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The impacts of climate change policies on the transportation sector

Saeed Solaymani [a,*], Roozbeh Kardooni [b,**], Sumiani Binti Yusoff [c], Fatimah Kari [d]

[a] Department of Economics, Faculty of Social Science, Razi University, Kermanshah, Iran
[b] Institute of Graduate Studies, University of Malaya, 50603 Kuala Lumpur, Malaysia
[c] Department of Civil Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[d] Department of Economics, Faculty of Economics and Administration, University of Malaya, 50603 Kuala Lumpur, Malaysia

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ABSTRACT

This study examines the impact of carbon tax and its alternative, energy tax, on both the Malaysian economy and the transport sector, using a CGE (Computable General Equilibrium) framework. In order to achieve government revenue neutrality, two schemes for revenue recycling, namely lump-sum transfer and labour tax recycling, are employed. The simulation's results show that the carbon tax policy is more effective than the energy tax policy in reducing carbon emissions; because it is less expensive. The negative impact of the carbon tax, on real GDP (Gross Domestic Product) and investment, is less than the energy tax in both recycling schemes. Through lump-sum transfer, both taxes lead to an increase in the consumption and welfare of households, because the tax interaction effect is less than the tax recycling effect; however, through labour tax recycling, they decrease the consumption and welfare of all household groups. These tax policies are not beneficial for the transportation sector, because they lead to decreases in domestic output, domestic demand, exports and imports of all transport sectors. The climate change policies would lead to mitigation of rebound effect in whole of the economy and the transport sector.

1. Introduction

The primary concern of the consumption of fossil fuels is its environmental impact; especially the emission of carbon dioxide. As a developing country, to maintain economic growth, Malaysia is still very much dependent on fossil fuels; mainly natural gas, coal, and oil, for its commercial energy demands and electricity generation. The total final energy demand in Malaysia in 2012 was estimated at 46.7 mtoe (million tonnes of oil equivalent); which is a 732% increase on that of the year 1980 (6.49 mtoe). According to the ITF (International Transport Forum), Malaysia is one of the top 10 CO_2 emitting non-ITF economies. North America and the top-ten CO_2-emitting non-ITF/OECD countries, namely Brazil, China (including Hong Kong), Islamic Republic of Iran, Indonesia, Kazakhstan, Malaysia, South Africa, Saudi Arabia, Chinese Taipei, and Thailand, dominate representing 55% of world emissions [26]. With an increase in energy demand to sustain the country's growth, it is inevitable that CO_2 emissions will continue to climb; as long as fossil fuels remain the main contributor in the energy mix. In 2009, the total CO_2 emissions from fuel combustion in Malaysia was 164.2 Mtc (million tonnes), of which the electricity and heat production sectors, with 68.2 Mtc, was the main CO_2 pollutant, followed by the transport sector with 41.2 Mtc, and manufacturing with 32.9 Mtc [25].

The main energy users in the transportation sector are motor vehicles [3]. In 2010, according to the Malaysia Environmental Quality Report, 95% CO, 29% NO_2, 17% PM (Particulate Matter), 8% SO_2, and significant quantities of hydrocarbons (VOC), were emitted by the transport sector [16]. Although passenger cars are the major contributors of CO_2, N_2O, and CO pollution emissions, motorcycles are the main source of HC (hydrocarbon) emissions [43]. Further results indicate that a CO_2 emission of 71% of the total CO_2 equivalent is the primary source of greenhouse gas pollution. In light of these statistics, the transport sector is the primary source (or the precursor) of air pollution in Malaysia.

By decomposing several indicators of the 1980–2005 period, Timilsina and Shrestha [61] found that the main factors for increased CO_2 emissions in the transport sector of Malaysia, and other Asian countries, are per capita gross domestic product,

* Corresponding author. Tel.: +98 9183871538 (mobile).
** Corresponding author. Tel.: +60 102440381 (mobile).
E-mail addresses: saeedsolaymani@gmail.com (S. Solaymani), r.kardooni@gmail.com (R. Kardooni).

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transportation energy intensity and population growth. In contrast, Wee et al. [67] showed that Malaysia as a developing county needs the most important development plans with minimum energy consumption and CO_2 emission to achieve its development targets. Therefore, in this country, reducing CO_2 emissions by reducing per capita activity is not feasible. However, reducing CO_2 emissions is possible by reducing energy intensity and carbon intensity. This finding was supported by Ong et al. [42], who analysed the trends of energy patterns and emissions from road transport in Malaysia, and Al-Mofleh et al. [3], who analysed the factors influencing the pattern and emission level of energy consumption in the Malaysian transport sector.

The analytical findings of the aforementioned studies show that adopting suitable energy policies is necessary to decrease energy demand and emissions. Furthermore, Almselati et al. [4], using an analytical approach, concluded that a shift towards public transportation can reduce CO_2 emissions through a decrease in fuel consumption. However, this is not possible unless the quality of public transport improves. Although Almselati et al. [4] studied GHG (greenhouse gas) emissions in the Malaysian transport sector, they failed to address the effects of policy instrument on the reduction of carbon emissions. From the above literature, it can be concluded that, not only is the adoption of suitable energy policies necessary for reducing carbon emissions, but efficient public transport is essential.

Empirical studies on climate change policies have shown that a carbon tax can help the environment by reducing emissions from GHGs, all be it with an initial negative impact on economic growth [6,11,14,36]. Studies on the Malaysian economy regarding this policy instrument showed that a carbon tax is effective in reducing carbon emissions. Nurdianto and Resosudarmo [41] explored the impact of coordinated and non-coordinated carbon tax policies on the economy and the environmental performance of each ASEAN country. The findings for Malaysia showed that, in the symmetric carbon tax policies, the level of carbon emissions decreased and these policies had negative effects on real GDP (Gross Domestic Product), household income, and sectoral output. However, the effects of the asymmetric carbon tax policies on carbon emissions were positive; but on other economic indicators were negative.

In the international literature, many studies have investigated emissions from the transport sector such as [22,46,70]. Michaelis and Davidson [39] argued that, due to the high pollution of CO_2 from this sector, the first priority is the energy intensity (energy use per passenger km or tonne km) reductions, and the renewable energy sources can reduce GHG emissions per unit of energy. In contrast, Creutzig et al. [15] concluded that standards and regulations regarding low carbon fuel emissions are more effective than renewable fuel standards in controlling the amount of greenhouse gases from transportation fuels. These studies concluded that policies that lead to a decrease in the consumption of energy in the transport sector are more effective than using renewable energy sources to reduce GHG emissions.

Almselati et al. [4] mentioned that in order to reduce CO_2 emissions, it is suitable to expand public transport and improve the quality of vehicles. Under the VIBAT London study, Hickman et al. [23] found that the techno-optimist user role is only likely to achieve reductions of 6.2% in CO_2 reduction relative to the business as usual scenario in 2025.

Pongthanaisawan and Sorapipatana [47] developed an econometric model based on two mitigation scenarios, namely fuel switching and energy efficiency options, to investigate the prospective trends of energy demands and GHG emissions in the Thai transport sector. They found that the fuel-switching option could significantly reduce the amount of GHG emissions in a relatively short period; whereas, the energy efficiency option was more effective for reducing GHG emissions in the long-term.

Van Dender [63] suggested that the high levels of fuel taxes, used to create conditions for low-carbon emissions in private road transport, are no more effective than a stable environment program for investment, research, and development. Similarly, Yan and Crookes [69] showed that private vehicle control, fuel economy regulation, and fuel tax, were the most effective instruments at reducing total energy demand, petroleum demand, and greenhouse gas emissions in China's road transport during the 2000–2005 period. However, the promotion of diesel and gas and biofuel promotion measures was not effective. That said, the biofuel promotion measure was more effective in reducing petroleum demand than total energy demand.

By employing an econometric method, Kim et al. [30] showed that a carbon tax on gasoline is an effective policy to reduce GHG emissions in the Korean transport sector, and that it is cost-effective. In short, an effective plan to reduce GHG emissions is the implementation of both renewable or environmental programs, and carbon or energy tax policies. Relevant studies in the transport sector that employed a CGE (Computable General Equilibrium) model to analyse CO_2 emissions and GHGs (Greenhouse Gases), showed that in countries with pre-existing taxes, such as the US and Europe, exemption of transport from a carbon tax increases the level of carbon emissions and the welfare of households [1,2,45].

Similar to Yan and Crookes [69], He et al. [21] showed that fuel economy was useful in reducing energy consumption and CO_2 emissions in China's road transport sector. Their findings indicated that China requires an immediate improvement of vehicle quality, in order to decrease the high consumption of oil and CO_2 emissions in transport.

The above CGE studies investigated the policy instruments for a specific area within the transport sector. They concluded that environmental and carbon tax policies are required for the effective reduction of GHG emissions in the transport sector. These findings emphasise the importance of analysing the effects of climate change policies, such as carbon and energy tax policies in all transport sectors.

The Malaysian government is committed to carbon emissions reduction according to the Copenhagen agreement. It wants to achieve a 40% carbon intensity reduction by 2020, compared to 2005. One of the proposed measures is carbon taxation. Carbon taxation will have a significant impact on all economic sectors; especially the transport sector.

The contribution of this study, in comparison to previous studies in Malaysia, is that it employs a CGE framework and analyses the impact of climate change policies on the transport sector. In the context of carbon emissions, studying the transport sector is essential; given that in Malaysia, 68.2% of air pollution is attributable to the transport sector, compared to 29.5% from stationary sources (i.e., industries, including power plants) [17]. In addition, the transport sector is also the main energy user in Malaysia. In 2010, it used over 40% of total final energy, and over 60% of petroleum products [40]. This paper, using a CGE (Computable General Equilibrium) framework, attempts to explore the impact of the carbon tax policy, compared to an energy tax policy, on the Malaysian economy, welfare, and emissions, and on the main Malaysian transport sector indicators, such as output, value added, employment, household consumption, and demand for fossil fuels. This study also aims to answer to this question that how climate change policies affect rebound effect in transport sectors. Computable general equilibrium models assist in tracing the effects of these policies on a specific sector. In this study, the transportation sector includes four sub-sectors, namely land, water, air, and other transport.

2. Materials and method

2.1. Model specification

This study uses a CGE (Computable General Equilibrium) framework to investigate the impact of climate change policy on the Malaysian economy and the transportation sector. The basic model of this study was adapted from Solaymani and Kari [54], with extensions from other studies, such as Solaymani et al. [52], Hausner [20] and Kim [29]. The model includes 22 sectors, namely Agriculture, Forestry and logging, Crude oil, Natural gas, Mining, Food processing, Textiles, Petroleum refinery, Chemical products, Cement, Iron and Steel products, Manufacturing, Electricity, Gas, Trade works, Four transport sectors, Communications, Financial institutions, and Other services. The transport sector includes Land, Water, Air, and Other transport sub-sectors.

Production function takes a CES (Constant Elasticity of Substitution) form of value added, *VA*, and intermediate inputs, *IN*. The value added also takes a *CES* form and is a function of three primary inputs, namely rural and urban workers, and capital.

$$X_i = \alpha_i^x \cdot \left[\beta_i^x \cdot IN_i^{-\rho_i^x} + (1-\beta_i^x)\cdot VA_i^{-\rho_i^x}\right]^{-\frac{1}{\rho_i^x}} \tag{1}$$

$$VA_i = \alpha_i^v \cdot \left[\sum_f \beta_{i,f}^v \cdot FDSC_{if}^{-\rho_i^v}\right]^{-\frac{1}{\rho_i^v}} \tag{2}$$

where, $\propto_i^x$ and $\propto_i^v$ are shift parameters of the production function and the value added function, respectively. $FDSC_{\text{if}}$ denotes the employment of factor *f* (capital, rural and urban labour) in sector *i*., and β_i^x and β_{if}^v denote the share parameters of the production function and the value added function, respectively. The first order condition for profit maximisation is as follows:

$$\frac{IN_i}{VA_i} = \left(\frac{PV_i}{PN_i}\cdot\frac{\beta_i^x}{(1-\beta_i^x)}\right)^{\frac{1}{1+\rho_i^x}} \tag{3}$$

PN and *PV* denote prices of intermediate inputs and value added, respectively. The factors' demand function shows the marginal cost of each factor (defined on the left-hand side), which is equal to the marginal revenue product (net of intermediate input costs) of the factor:

$$\frac{FDSC_{i,f}}{VA_i} = \left(\frac{\beta_{if}^v \cdot PV_i}{\left(\alpha_i^v\right)^{\rho_i^v}\cdot WF_i \cdot wfdist_{i,f}}\right)^{\frac{1}{1+\rho_i^v}} \tag{4}$$

where, WF_i is the price of factor *f*. $wfdist_{if}$ is the wage distortion factor for factor *f* in sector *i*. The material aggregate, *MTAG*, is a *CES* (Constant Elasticity of Substitution) function of energy, *EN*, and non-energy, *NEN*, aggregates [27].

$$MTAG_j = \alpha_j^{mt}\cdot\left[\delta_j^{mt}\cdot NEN_j^{-\rho_j^{mt}} + \left(1-\delta_j^{mt}\right)\cdot EN_j^{-\rho_j^{mt}}\right]^{-\frac{1}{\rho_j^{mt}}} \tag{5}$$

The production function of energy is a *CES* function of all energy inputs as follows:

$$EN_j = \alpha_j^{en}\cdot\left[\sum_{e1}\delta_{e1,j}^{en}\cdot EDEM_{e1,j}^{-\rho_j^{en}}\right]^{-\frac{1}{\rho_j^{en}}},\quad e1\subset i \tag{6}$$

where, $EDEM_{e1,j}$ is demand for energy carrier $e1$ in sector j; ρ_i^{en} denotes the substitution parameter in the energy mix function; α_i^{en} denotes the transforming coefficient in sector i; and $\delta_{e1\cdot i}^{en}$ denotes the share of energy type $e1$ in sector i; $\sum_{e1}\delta_{e1\cdot j}^{en} = 1$.

Meanwhile, the production of non-energy is a function of transport, *TRANS*, and non-transport, *NTRANS*, intermediate inputs [54].

$$NEN_j = \alpha_j^{nen}\cdot\left[\delta_j^{nen}\cdot TRANS_j^{-\rho_j^{nen}} + \left(1-\delta_j^{nen}\right)\cdot NTRANS_j^{-\rho_j^{nen}}\right]^{-\frac{1}{\rho_j^{nen}}} \tag{7}$$

where, α_j^{nen} and δ_j^{nen} denote the shift and share parameters of the non-energy function, respectively. ρ_j^{nen} denotes the elasticity of substitution between transport and non-transport intermediate inputs in the energy function. The demand for transport is derived from minimising the costs of using non-intermediate inputs, subject to the *CES* function of Equation (5), i.e.,

$$TRANS_j = NEN_j\cdot\left[\left(\alpha_j^{nen}\right)^{-\rho_j^{nen}}\cdot\delta_j^{nen}\cdot\left(\frac{P_j^{nen}}{P_j^{trans}}\right)\right]^{\frac{1}{\left(1+\rho_j^{nen}\right)}} \tag{8}$$

As in many *CGE* models, the model is consistent with the *Armington* function (Eq. (9)), which shows the substitution of imported products and domestically produced products, and the *CET* (Constant Elasticity of Transformation) function (Eq. (11)), which is used to allocate domestic products between domestic consumption and exports:

$$Q_{im} = \alpha_{im}^c\cdot\left[\beta_{im}^c\cdot M_{im}^{-\rho_{im}^c} + (1-\beta_{im}^c)\cdot D_{im}^{\rho_{im}^c}\right]^{-\frac{1}{\rho_{im}^c}},\quad im\subset i \tag{9}$$

where, Q_{im} denotes the aggregate demand for imported commodities in sector *im*; M_{im} denotes the total of imported commodities by importer sector *im*; D_{im} denotes the domestic sales of the imported commodities by sector *im*; α_{im}^c denotes the transforming coefficient; β_{im}^c denotes the share coefficient; and ρ_{im}^c denotes the substitution parameter. Import demand (Eq. (10)) is a function of the domestic good's price to import price ratio, the elasticity of substitution, and the *CES* share parameter.

$$M_{im} = D_{im}\cdot\left[\frac{PD_{im}}{PM_{im}}\cdot\frac{\beta_{im}^c}{(1-\beta_{im}^c)}\right]^{\frac{1}{\left(1+\rho_{im}^c\right)}} \tag{10}$$

$$X_{ie} = \alpha_{ie}^t\cdot\left[\beta_{ie}^t\cdot E_{ie}^{\rho_{ie}^t} + (1-\beta_{ie}^t)\cdot D_{ie}^{\rho_{ie}^t}\right]^{\frac{1}{\rho_{ie}^t}},\quad ie\subset i \tag{11}$$

where, E_{ie} denotes the total exported commodity by exporter sector *ie*. The export supply is a function of the export to domestic price ratio, the elasticity of transformation, and the share parameters in the *CET* function.

$$E_{ie} = D_{ie}\cdot\left[\frac{PE_{ie}}{PD_{ie}}\cdot\frac{(1-\alpha_{ie}^t)}{\alpha_{ie}^t}\right]^{\frac{1}{\left(\propto_{ie}^t-1\right)}} \tag{12}$$

In the income block, the production factors, the rural and urban workers, and capital receive their income from the employment and wage rate of the production factors. Households also receive their income from labour and capital employment, and their wages. Government transfers and factor income from abroad are other sources of household income. In addition, in the income block, corporate income is a function of capital income and net receipts from the government and abroad. Government income is the sum of revenue collected from tariffs, indirect taxes, export taxes, and household and corporate income taxes. The government uses this income to purchase commodities for its consumption and transfers a part of it to households and enterprises. Government saving is a flexible residual. Household saving is derived from the marginal propensity to save out of the after-tax income. Total savings is a function of household, government, and company's savings minus the current account.

On the demand side, the demand for commodities can be divided into household consumption demand, government consumption demand, intermediate inputs, investment demand, and inventory. Total household consumption is a function of household income deducted from household savings and taxes. For full list of equations please refer to Solaymani et al. [52].

In the carbon emission block, the carbon or energy tax revenue is a function of composite commodities multiplied by the rate of taxes.

$$TC_i = Q_i \cdot \tau_i^{env} \tag{13}$$

Sectoral CO_2 emission, CO_{2_j}, is a function of use of fossil fuel, *IOF*, (in monetary units) in sector *j*; ω_{ful}, converts *IOF*, to energy units; and ef_i is an emission factor for fuel *i*.:

$$CO_{2_j} = \sum_{ful} IOF_{ful,j} \cdot ef_{ful} \cdot \omega_{ful} \cdot \tau_{ful}^{env}, \;\; ful = crude\ oil, natural\ gas, \ petroleum, \ \ gas \tag{14}$$

Total CO_2 emissions, TCO_2, include sectoral CO_2 emissions and emission in consumption (households, *THCON*, and government, *GD*), and investment.

$$TCO_2 = \sum_j CO_{2_j} + \sum_i \left[(THCON_i + GD_i + ID_i) \cdot ef_i \cdot \omega_i \cdot \tau_i^{env} \right] \tag{15}$$

2.2. Rebound effect

Although rebound phenomenon goes back to Jevons' work in 1865, Khazzoom [28] and Brookes [9,10] attempted to express it by economic theories. In the modern theory, the so-called Khazzom–Brookes postulate, states that the aggregate energy saving from energy efficiency measures can paradoxically lead to increases in energy consumption. The macroeconomic effects of rebound effect were extended by Saunders [48–50] by applying a neo-classical growth approach. More recent contributions to development of the theory and applications of rebound effect include Sorrell [58], Sorrell and Dimitropoulos [55], Sorrel [57] and Sorrell et al. [56].

The so called "rebound effect" will happen when improvements in energy efficiency, through decreasing energy prices, encourage increased energy consumption. Basically the key mechanism of rebound effect is that technical advancement enhances the efficiency, and further reduces the price [24]. While rebound effect and climate change policies have intersections, in order to identify such interaction we attempt to find how climate change policies affect rebound effect.

Li et al. [31] and Hong et al. [24] separately showed that by removing fossil energy subsides in China, the rebound effect would be effectively mitigated, and removing all subsides would reduce the rebound effect most.

Barker et al. [7] forecasted that the total rebound effect arising from the IEA energy-efficiency policies for final energy users for period 2013–2030 is around 50%, averaged across sectors of the economy. In the Chinese road transport, Wang and Lu [66] argued that, in the long term, the magnitudes of a partial rebound effect of freight transport for entire nation, eastern, central and western regions are 84%, 52%, 80% and 78%. In aspect of short term, a tiny super conservation effect exists in Chinese road freight transportation. Similarly, Wang et al. [64] found that the magnitudes of the direct rebound effect are respectively 45% and 35% for 1993–2009 and 2002–2009 periods, which indicates that in Hong Kong there was a declining trend in the direct rebound effect for passenger transport over time. Moreover, for passenger transport in urban China, Wang et al. [65] revealed that a majority of the expected reduction in transport energy consumption from efficiency improvement could be offset due to the existence of rebound effect. However, in Switzerland, Spielmann et al. [59] showed that implementation of new high-speed transport technologies leads to an increase in the size of environmental rebound effect between 11% and 114%. More recent contributions for other sectors include Lin and Liu [33,34], Lin et al. [35], Ouyang et al. [44] and Madlener [37].

Following Li et al. [31] study, we can define the rebound effect for sector *i*, RE_i, as follows.

$$RE_i = \frac{EN_i^2 - EN_i^1}{EN_i^0 - EN_i^1} \tag{16}$$

where,

EN_i^0: Initial market equilibrium quantity of energy demand in sector *i*,
$EN_i^1 = EN_i^0 \cdot (1 - \alpha_i^{en})$: Quantity of energy demand before implementing of the policies with an energy efficiency parameter α,
EN_i^2: Market equilibrium quantity of energy demand after implementing of the policies with energy efficiency parameter α.
α_i^{en}: Energy efficiency parameter

We used the shift parameter, α_i^{en}, of the *CES* energy function (Eq. (6)) as a proxy for energy efficiency parameter. This coefficient has different values in different sectors and is defined as follows:

$$\alpha_i^{en} = \frac{EN_i}{\left[\sum_{e1} \delta_{e1,j}^{en} \cdot EDEM_{e1,j}^{-\rho_j^{en}} \right]^{-1/\rho_j^{en}}}$$

We assumed that when climate policies implemented into the economy the energy efficiency would increase by 3%.

2.3. Closures and data

The choice of exogenous variables is the closure rule of the model. In the model, the general price index is fixed exogenously. All prices in the model are fixed at unity. Therefore, a change in total utility before and after the simulation equates to a welfare change; as measured by the Hicksian EV (Equivalent Variation).

$$EV_h = \frac{\left(U_h^1 - U_h^0\right)}{U_h^0} \cdot Y_h \tag{17}$$

where, *EV* denotes the Hicksian equivalent valuation. $U^0$and U^1 denote utility level before and after policy shock, and Y_h denotes total income of household *h*.

Government consumption, as well as its transfer to households, is fixed exogenously. The foreign exchange rate market is cleared by fluctuations in the exchange rate, whereas the current account is fixed. Three labour types and capital supply are exogenously fixed; but both are sectorally mobile. Markets for three labour categories and capital are cleared by endogenous factor prices. Since the model is static, with a fixed total factor supply, the results of the model must be interpreted as long-term results and outcomes, which shows what the new equilibrium would reach after the economy has had time to adjust.

The experiment was carried out within a long-run macro closure. In the long-run closure, both capital and labour are sectorally mobile with fixed total supplies. Furthermore, sectoral rates of interest, nominal exchange rate, government savings, and real investment expenditure are also considered endogenous. The CGE model was solved using GAMS (General Algebraic Modelling System) software.

The parameters of the functions in the model were adapted from literature on other CGE models. The extraneous parameters required for the model calibration are presented in Table 1. The assumed elasticities are deemed conservative and were based on a literature search on elasticities in the Malaysian economy, such as Solaymani and Kari [53] and Solaymani et al. [54].

The main data source for the present study comes from the latest Malaysian input–output table and Socio economic data for 2005 in order to mack a SAM (Social Accounting Matrix). The 2005 input–output table consists of 120 sectors that are aggregated into 22 sectors. These industries can also be sorted into two broad categories, namely transport sectors (i.e., land, water, air, and other transport services), and non-transport sectors.

The impact of climate change taxes depends on the value of the intensity coefficients. The intensity coefficients of the carbon tax and the energy tax are the proportion of the carbon emissions to real GDP (ton of carbon/Million Ringgit Malaysia) and the fossil fuels to real GDP (ton of oil equilibrium/Million Ringgit Malaysia), respectively. The measures of carbon emissions and energy content are based on tc (ton of carbon) and toe (tonne of oil equivalent), respectively.

Table 1
Model elasticities.

Sectors	Elasticity of substitution between	
	Imports and domestic sales	Exports and domestic sales
Agricultural	0.9	0.7
Forestry and logging	0.9	0.9
Crude oil	0.9	0.9
Natural gas	0.9	0.9
Mining	0.9	0.9
Food processing, beverage and tobacco products	1.2	1.2
Textiles, wood and paper products	0.7	0.7
Petroleum refinery	0.6	0.6
Chemical products, rubber and plastic	0.7	0.7
Cement and non-metallic mineral products	0.7	0.7
Iron and steel products	0.7	0.7
Manufacturing	0.7	0.5
Electricity	0.9	0.5
Gas	0.9	0.5
Trade works, wholesale & retail trade, hotel & restaurant	0.5	0.5
Land transport	0.5	0.5
Water transport	0.5	0.5
Air transport	0.5	0.5
Other transport services	0.5	0.5
Communication	0.5	0.5
Financial institutions	0.5	0.5
Services	0.5	0.5
Substitution elasticities between		
Intermediate inputs and value added in the production function		0.6 – 0.9
Factors of production in the value added equation		0.5 – 0.6
Aggregate materials: energy and non-energy inputs		0.62
Non-transport inputs and transport inputs		0.65
Energy inputs		0.50
Transport inputs		0.62

Source: Various studies.

Table 2
Tax levels which are required to reduce different levels of carbon dioxide emission.

Carbon emissions reduction rate (%)	Carbon tax ($/ton of carbon)		Energy tax ($/TOE)	
	Recycling		Recycling	
	Lump-sum	Labour tax	Lump-sum	Labour tax
5	3.92	5.93	9.37	7.71
10	8.01	12.12	12.70	19.21
15	12.31	18.60	19.55	29.54
20	16.81	25.38	26.77	40.41

Source: Simulation results.

2.4. Revenue recycling

Two schemes for recycling tax revenue are considered in the study. These schemes are incorporated in the model as follows:

(a) Recycling of tax revenue to households through a lump-sum transfer: Tax revenue is recycled to households through a lump-sum transfer in which the revenue gap; which is the difference between government revenue after (GR) and before (GR^0) the carbon tax policy, is added to household revenue. (b) Recycling of tax revenue to finance cuts in the existing labour tax rate: Tax revenue is used to reduce tax rates on labour incomes (see Timilsina and Shrestha [62] for further details).

3. Results

The economic impact of tax policy instruments depends on the magnitude of taxes, the types of tax instruments and the revenue recycling methods used. In order to assess the economic impact of climate change policies on fossil fuels, we used two tax instruments, namely carbon and energy taxes. These are types of environmental taxes because they are imposed on fossil fuels to reduce pollution from the combustion of fuels. The welfare impact of an environmental tax depends on the relative magnitude of the tax interaction effect and the tax recycling effect. If the tax interaction effect is greater than the tax recycling effect, welfare loss occurs and vice versa [29]. In order to analyse the welfare effects of tax instruments under revenue neutrality, simulations are implemented for two schemes of revenue recycling, namely lump-sum tax and labour tax recycling. After describing different tax rates for different carbon emission reductions, we are only focussing on the tax rates of a 15% reduction on carbon emissions. The effects of higher or lower taxes on the economy and transportation sectors are higher or lower than the effects of tax rates of a 15% reduction on carbon emissions.

Table 3
Effects on selected variables (the 15% case).

Variables	% Change from base-run			
	Carbon tax ($/ton of carbon)		Energy tax ($/TOE)	
	Recycling		Recycling	
	Lump-sum tax	Labour tax	Lump-sum tax	Labour tax
Real GDP	−1.50	−1.42	−1.80	−1.71
Investment	−66.81	−66.87	−80.28	−80.38
Total exports	−0.16	0.04	−0.19	0.05
Total imports	−0.30	0.03	−0.36	0.04
Fossil fuels demand	−0.05	−0.04	−0.06	−0.05

Source: Simulation results.

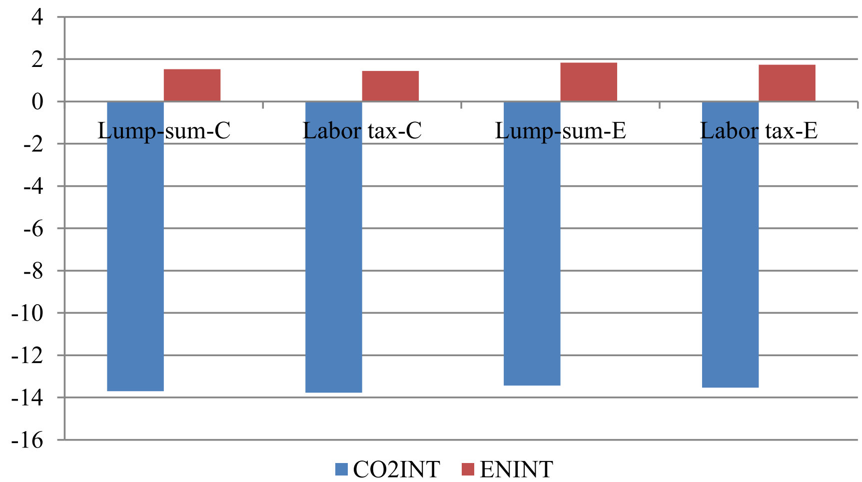

Fig. 1. Impacts on energy intensity (ENINT) and CO_2 intensity (CO_2INT). (% changes from base-run: the 15% case). Note: -C and -E denote carbon and energy tax policies, respectively. Source: Simulation results.

Table 2 shows the carbon and energy tax rates that are required to reduce a particular level of carbon dioxide emissions. For example, under the labour tax recycling, in order to reduce 5% of carbon emissions from the emissions level of the base-run, a carbon tax rate of 5.93 dollars per ton of carbon and an energy tax rate of 7.71 dollars per ton of oil equivalent ($/toe) are required. Under the lump-sum tax recycling, a carbon tax rate of 3.92 dollars per ton of carbon and an energy tax rate of 9.37 ($/toe) are required. These results show that the carbon tax is less costly than the energy tax.

Therefore, in comparison with the base-run situation, in order to reduce to a certain level of the carbon emission, for example 10%, we need to impose higher levels of energy taxes than carbon taxes. It means that the energy tax policy is more costly than the carbon tax policy. These findings are in line with McDougall [38], Scrimgeour et al. [51], and Timilsina and Shrestha [61]. Furthermore, under the labour tax recycling, higher levels of taxes than the lump-sum recycling are needed to reduce to a certain amount of carbon emissions. Moreover, under the lump-sum recycling scheme of the carbon tax policy we need the rates of 3.9, 8 and 16.8 dollar per ton of carbon to reduce 5%, 10% and 20% of carbon emissions. This shows that, in general, in order to reduce by 10%, 20% and above rates of carbon emission from the base-run situation, we need to increase the rates of the carbon tax policy by double. This pattern is same for energy tax policy in its both recycling schemes. Therefore, in order to reduce a higher level of carbon emissions in the Malaysian economy, double amounts of the carbon and energy taxes are required under both schemes for recycling tax revenue. Gerbelová et al. [19] showed that higher rates of carbon tax lead to greater decreases in CO_2 emission in the economy.

The energy tax and the carbon tax for all recycling schemes lead to a fall in real GDP because of significant decreases in intensive to invest in energy-intensive sectors (Table 3). The demand for factors, especially labour, decreases in energy-intensive sectors. This reflects structural changes in the economy, and a shift from more energy-intensive sectors towards more labour-intensive sectors. These results are in line with the results of Duan et al. [18].

The energy tax policy, in comparison to the carbon tax policy, leads to more decrease in real GDP in both lump-sum and labour tax recycling schemes. Further simulation by authors, which is not mentioned here, with a target of 5% reduction in carbon emissions on the Malaysian economy, shows that real and nominal GDP for labour tax recycling decreased slightly by 0.48% and 0.26%, respectively. Therefore, low levels of climate change policies have a small negative effect on macroeconomic indicators.

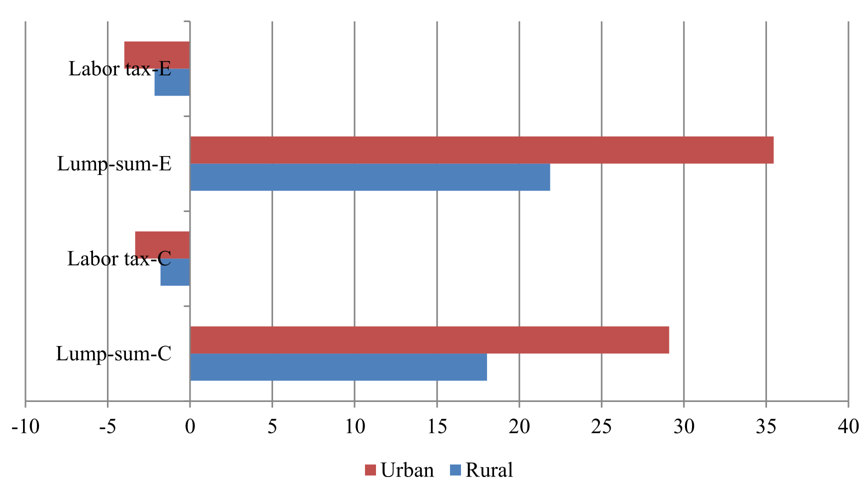

Fig. 2. Welfare changes of climate change policies (% changes from base-run: the 15% case). Note: -C and -E denote carbon and energy tax policies, respectively. Source: Simulation results.

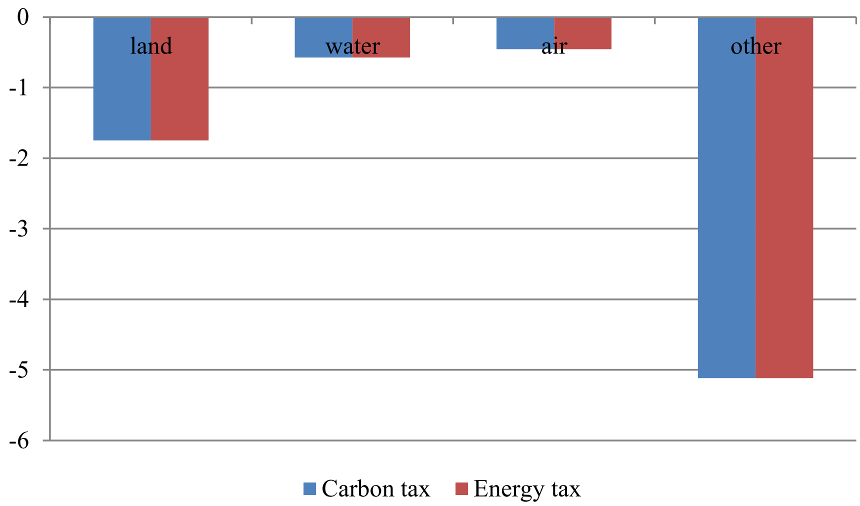

Fig. 3. Impact of climate change policies on rebound effect policies (Lump-sum transfer, the 15% case). Source: Simulation results.

The climate change policies also lead to an appreciation in the national currency against foreign currencies (depreciation in the exchange rate), which occurs in both policy taxes, resulting in a decrease in total exports for the lump-sum tax recycling.[1] However, total imports decrease due to a significant decrease in domestic demand for intermediate inputs and domestic products. The energy and carbon taxes for both revenue recycling schemes lead to a reduction in both carbon dioxide emissions and fossil fuel consumption (Table 3). These findings are consistent with McDougall [38], Scrimgeour et al. [51], and Timilsina and Shrestha [62].

Fig. 1 shows the impacts of climate change policies on energy and CO_2 intensities. It shows that the carbon tax policy, in both revenue recycling schemes, is more effective than the energy tax policy to reduce energy intensity and CO_2 intensity in the Malaysian economy. These results are consistent with the results of Lin and Li [32] study.

Fig. 2 shows the welfare effects of climate change policies. In the lump-sum tax recycling of both policies, due to transfer of government revenue the consumption and welfare of all household types increase significantly, while the magnitudes for energy tax are greater than those of the carbon tax. However, the effect of these policies under the labour tax recycling on the consumption and welfare of rural and urban households are negative.[2] This is because the tax interaction effect of labour tax recycling is greater than the tax recycling effect. Therefore, households lose from both climate change policies when the government transfers the revenue through labour taxes. These findings are consistent with the findings of Wissema and Dellink [68] and Timilsina and Shrestha [61].

Since Malaysia does not have any pre-existing taxes on the consumption of fossil fuels, recycling of the savings from these taxes by the government leads to high impacts on the consumption and welfare of households; but only through the lump-sum tax recycling. Therefore, according to the results of the lump-sum tax recycling of both tax policies, the interaction effects of taxes are less than the tax recycling effects resulting in an increase in their welfare. This finding corresponds to other studies such as Bye [13], Stampini [60], Callan et al. [14], and Lu et al. [36] who showed that imposing a carbon tax can result in welfare gain, and a pre-existing tax system may lead to welfare loss. Bye [13] argued that a carbon tax with a reduction in the payroll tax in Norway obtained a welfare gain, because the distortion of the pre-existing payroll tax was large enough. Furthermore, Bor and Huang [8] showed that the use of energy tax revenue, generated for the purpose of reducing income tax, was the best choice; since it will effectively stimulate domestic consumption, and, consequently, decrease the negative impacts of the distortionary tax policy. Bureau [12] also found that recycling tax revenues in equal amounts to each household increased the welfare of poor households.

Imposing carbon and energy tax policies on the consumption of energy leads to an increase in the prices of energy commodities. For example, in the lump-sum recycling for the carbon tax policy, the prices of crude oil, natural gas, petroleum products, and city gas increase by 1.31%, 1.31%, 0.76%, and 0.43%, respectively.

Since petroleum products are the main energy source for transport, an increase in their prices, due to the climate change policies, would lead to a fall in their consumption in the transport sectors; thus resulting in a decrease in domestic output and domestic demand of all transport sectors. The transport value added also decreases in both tax policies and their recycling. This finding

Table 4
Sensitivity analysis: Impacts of climate change policies on selected variables (the 15% case).

Variables	% changes from base-run			
	Low elasticity		High elasticity	
	Carbon tax	Energy tax	Carbon tax	Energy tax
	Lump-sum tax recycling		Lump-sum tax recycling	
Real GDP	−1.43	−1.72	−1.53	−1.83
Total investment	−66.83	−80.35	−66.80	−80.27
Total exports	−0.32	−0.39	−0.14	−0.17
Total imports	−0.57	−0.69	−0.27	−0.32
Welfare	12.86	15.47	12.58	15.13
Fossil fuels demand	−0.03	−0.04	−0.05	−0.05

Note: The results from Labour tax replacement are higher and lower than the results from 15% carbon reduction target.
Source: Simulation results.

[1] In the carbon tax policy, the exchange rate depreciated by 0.4% and 0.5% for lump-sum and labour tax transfers, respectively. Meanwhile, in the energy tax policy, it depreciated by 0.05% and 0.6%, respectively.

[2] In the carbon tax policy, the consumption of rural and urban households for lump-sum transfer are 8.61% and 13.57%, respectively, and for labour tax recycling, they are −093% and −1.73%, respectively. In the energy tax policy, the consumption of rural and urban households for lump-sum transfer are 8.61% and 13.57%, respectively, and for labour tax recycling, they are −1.11% and −2.07%, respectively.

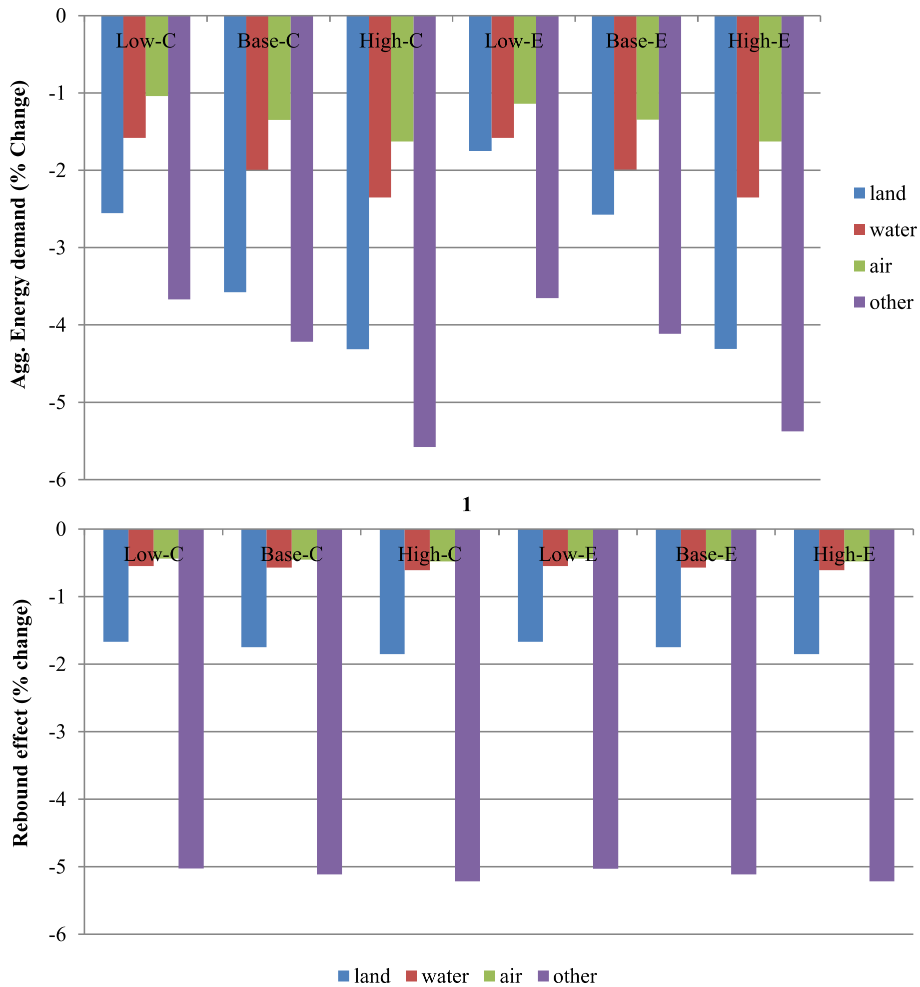

Fig. 4. Sensitivity analysis, impact of change in Energy Substitution Elasticity on aggregate energy consumption and rebound effect. Note: -C and -E denote carbon and energy tax policies, respectively. Source: Simulation results.

also shows that the negative effects of the carbon tax on value added are less than those of the energy tax policy. This finding is similar to other studies such as Alton et al. [5].

The carbon tax and the energy tax shift the factors of production from high energy-intensive sectors to less energy-intensive sectors because they increase the prices of energy inputs resulting in an increase in production costs. Therefore, in both recycling schemes of both tax policies, the total employment in all transport sectors, except for other transport sectors, decreased significantly, because they are energy-intensive sectors. In contrast, employment in agriculture, communication, finance, and food-processing sectors increased significantly. Moreover, in all transport sectors, both the carbon and energy tax policies would increase the total consumption of households, due to the redistribution of savings from these policies to households. The carbon and energy taxes lead to a decrease in the exports of all transport sectors. This is because the domestic demand of transport sectors decreased significantly due to the decline in their demands for intermediate inputs and depreciation in foreign exchange rate.

While rebound effect and climate change policies have intersections, in order to identify such interaction we attempt to find these intersections as presented in Fig. 3. We found that the climate change policies and ensuing energy consumption reduction, which come from an increase in fossil fuel prices, would contribute to the mitigation of rebound effect, realising the economic and environmental gains. These policies also would lead to mitigation of rebound effect by more than 10% in the whole of the economy.

3.1. Sensitivity analysis

In order to evaluate the robustness of the above qualitative results, this study runs an additional simulation for sensitivity analysis. In the first sensitivity analysis, the trade elasticity parameters (in the *Armington CES* and *CET* functions) in all sectors decreased and increased by 25% lower and upper than their benchmark elasticities, respectively. The simulations were performed with these adjustments, again using a 15% reduction in carbon emissions.[3] Table 4 reports the aggregate impacts of these simulations. While the impact's magnitudes are initially lower and larger, with lower and higher values of elasticity, respectively, the qualitative results obtained for the impact of carbon and energy tax policies on the Malaysian economy are still valid.

In the second sensitivity analysis, the study turns factors affecting the size of energy demand and rebound effect in the transport sectors. Fig. 4 illustrates the relationship between the

[3] In order to achieve the target of 15% carbon reduction, the carbon tax rates of 12.41and 12.28 per ton of carbon and the energy tax rates of 19.70and 19.51 dollars per ton of oil equivalent are required.

transport industry's energy demand and rebound effect and the values of energy substitution elasticity. These elasticity parameters decreased and increased by 25% lower and upper than their benchmark elasticities, respectively.

Fig. 4-1 shows that an increase and decrease in energy substitution elasticity decreases less and more aggregate demand for energy in all the transport sub-sectors in comparison to the base scenario. These results are not surprising, since climate change policies would lead to a relative switch from energies with high prices to energy carriers with lower prices. In the transport sector, the use of alternative energy carriers due to the climate change policies has increased. The value of energy substitution elasticity would play an important role in determining the size of the inter-fuel substitution effects, and, consequently, affect the size of the transport's energy demand changes. Fig. 4-2 also shows that the transport industry's rebound effect would mitigate more and less if the energy substitution elasticity increases and decreases. The rebound effect also follows the same pattern as those of aggregate energy demand.

4. Conclusion and recommendations

This study analysed the impact of a carbon tax and its alternative tax, energy tax, policy on carbon emissions, energy consumption, and the main transport indicators on Malaysian economy, using a CGE framework. Implementation of these policies leads to an increase in government revenue. In order to redistribute this new government revenue and achieve revenue neutrality, we used two schemes for revenue recycling. First, the government revenue transfers to households as a lump-sum transfer, and second, the government revenue returns to households as a negative labour tax to reduce or cut a part of the labour income taxes.

Simulation results show that the carbon tax, in comparison with the energy tax, is more effective in reducing carbon emissions, CO_2 and energy intensities. Furthermore, in the mitigation target rates from 5% to 20% of carbon emissions, the impact of the carbon tax policy on decreasing of real GDP in the Malaysian economy is less than the energy tax policy. However, for both taxes, the interaction effects of the lump-sum recycling were less than the tax recycling effects resulting in an increase in household consumption and welfare, while the interaction effects of the labour tax recycling were greater than the tax recycling effects resulting in a decrease in the consumption and welfare of households. Furthermore, both carbon and energy tax instruments led to the reallocation of resources such as labour and capital. These policy instruments reallocated resources from energy-intensive sectors to the labour-intensive sectors that experienced a progress in their output.

The carbon and energy tax policies led to a decrease in domestic output, domestic demand, and employment in all transport sectors while the magnitude effects of the carbon tax policy were greater than those of the energy tax policy. These policies also increased the use of all transport sectors by households with greater magnitude for the energy tax policy, because it recycled a greater amount of saving from the energy tax to households. Meanwhile, the land and air transport sectors experienced initial decreases in their exports and imports, both climate change policies significantly decreased the total imports and exports of water and other transport sectors. In general, transport does not gain from these policies. Finally, the climate change policies would lead to mitigation of rebound effect at the aggregate and transport level.

It is recommended that if the government wants to implement a tax on the consumption of energy, it is more suitable to consider low rates of carbon reduction targets than the high levels (for example, 5% or lower); because its adverse effects on the economy are insignificant and cause a less severe shock to the economy.

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