and the petroleum refinery industry are affected

[18] Eq. (22) in Appendix A shows the formula for calculating the total carbon emission intensity of GDP.

[19] In percentage form, Eq. (A22) becomes $co_2overgdp = co_2tot - gdp\exp$, where small letters show the corresponding variables in percentage forms transformed from the depicted variable levels.

Table 3
Percentage change in output by selected industries.

Industry	Carbon tax plus compensation (MYR 74 per tonne CO_2)	Emission standards
Forestry	−0.35	−1.07
Fishing	−1.34	−2.29
Crude oil	−0.02	−0.14
Natural gas	−0.02	−0.14
Metal mining	−0.12	−0.53
Stone clay	−0.16	−0.53
Coal	−8.3	−8.48
Sawmilling and wood	−0.13	−0.87
Petroleum refinery	−1.31	−1.39
Basic chemicals	−0.57	−0.88
Rubber gloves	−1.38	−1.86
Iron and steel prod	−0.11	−0.61
Basic precious	−0.09	−0.51
Coal-electricity	−1.13	−1.27
Oil-electricity	0.39	0.29
Gas-electricity	−1.32	−1.4
Renewable-electricity	1.02	0.85
Distributed gas	−0.27	−0.37
Water transport	−0.34	−0.82
Air transport	−2.95	−3.51
Banks	1.16	−0.51
Financial institutions	0.09	−0.53
Other private services	0.42	−0.33

Source: author's calculation.

Table 4
Percentage changes in commodity prices.

Commodity	Carbon tax plus compensation (MYR 74 per tonne CO_2)	Emission standards
Natural gas	9.09	6.58
Coal	39.98	37.64
Motor petrol	14.11	11.39
Diesel	16.86	14.20
Fuel oil	23.24	20.72
LPG	17.97	15.34
Kerosene	24.80	22.32
ATF&AV gas	15.93	13.26
Coal-electricity	14.58	11.83
Oil-electricity	12.40	9.63
Gas-electricity	13.82	11.14
Renewable-electricity	11.15	8.50
Distributed gas	48.20	46.55
Land transport	4.45	1.31

Source: author's calculation.

much more compared to others. Further, in terms of non-energy but energy-intensive sectors the rubber, chemicals, and transport sectors suffer substantial declines in output.

A comparison between the two policies reveals that under emissions standards, output reductions are more pronounced relative to a carbon tax. In terms of production of renewable energies, a carbon tax is more effective than imposing emission standards, as confirmed by Dissou (2005) and Wissema and Dellink (2007). This is mainly due to the better targeting for CO_2 emissions under the tax scenario. As expected, coal, gas, and coal-based electricity generators are most affected by a carbon tax. Interestingly, the oil-electricity sector would see an increase in output following imposition of emission reduction measures, due to the substitution effect. When coal- and gas-based electricity producers reduce output substantially, the oil-based electricity sector will step in to meet market demand. This corroborates Meng et al. (2013) who noted that the introduction of a carbon tax in Australia led to an increase in the output of its oil-based electricity sector. Therefore, positive output changes are experienced by the renewable-based and oil-generated electricity sectors.

The simulation results show that the output from natural gas industry decreases marginally. The sectoral output reduction effect reveals that high energy intensive sectors such as iron and steel, and manufacturing experience higher output reduction especially under the emissions standard scenario. The channelling of carbon tax revenues to households through a consumption subsidy increases the output of service-based industries since the demand for their products is enhanced by the higher purchasing power of households. These findings are consistent with Solaymani (2017) in which revenues from a carbon tax were returned to households in the form of a lump-sum transfer or lower labour tax rates.

Regarding the chosen energy commodities, the relative percentage changes in prices are shown in Table 4. The rise in energy commodity prices is in line with the emission intensity of commodities. The higher increase arising from the carbon tax plus compensation scenario is due to the price induced mechanisms of the tax policy. Across different fuels, coal and distributed gas experienced higher increases. In the former it is due to the high emission intensity of coal energy while in the latter it is caused by the high emission levels from this energy in Malaysia's energy mix, as highlighted in the database of the model.[20] The increase in the prices of petroleum products is also consistent with their emission intensity and is proportional to the consumption of these fuels in the model's database.

Fig. B3 in supporting materials shows the percentage change in demand for energy and non-energy commodities from the carbon tax and the phasing-out of petroleum subsidies when the revenues are recycled. As shown, the demand for energy commodities is affected negatively except that for renewable and oil-based electricity and crude oil energies. The reduced demand for energy commodities is due to the increase in the price of fossil-fuels following the introduction of emission abatement policies (see Table 4). However, the increase in demand for renewable and oil-based electricity is due to the substitution effect. The reason for an increase in demand for crude oil is that this fuel is exempted from the CO_2 tax due to the double-accounting concerns. The figure for non-energy and, specifically, service-based commodities shows that demand increased. This is due to the recycling of carbon tax revenues to households which increases demand for services such as education and health and for agricultural products.

In general, under revenue-neutrality assumptions, a carbon tax is more efficient and offers a dual bonus if the tax revenue is applied as a consumption subsidy, assuming enforcement costs are excluded from the analysis. This double dividend is confirmed as changes in the tax structure improve welfare and reduce CO_2 emissions. The study also found that renewable energy will be increasingly used under a carbon tax policy than a CAC programme. It is noteworthy that the simulation results from Scenario IV show that the marginal abatement costs (MAC) in reaching similar CO_2 emission reduction levels from such a policy is relatively higher (about MYR76 per tonne CO_2) due to the higher distortionary effects of a CAC policy. This outcome is confirmed in the literature by Dissou (2005).

Finally, a sensitivity test on behavioral and elasticity parameters reveals a correlation between the values for two elasticities (elasticity of substitution between composited energy and capital, and between renewable-based and fossil-based electricity) and the macroeconomic variables. Table B4 in supporting materials presents the results of four extra simulations aimed at testing the robustness of outcomes presented in this section. They take into account the medium and high cases, first for the value of the elasticity of substitution between the capital and energy bundle and second for imposing medium and high CO_2 tax rates. Interestingly, when higher values are chosen for these two elasticities, the switch from fossil to greener fuels or from energy to capital is more easily accomplished; subsequently, there is a larger decrease in CO_2 emissions, and GDP is affected moderately (columns 2 and 3 in

[20] The constructed CO_2 emission matrix is consistent with the sectoral CO_2 data in the GTAP database developed by Narayanan et al. (2015).

Table B4). Further, as depicted in Table B4 (columns 4 and 5), applying higher levels of CO_2 taxes lead to an increase in the magnitude of reduction in emission and increases the values for other macroeconomic variables.

5. Conclusion and policy implications

Efforts aimed at reducing CO_2 emissions are receiving much attention globally including in Malaysia making it important to quantitatively study the economy-wide repercussions of environmental policies. In Malaysia, the unsustainable use of natural resources, energy security, and the degradation of air quality are issues are being actively addressed by the government. Higher energy consumption especially of fossil-fuels is a major factor contributing to various greenhouse gas emissions that have led to biodiversity loss and climate change. As such, energy policies have to ensure that economic growth and energy security need not to be at the expense of environmental quality. Government policies in this regard will impact the economic parameters among energy sub-sectors specifically, the business community, and the nation's overall trade and economic outlook. This study establishes that the CGE model is a suitable instrument for analysing the impacts of different CO_2 emission abatement policies on the abovementioned sectors. Its findings will contribute to efforts aimed at addressing issues such as environmental pollution from CO_2 emissions and natural resource degradation as well as the depletion of fossil fuels such as crude oil and natural gas.

To make informed decisions, environmental policy makers need to be aware of the various implications on the environment of the measures and policies they intend to implement. As noted in this study, CGE modelling allows for appropriate assessments that take into account macroeconomic, welfare, environmental, and sectoral aspects in examining alternative environmental instruments aimed at checking CO_2 emission levels in Malaysia. Specifically, this study employed a 131-industry, 136-commodity CGE model based on Malaysia's latest Supply-Use tables (2015) for that purpose. The extended input-output table shows the impact on CO_2 emissions of fuel consumption. Two major scenarios were analyzed. One studied the impact of a MYR74 carbon tax with the revenues derived rechanneled to the system through a household consumption subsidy on other commodities while the second analyzed a CAC on emission standards. Since the original input-output tables included the subsidy for petroleum products used in the transportation sector, the constructed database also took them into consideration. However, to simulate the real situation in Malaysia where fuel subsidies for transportation were fully removed, both scenarios involve the removal of subsidies for petroleum products and are complemented by CO_2 abatement policies.

The scenarios studied produced the following conclusions. First, compared to the percentage reduction in CO_2 emissions the downside impact of imposing a carbon tax and CAC policies would be fairly small. Secondly, in relation to efforts at reducing CO_2 emissions, fuel switching poses a major challenge and is extremely effective in meeting emission reduction targets and preventing an underestimation of the costs of mitigation. In other words, this approach allows producers to make the transition towards more efficient energy or other non-energy intensive goods or other primary factors, thus reducing the equity impacts of any CO_2 emission abatement policies in the Malaysian economy. Thirdly, introducing both the carbon tax and CAC polices would lead to a change in relative prices and consumption patterns as the demand for high carbon emission intensity fuels will decrease and also result in a switch from energy consumption to other commodities. Fourthly, there would be greater incentives for making structural changes towards using renewable energy in a carbon tax plus revenue recycling scenario. Fifthly, a double dividend is achieved when carbon tax revenues are applied towards consumption subsidies for the household sector as welfare is enhanced while carbon emissions decrease. Sixthly, the findings highlight the importance of having a compensation plan in addition to other policies and emission reduction measures. This is achieved by redistributing the carbon tax revenues through the household consumption subsidy to ease the negative economic consequences of the tax and enhance the environment in addition to assisting households and heavy energy-dependent industries. Finally, the general equilibrium quantification of alternative policy instruments on the direction and order of changes in the endogenous variables sheds light on facilitating objective decision-making by environmental and macro policy makers in Malaysia.

In conclusion, the findings provide important insights for Malaysian policy makers seeking to address emission issues in a comprehensive manner. Implementing an environmental instrument does not necessarily have negative effects on the macroeconomic position of the country and the actual outcome of each policy depends mainly on the choice of appropriate complementary measures. As this study shows, of the various environmental instruments available, the carbon reduction approach through a carbon tax would be most cost-effective in increasing the cost of consuming emission-intensive goods. The positive macroeconomic and welfare effects of environmental policies such as a CO_2 tax have important implications for Malaysian policy makers as they contribute to the reallocation of economic resources in the country. The substitution of energy inputs with primary factors such as capital and labour results in factor mobility and their more efficient use while household welfare increases. The findings note that the 40% emission intensity of GDP target in Malaysia can be met by introducing a high CO_2 tax rate although overall results will depend on the effectiveness and efficiency of interrelated instruments. Based on this study's findings and in line with the experience of other countries, it is recommended that Malaysia's emission abatement policies begin with the imposition of low levels of CO_2 emission taxes as their negative macroeconomic impacts have been shown to be minimal.

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Appendix A. Supplementary data

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