Macroeconomic effects of carbon dioxide emission reduction: a computable general equilibrium analysis for Malaysia

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MACROECONOMIC EFFECTS OF CARBON DIOXIDE EMISSION REDUCTION: A COMPUTABLE GENERAL EQUILIBRIUM ANALYSIS FOR MALAYSIA

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Abstract

This study analyzes the macroeconomic effects of limiting carbon emissions using computable general equilibrium (CGE) model in the Malaysian economy. Doing so, we developed an environmental computable general equilibrium model and investigate carbon tax policy responses in the economy applying exogenously different degrees of carbon tax into the model. Three simulations were carried out using a Malaysian Social Accounting Matrix. The carbon tax policy illustrates that a 1.21% reduction of carbon emission reduces the nominal GDP by 0.82% and exports by 2.08%; a 2.34% reduction of carbon emission reduces the nominal GDP by 1.90% and exports by 3.97%and a 3.40% reduction of carbon emission reduces the nominal GDP by 3.17% and exports by 5.71%. Imposition of successively higher carbon tax results in increased government revenue from baseline by 26.67%, 53.07% and 79.28% respectively. However, fixed capital investment increased in scenario 1a (1st) by 0.43% but decreased in scenarios 1b (2nd) and 1c (3rd) by 0.26% and 1.79% respectively from the baseline. According to our findings policy-makes should consider initial (1st) carbon tax policy. This policy results in achieving reasonably good environmental impacts without losing the investment, fixed capital investment, investment share of nominal GDP and government revenue.

Keywords: Emission, Environmental General Equilibrium, Malaysian Economy

JEL Classifications: Q5, B22, C68

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1. Introduction

The impact of economic development and trade liberalization policies on the environmental quality is becoming increasingly important concerns into main public policy agenda. This is especially important nowadays as the environmental consequences of human activities exceeded certain limits and degrading environmental quality worldwide. Higher awareness has led to greater scrutiny being placed on development policies in order to assess the long-term negative effects of further economic development on the environment and its sustainability (Levinson & Taylor 2004; Cole & Elliot 2003, 2005). In the last four decades a number of environmental quantitative models are developed to capture the economic development and complex concept of economic sustainability. These models were analyzing systematically and quantitatively the evolution of the variables related to its three macro objectives (economic growth, equity and environmental sustainability). In particular, since the late seventies and especially in the eighties, applications based on computable general equilibrium models (CGE) were developed. These multi-sectoral models solve the limitations of some previous quantitative models as evaluation instruments, representing in a more realistic way the economy of a country by incorporating market mechanisms in the assignment of resources.

Empirical studies for developed countries reveal that imposition of a carbon tax would decrease carbon emissions significantly and might not dramatically reduce economic growth. A good number of previous studies (i.e. Bullard and Herendeen (1975); Stephenson and Saha (1980); Strout (1985); Forsund & Strom (1988); Robinson (1990); Han and Lakshmanan (1994); Wier (1998); Antweiler et al. (2001); Munksgaard and Pedersen (2001); Beghin et al. (2005)) have given a detailed evaluation of economic development and environment in the world perspective, however little attention has been given to enquiring about these relationships in the newly industrializing countries of Southeast Asia, in particular Malaysia. Due to lack of efficiency of environmental policy options, Malaysia failed to achieve the environmental goal. The existing Malaysian environmental tax policies have lack of effectiveness and the present level of pollution charge is very low as most of the cases it found insignificant (DOE 2001). The main reason is that the environmental tax is not appropriate. Currently there is no carbon tax policy model in Malaysia and environmental monitoring system does not cover the whole economy. Therefore, the goal of this paper is to develop an environmental CGE model and show the potential of CGE modeling and economy wide impacts of using CGE analysis as a tool for policy evaluation. Our model captures the changes in factors of production, industry output, consumer demand, trade, private consumption, public consumption and other macroeconomic variables resulting from environmental policy changes. Specifically, several carbon tax policies are developed for Malaysia to analyze the impacts of trade, economic development as well as to limit the further environmental degradations in the economy.

The paper is organized as follows. In the next section, we review the environmental CGE literature. Section three presents underlying model, which is based on the extended environmental CGE techniques. Simulation results are presented in Section 4. Discussions on policy recommendations are given in Section 5. Appendix A is a presentation of the Malaysian computable general equilibrium model in complete equation form.

2. Review of literature on CGE model and environment

Studies on incorporating environmental components into a CGE framework emerged in the late 1980s. Forsund & Strom (1988), Jorgenson & Wilcoxen (1990), Robinson (1990), Blitzer et al (1992), Lee & Roland-Holst (1993), Robinson et al. (1993), Bergman (1993), Beghin et al. (1994), Copeland & Taylor (1994), Beghin et al. (1997), Reinert & Roland-Holst (2001), Antweiler et al (2001), Beghin et al. (2005) contributed to the development of environmental CGE models. These CGE models are distinct from each other in terms of the ways they integrate environmental components with economic activities in their CGE models.

There are several types of environmental CGE models according to the level of pollution-related activities integrated into them. The first type of models is not very different from a standard CGE model. These models are the extension of the standard CGE models. The extensions include either estimating pollution emissions using fixed pollution coefficients per unit of sectoral outputs or intermediate inputs or exogenously changing prices or taxes concerning environmental regulations without any changes in model structure. To extend the applications of a standard CGE model in such ways do not affect the behavioral specification of a standard CGE model and provide detailed description of production results from the environmental prospective. The models of Blitzer et al (1992), Lee & Roland-Holst (1993) and Beghin et al. (1997, 2005) belong to this group. The second type of environmental CGE models, represented by Jorgenson and Wilcoxen's (1990) model, have pollution control costs specified in production functions. It extends the production specification and considers the effects of environmental quality on productivity. To represent the effects of pollution emission and abatement activities on consumption, a number of models have environmental effects incorporated in utility functions. Robinson (1990), Piggott et al. (1992), and Bergman (1993) belong to this group.

Robinson (1990) develops a two-component general equilibrium framework to evaluate the efficiency of two policy instruments - pollution taxes and government pollution cleaning - in an economy where pollution is treated as a public good. The first component is a CGE model which incorporates pollution and pollution cleaning. Pollution is generated as a fixed-proportions byproduct of certain production activities and enters the households' utility functions as a public good. Pollution cleaning is undertaken by the government and financed via Pigouvian taxes. For an exogenously determined pollution cleaning and specified tax rate, the solutions of the CGE model satisfy the market equilibrium conditions but are not welfare maximizing. This happens because the amount of the public good, pollution and its price, the Pigouvian tax, are not optimally determined, i.e. they do not maximize social welfare. Using an iterative nonlinear optimization procedure (the second component), Robinson maximizes the social welfare function corresponding to the economy simulated in the CGE model over the values of the policy instruments. Since his CGE model contains only one consumer, the social welfare function is equivalent to the representative consumer's utility function.

Beghin et al. (1997) developed a theoretical computable general equilibrium (CGE) model (applied in Chile 2003) which underlies six country case studies. The research describes the base model specification for a series of six country case studies undertaken at the OECD Development Centre to analyze the links between growth and emissions, and emissions and trade instruments. The CGE model of this research attempts to capture some of the key features relating to environmental emissions. These features include: a) linking emissions to the consumption of polluting inputs (as opposed to output); b) including emissions generated by final demand consumption; c) integrating substitutability between polluting and non-polluting inputs (including capital and labour); d) capturing important dynamic effects such as capital accumulation, population growth, productivity and technological improvements, and vintage capital (through a putty/semi-putty specification); and e) the impact of emission taxes to limit the level of pollution.

Reinert, K.A. & D.W. Roland-Holst (2001) studied NAFTA and industrial pollution. In this paper, the authors utilize a three-country, applied general equilibrium (AGE) model of the North American economy and data from the World Bank's Industrial Pollution Projection System (IPPS) to simulate the industrial pollution impacts of trade liberalization under NAFTA. According to their studies they find that the most serious environmental consequences of NAFTA occur in the base metals sector. In terms of magnitude, the greatest impacts are in the United States and Canada rather than Mexico. However, the Mexican petroleum sector is also a significant source of industrial pollution, particularly in the case of air pollution. Beside petroleum sector the transportation equipment sector is also an important source of industrial pollution in Mexico. This is the case for both volatile organic compounds and toxins released into the air in Canada and the United States. Finally, the authors identified that the chemical sector is a significant source of industrial toxin pollution in the United States and Mexico, but not in Canada.

Recently Karen Fisher-Vanden and Ian Sue Wing (2007) employ a CGE simulation of the Chinese economy for climate policy analysis. The authors construct an analytical model to show that efficiency-improving and quality-enhancing R&D have opposing influences on energy and emission intensities, with the efficiency-improving R&D having an attenuating effect and quality enhancing R& D having an amplifying effect. They find that the balance of these opposing forces depends on the elasticity of upstream output with respect to efficiency-improving R&D, the elasticity of downstream output with respect to upstream quality-enhancing R&D occurring upstream, and the relative shares of emissions intensive inputs in the costs of production of upstream versus downstream industries. They construct a theoretical model in which there are two industries, one upstream (U) and the other downstream (D), where the latter uses the output of the former as an input to production. The numerical economic simulations using the CGE model of China's economy which is calibrated based on econometric estimates of the sectoral impacts.

3. Methodology

A static environmental computable general equilibrium (CGE) model of the Malaysian economy is constructed for this study.[2] The model consists of ten

[2] Compared with other modeling techniques, such as the input–output approach or linear programming, the CGE approach has appealing features for modeling environmental policy analysis. This modeling approach can consider simultaneously environmental policy analysis and welfare effects of trade and trade policies. A prominent advantage of CGE models lies in the possibility of combining detailed and

industries, one representative household, three factor production, and rest of the world. The CGE technique is an approach that models the complex interdependent relationships among decentralized actors or agents in an economy by considering the actual outcome to represent a 'general equilibrium'. Briefly, the technique expresses that the 'equilibrium' of an economy is reached when expenditures by consumers exactly exhaust their disposable income, the aggregate value of exports exactly equals import demand, and the cost of pollution is just equal at the marginal social value of damage that it causes. The benchmark model representing the baseline economy is constructed using a Social Accounting Matrix (SAM).[3] A SAM is a snapshot of the economy and it reflects the monetary flow arising from interactions among institutions in the Malaysian economy. The Malaysian year 2000 SAM is shown in Table 1.

The Malaysian CGE model is comprised of a set of non-linear simultaneous equations and follows closely the specifications in Dervis et al (1982) and Robinson et al. (1999) with some modifications in terms of functional form in the production technology to allow for pollution emission estimation incorporating carbon emission block into the model; where the number of equations is equal to the number of endogenous variables. The equations are classified in four blocks, i.e., (i) the price block, (ii) the production block, (iii) the institutions block, and (iv) the system constraints block.

3.1 Price block

Domestic price

Domestic goods price by sector, PD_i is the carbon tax induced goods price t_i^d times net price of domestic goods $\widetilde{PD_i}$ can be expressed as follows:

$$PD_i = \widetilde{PD_i}(1+t_i^d) \quad (1)$$

Import price

Domestic price of imported goods PM_i, is the tariff induced market price times exchange rate (ER) and can be expressed as:

$$PM_i = pwm_i(1+tm_i)\cdot ER \quad (2)$$

where tm_i is import tariff and pwm_i is the world price of imported goods by sector.

Export price

Export price of export goods, PE_i, is the export tax induced international market price times exchange rate and is express as:

$$PE_i = pwe_i(1-te_i)\cdot ER \quad (3)$$

where te_i export tax by sector and pwe_i is the world price of export goods by sector.

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consistent real-world database (Social Accounting Matrix) of trade and environment with a theoretically and empirically sound framework (Perroni & Wigle, 1994).

[3] SAM matrix is estimated by the Authors using the Malaysian 2000 input-output table and national accounts Malaysia 2000.

Composite price

The composite price, P_i, is the price paid by the domestic demanders. It is specified as:

$$P_i = \left(\frac{PD_i D_i + PM_i M_i}{Q_i} \right) \tag{4}$$

where D_i and M_i are the quantity of domestic and imported goods respectively; and PD_i is the price of domestically produced goods sold in the domestic market, PM_i is the price of imported goods, and Q_i is the composite goods.

Activity price

The sales or activity price PX_i is composed of domestic price of domestic sales and the domestic price of exports can be expressed as:

$$PX_i = \frac{PD_i.D_i + PE_i.E_i}{X_i} \tag{5}$$

where X_i stands for sectoral output.

Value added price

Value added price PV_i is defined as residual of gross revenue adjusted for taxes and intermediate input costs, is specified as:

$$PV_i = \frac{PX_i \cdot X_i(1-tx_i) - PK_i \cdot IN_i}{VA_i} \tag{6}$$

where tx_i is tax per activity and IN_i stands for total intermediate input, PK_i stands for composite intermediate input price and VA_i stands for value added.

Composite intermediate input price

Composite intermediate input price PK_i is defined as composite commodity price times input-output coefficients.

$$PK_i = \sum_j a_{ij} \cdot P_j \tag{7}$$

where a_{ij} is the input-output coefficient.

Numeraire price index

In CGE model, the system can only determine relative prices, and solves for prices relative to a numeraire. In this model the numeraire is the gross domestic product price deflator (or gross national product can also be used). Producer price index and CPI are also commonly used as numeraire in applied CGE studies. In this model:

$$PP = \frac{GDPVA}{RGDP} \tag{8}$$

where *PP* is GDP deflator, *GDPVA* is the GDP at value added price, and *RGDP* is the real GDP.

Table 1 Sectoral aggregation of Malaysian SAM 2000 (‘000 RM)

Incomes			1	24		3			4	5	Total
			Commodities /activities (1..94)	Factors		Institutions			Capital account	Rest of the world	
				Labor	Capital	Household	Firms	Government			
1	Commodities /activities (1..94)		Intermediate inputs 271,699,945			Household consumption 116,582,745		Government consumptions 34,861,875	Investment 74,303,819	Exports 399,379,409	Domestic demand 896,827,793
2	Factors	Labor	Value added 99,138,139							Factor incomes from abroad 0	GNP at factor cost 345,270,111
		Capital	Value added 246,131,970								
3	Institutions	Household		Household income from labor 99,138,140	Household income from capital 42,289,296		Transfers 10,890,000	Transfers 3,700,138		Transfers from abroad 0	Household income 156,017,574
		Firms			Farm cap. Income 154,100,045	Transfers		1,940,000			Firms income 158,699,045
		Government	Tariffs, indirect taxes 8,406,755			Income taxes 7,015,000	Taxes 22,141,000		Others 1,771,839	Borrowing 11,357,419	Government income 50,692,013
4	Capital account					Households savings 32,419,829	Firms savings 125,668,045	Government savings 10,190,000			Total savings 168,277,875
5	Rest of the world		Imports 271,450,981		Inflow 49,742,630				Foreign capital 92,202,217	Capital transfer 14,028,333	Total row 427,424,161
Total			Domestic supply 896,827,792	Factor outlay 345,270,111		Household expenditure 156,017,574	Firms expenditure 158,699,045	Government expenditures 50,692,013	Total investment 168,277,875	Foreign exchange earnings 427,424,161	2,203,208,571

Source: Authors’ calculation

3.2 Production block

This block contains quantity equations that describe the supply side of the model. The fundamental form must satisfy certain restrictions of general equilibrium theory. This block defines production technology and demand for factors as well as CET (constant-elasticity-of-transformation) functions combining exports and domestic sales, export supply functions and import demand, and CES (constant elasticity of substitution) aggregation functions. Sectoral output X_i is express as:[4]

$$X_i = a_i^D \prod_f FDSC_{if}^{\alpha_{if}} \tag{9}$$

where, $FDSC_{if}$ indicates sectoral capital stock and a_i^D represents the production function shift parameter by sector.

The first order conditions for profit maximization as follows:

$$WF_f .wfdist_{if} = PV_i .\alpha_{if} \frac{X_i}{FDSC_{if}} \tag{10}$$

where $wfdist_{if}$ represents sector- specific distortions in factor markets, WF_f indicates average rental or wage; and α_{if} indicates factor share parameter of production function.

Intermediate inputs IN_i are the function of domestic production and defined as follows:

$$IN_i = \sum_j a_{ij} \cdot X_j \tag{11}$$

On the other, the sectoral output is defined by CET function that combines exports and domestic sales. Sectoral output is defined as:

$$X_i = a_i^T [\gamma_i E_i^{\rho_i^T} + (1-\gamma_i) D_i^{\rho_i^T}]^{\frac{1}{\rho_i^T}} \tag{12}$$

where a_i^T is the CET function shift parameter by sector, γ_i holds the sectoral share parameter, E_i is the export demand by sector and ρ_i^T is the production function of elasticity of substitution by sector.

The sectoral export supply function which depends on relative price (P^e/P^d) can be expressed in the following functional form:

$$E_i = D_i \left[P_i^e (1-\gamma_i) \Big/ P_i^d \cdot \gamma_i \right]^{1/\rho_i^T} \tag{13}$$

Similarly, the world export demand function for sectors in an economy, $econ_i$, is assumed to have some power and is expressed as follows:

[4] The production function here is nested. At the top level, output is a fixed coefficients function of real world value added and intermediate inputs. Real value added is a Cobb-Douglas function of capital and labor. Intermediate inputs are required according to fixed input-output coefficients and each intermediate input is a CES aggregation of imported and domestic goods.

$$E_i = econ_i \left[{pwe_i}\Big/{pwse_i} \right]^{\eta_i} \tag{14}$$

where $pwse_i$ represents the sectoral world price of export substitutes and η_i is the CET function exponent by sector.

On the other, composite goods supply describes how imports and domestic product are demanded. It is defined as:

$$Q_i = a_i^C \left[\delta_i M_i^{-\rho_i^C} + (1-\delta_i) D_i^{-\rho_i^C} \right]^{-1/\rho_i^C} \tag{15}$$

where a_i^C indicates sectoral Armington function shift parameter, and δ_i indicates the sectoral Armington function share parameter.

Lastly, the import demand function which depends on relative price (P^d/P^m) can be expressed as follows:

$$M_i = D_i \left[{P_i^d . \delta_i}\Big/{P_i^m (1-\delta_i)} \right]^{1/1+\rho_i^C} \tag{16}$$

3.3 Domestic institution block

This block consists of equations that map the flow of income from value added to institutions and ultimately to households. These equations fill out the inter-institutional entries in the SAM.

First is the factor income equation Y_f^F defined as:

$$Y_f^F = \sum_i WF_f \cdot FDSC_{if} \cdot wfdist_{if} \tag{17}$$

where $FDSC_{if}$ is the sectoral capital stock, $wfdist_{if}$ represents sector-specific distortion in factor markets, and WF_f represents average rental or wage.

Factor income is in turn divided between capital and labor. The household factor income from capital can be defined as follows:

$$Y_{capeh}^H = Y_1^F - DEPREC \tag{18}$$

where Y_{capeh}^H is the household income from capital, Y_1^F represents capital factor income and $DEPREC$ is capital depreciations.

Similarly household labor income Y_{labeh}^H is defined as:

$$Y_{labeh}^H = \sum_{f \neq 1} Y_f^F \tag{19}$$

where Y_f^F is the factor incomes.

Tariff equation $TARIFF$ is expressed as follows:

$$TARIFF = \sum_i pwm_i \cdot M_i \cdot tm_i \cdot ER \qquad (20)$$

Similarly, the indirect tax $INDTAX$ is defined as:

$$INDTAX = \sum_i PX_i \cdot X_i \cdot tx_i \qquad (21)$$

Likewise, household income tax is expressed as:

$$HHTAX = \sum_h Y_h^H \cdot t_h^H \qquad (h = cap, lab) \qquad (22)$$

where Y_h^H is households income, t_h^H represents household income tax rate.

Export subsidy $EXPSUB$ (negative of export revenue) is be expressed as:

$$EXPSUB = \sum_i pwe_i \cdot E_i \cdot te_i \cdot ER \qquad (23)$$

Total government revenue (GR) is obtained as the sum up the previous four equations. That is:

$$GR = TARIFF + INDTAX + HHTAX + EXPSUB \qquad (24)$$ [5]

Depreciation ($DEPREC$) is a function of capital stock and is defined as:

$$DEPREC = \sum_i depr_i \cdot PK_i \cdot FDSC_i \qquad (25)$$

where $depr_i$ represents the sectoral depreciation rates.

Household savings ($HHSAV$) is a function of marginal propensity to save (mps_h) and income. It is expressed as:

$$HHSAV = \sum_h Y_h^H \cdot (1 - t_h^H) \cdot mps_h \qquad (26)$$

Government savings ($GOVSAV$) is a function of GR and final demand for government consumptions (GD_i). That is:

$$GOVSAV = GR - \sum_i P_i.GD_i \qquad (27)$$

Lastly, the components of total savings include financial depreciation, household savings, government savings and foreign savings in domestic currency ($FSAV \cdot ER$)

$$SAVING = HHSAV + GOVSAV + DEPREP + FSAV.ER \qquad (28)$$

The following section provides equations that complete the circular flow in the economy and determining the demand for goods by various actors. First, the private consumption (CD) is obtained by the following assignments:

[5] The sign for *EXSUB* depends on the economic policy on whether the government is receiving export tax revenue or giving export subsidies.

$$CD_i = \sum_h \left[\beta_{ih}^H \cdot Y_h^H (1 - mps_h)(1 - t_h^H) \right] / P_i \qquad (29)$$

where β_{ih}^H is the sectoral household consumption expenditure shares.

Likewise, the government demand for final goods (*GD*) is defined using fixed shares of aggregate real spending on goods and services (*gdtot*) as follows:

$$GD_i = \beta_i^G \cdot gdtot \qquad (30)$$

where β_i^G is the sectoral government expenditures.

Inventory demand (*DST*) or change in stock is determined using the following equation:

$$DST_i = dstr_i.X_i \qquad (31)$$

where $dstr_i$ is the sectoral production shares.

Aggregate nominal fixed investment (*FXDINV*) is express as the difference between total investment (*INVEST*) and inventory accumulation. That is:

$$FXDINV = INVEST - \sum_i P_i.DST_i \qquad (32)$$

The sector of destination (*DK*) is calculated from aggregated fixed investment and fixed nominal shares ($kshr_i$) using the following function:

$$DK_i = kshr_i.FXDINV / PK_i \qquad (33)$$

The next equation translates investment by sector of destination into demand for capital goods by sector of origin (ID_i) using the capital composition matrix (b_{ij}) as follows:

$$ID_i = \sum_j b_{ij}.DK_j \qquad (34)$$

The last two equations of this section show the nominal and real GDP, which are used to calculate the GDP deflator used as numeraire in the price equations. Real GDP (*RGDP*) is defined from the expenditure side and nominal GDP (*GDPVA*) is generated from value added side as follows:

$$GDPVA = \sum_i PV_i.X_i + INDTAX + TARIFF + EXPSUB \qquad (35)$$

$$RGDP = \sum_i \left(CD_i + GD_i + ID_i + DST_i + E_i - pwm_i \cdot M_i \cdot ER \right) \qquad (36)$$

3.4 Systems constraints block

This block defines the constraints that are must be satisfied by the economy as a whole. The model's micro constraints apply to individual factor and commodity markets. With few exceptions, in the labor, export and import markets, it is assumed that flexible prices clear the markets for all commodities and factors. The macro constraints apply to the government, the savings-investment balance, and the rest of the world. For the government, savings clear the balance, whereas the investment value adjusts to changes in the value of total savings.

Product market equilibrium condition requires that total demand for composite goods (Q_i) is equal to its total supply as follows:

$$Q_i = IN_i + CD_i + GD_i + ID_i + DST_i \tag{37}$$

Market clearing requires that total factor demand equal total factor supply and the equilibrating variables are the average factor prices which were defined earlier and this condition can be expressed as follows:

$$\sum_i FDSC_{if} = fs_f \tag{38}$$

The following equation is the balance of payments represents the simplest form: foreign savings (*FSAV*) is the difference between total imports and total exports. As foreign savings set exogenously, the equilibrating variable for this equation is the exchange rate (*ER)*. Equilibrium will be achieved through movements in *ER* that effect export import price. This balancing equation can be expressed as:

$$pwm_i \cdot M_i = pwe_i \cdot E_i + FSAV \tag{39}$$

Lastly the macro-closure rule is given as:

$$SAVING = INVEST \tag{40}$$

where total investment adjusts to equilibrate with total savings to bring the economy into the equilibrium.

3.5 Carbon emission

The aggregate CO_2 emission is formulated as follows:

$$TQ_{CO_2} = \varphi_{coal} X_{coal} + \varphi_{oil} X_{oil} + \varphi_{gas} X_{gas} \quad \text{or} \quad TQ_{CO_2} = \sum_i \varphi_i \mathrm{X}_i \tag{41}$$

and

$$TQ_{CO_2} - \overline{TQ}_{CO_2} \leq 0 \tag{42}$$

where TQ_{CO_2} is the total CO_2 emission and $\overline{TQ}_{CO_2}$ is the carbon emission limit.

Total carbon tax revenue (T_{CO_2}) is given by the following equation:

$$T_{CO_2} = \sum_i t_i^d \cdot PD_i \cdot D_i + \sum_i t_i^m \cdot PM_i \cdot M_i \tag{43}$$

where t_i^d is the carbon tax of domestic product by sector and t_i^m is the carbon tax of imported product by sector. These rates are in tern determined as follows:

$$t_i^d = P_{CO_2} \psi_i^d \omega_i^d \tag{44}$$

$$t_i^m = P_{CO_2} \psi_i^m \omega_i^m \tag{45}$$

where, ψ_i^d is the carbon emission coefficient per unit of (domestic) fuel use by sector, ω_i^d is a fossil fuel coefficient per unit of domestic goods by sector, ψ_i^m is the carbon emission coefficient per unit of (import) fuel use by sector, and ω_i^m is the fossil fuel coefficient per unit of import goods by sector and P_{CO_2} indicates price of carbon.

3.6 Database: *Social accounting matrix of Malaysia*

The model is based on a social accounting matrix (SAM) of information system that provides initial information on the structure and composition of production, the sectoral value added and the distribution of value added among factors of production and households. The Input-Output (I-O) table (94x94) of the year 2000 provides the principal data for SAM and main data source for CGE calibrations. The adopted Input-Output table is a transaction table of intermediate inputs grouped by commodity by commodity at producer prices. The parameter values on the other are obtained in such a way that the model's solution for the base year is capable of same reproducing the assembled equilibrium data in the SAM. By imposing this restriction, the parameter values have been determined from outside the SAM manner of the model's solution for the base year. Before doing so, the sectoral classification of the I-O table is redesigned for SAM 2000 to confirm the desired estimation and policy formulation. After some adjustments for balancing the 102x102 SAM are aggregated to 17x17 sectors, among which 10 are production sectors. Table 1 presents the aggregated SAM of the Malaysian Economy

4. Results and discussion

Using the Malaysian CGE model, several environmental policy alternatives are examined from the different policy simulations. This section presents the results obtained from different policy simulations carried out using CGE modeling designed in this study. The simulations carried out are based on SAM of the Malaysian economy of the year 2000 and illustrate the realistic situation of the economy and tried to fit the model as closely as possible. The scenarios are listed in Table 2.

Scenario 1 represents the carbon tax policy impact scenario. This scenario is carried out in three versions where an exogenously determined carbon tax was imposed on domestic products. Implementation of this scenario would allow us to see the possible reduction in CO_2 emissions and its impact on various economic variables such as domestic production, exports, imports, private consumption, gross investment, government revenues, GDP, as well as other incomes, revenues and savings variables.

Table 2 Scenario codes and definition of the simulations

Scenario codes		Simulation specifications
Scenario 1	Scenario 1a	Imposition of carbon tax of domestic product by sector
	Scenario 1b	2 times increase in carbon tax of domestic product by sector
	Scenario 1c	3 times increase in carbon tax of domestic product by sector

4.1 Carbon tax policy simulations

Uncertainties regarding the economic benefit of limiting carbon emissions breed hesitation. In particular, changes in economic activity due to carbon tax lead to significant changes in factor prices, factors of production, consumption pattern, terms of trade and consequently, consumer welfare and gross domestic product. It follows that policy makers would seek to determine how to minimize dampen to the economy while pursuing environmentally sound objectives. This section presents simulation results of imposing carbon tax into the model. The purpose of this exercise is to investigate the implications carbon tax in the Malaysian economy with respect to total domestic production, exports, value-added, real and nominal GDP, investment, fixed capital investment, household consumptions, household savings, enterprise savings, total and government revenue and savings.

4.1.1 *Carbon dioxide emission implications via carbon tax*

Figure 1 illustrates the outcome of imposing a unit carbon tax. Consider the supply and demand of a good where as equilibrium level prior to tax is point A. The quantity produced and consumed is Q_0, and the relevant price is P_m. Total surplus is given by the area MNA. When a unit carbon tax is imposed, the new equilibrium will be B where only Q_1 units will be consumed at price P_c.[6] Total surplus is reduced; the consumer surplus is now MBP_c and the producer surplus is now CP_PN and the government collects revenues represented by the area P_cP_PBC.

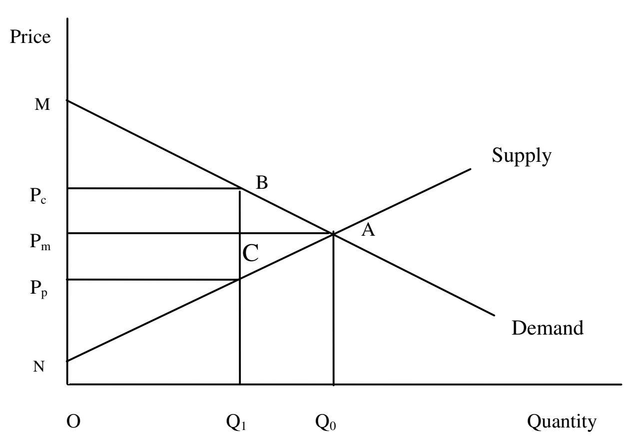

Figure 1 Effects of a carbon tax

[6] It is assumed that emission is linear function of outputs throughout this paper.

To capture the economy-wide effects of an artificial environmental tax policy, a unit carbon tax is imposed on the model where the unit of carbon tax is calculated by multiplying the exogenous carbon tax with the carbon content per unit domestic production. Changes in CO_2 emission is given by the difference between the baseline value and the simulated value. Tables 3 shows the impact of carbon tax on carbon emissions and effects on macroeconomic variables. It should be noted that the effects of the carbon tax presented are for the short run. Generally substitution will occur in the long run thus resulting in changes in energy structure and resources will shift from energy intensive industries to less energy intensive industries.

This study finds that the imposition of carbon tax on domestic production sectors reduce the carbon emissions (first row of Table 3). Simulations 1a, 1b and 1c indicate that imposition of carbon tax result in lower carbon emissions, domestic production, exports, value-added, private consumption, real and nominal GDP, tariff revenue, export tax revenue, enterprise tax revenue, household tax revenue, enterprise savings, and private savings (Table 3). In contrast the government revenue is positive in all versions of scenario 1 and investment share of nominal GDP is positive (1.39%) in version a of scenario 1 but negative in version b (2.22%) and version c (2.63%) from the base level. However, investment and fixed capital investment are higher than the baseline level at low level of carbon tax (scenarios 1a) but is lower than the baseline as the carbon tax becomes higher (scenario 1c).

More specifically, imposition of successively higher carbon tax result in 1.21%, 2.35% and 3.40% reduction in carbon emissions. However, these reductions are also accompanied by 0.82%, 1.90% and 3.17% decrease in nominal and real GDP. Exports decreased by 2.08%, 3.97% and 5.71% while value-added decreased by 2.39%, 3.97% and 4.74%, respectively. Enterprise savings is lower from the baseline by 1.30%, 2.92% percent and 4.80% respectively. However, government revenue increased from the baseline by 26.67%, 53.07% and 79.28 percent respectively. On the other hand, investment and fixed capital investment increased in scenario 1a by 0.56% and 0.43% respectively and fixed capital investment decreased in scenarios 1b and 1c by 0.26% and 1.79% respectively from the baseline (Table 3).

Carbon tax lowers household consumption and savings. Specifically, the simulation results show that for each of the three successively larger carbon tax, household consumptions decreased by 2.32%, 4.84% and 7.48% from the baseline, respectively. Household savings decreased by smaller percentages, i.e., 1.01%, 2.36% and 3.94% respectively for shown in Table 4, the industrial sector has the highest increase from the baseline for scenarios 1a, 1b and 1c. For the respective sub-scenarios, household consumption share of nominal GDP decline by 0.19%, 0.47% and 0.80%.

Table 3 Impact of carbon tax imposition on the Malaysian economy

Sectors	Baseline (100 million RM)	Percentage change from the baseline		
		Scen 1a	Scen 1b	Scen 1c
Carbon dioxide emission*	125.548	-1.212	-2.347	-3.401
Domestic production	8967.691	-1.213	-2.346	-3.401
Exports	4478.429	-2.079	-3.972	-5.707
Value added	3470.867	-2.393	-3.470	-4.736
Household consumption	1175.744	-2.316	-4.836	-7.477
Real GDP	3499.192	-0.817	-1.898	-3.166
Nominal GDP (nGDP)	3500.216	-0.818	-1.898	-3.167
Government revenue	356.898	26.668	53.072	79.281
Investment	968.237	0.555	0.278	-0.624
Fixed capital investment	706.323	0.430	-0.255	-1.788
Tariff	40.370	-2.175	-4.164	-5.992
Export tax	11.028	-2.503	-4.824	-6.955
Enterprise tax	204.856	-1.299	-2.924	-4.796
Household tax	67.843	-1.013	-2.357	-3.937
Enterprise savings	1162.722	-1.299	-2.924	-4.796
Household savings	303.704	-1.012	-2.357	-3.938
HH consumption share of nGDP**	33.078	-0.193	-0.466	-0.795
Investment share of nGDP**	27.662	1.385	-2.220	-2.625

Note: *million tonnes, ** percent

5. Conclusion and policy discussions

In general, as the environmental tax rate goes up, results in quantitatively decrease in production and a steady increase in the price index. Further, the decline in production further causes the investment rate to decrease and the level of pollution generation to decrease. The real gross domestic product (GDP) falls as well, following the decrease in the level of production. The trends observed from our simulations agree with the pollution taxation theory of environmental economics. The simulation finds that 1.21% reductions of carbon emissions reduce the nominal GDP by 0.82%, domestic production by 1.21%, exports by 2.08%, enterprise savings by 1.30%, household consumptions by 2.32%, household savings by 1.01%, and household consumption share of nominal GDP by 0.19%. Likewise, 2.35% reductions of carbon emissions reduce the nominal GDP by 1.90%, domestic production by 2.35%, exports by 3.97%, value added by 3.97%, enterprise savings by 2.92%, fixed capital investment by 0.25%, household savings by 2.36%, and household consumption share of nominal GDP by 0.47. Finally, 3.40% reductions of carbon emissions reduce the nominal GDP by 3.17%, domestic production by 3.40%, exports by 5.71%, value added by 4.74%, enterprise savings by 4.80%, household consumptions by 7.48% percent and household savings by 0.80%. However, the government revenue increases by 26.67% in simulation 1a, 53.07% in simulation 1b and 79.28% in simulation 1c from the base level.

4.1 Policy recommendations

The model results illustrate that the investment losses in the economy tend to rise more sharply as the degree of emission reduction increases[7]. Different degrees of carbon tax decrease the welfare in terms of losses of household consumption, household savings, enterprise consumption and enterprise savings and eventually total economic savings (i.e. see figures of 1a, 1b and 1c). The aggregate production tends to decrease at a proportional rate as the carbon emissions target becomes more stringent (drop by more than 3.4%, in scenario 1c), and the decrease in gross production quite significant. Considering higher carbon tax policy such as version b and c of scenario 1, the simulation illustrates that the macroeconomic impacts could be strongly negative. Higher reductions of pollution emission such as a 2.35% of carbon emissions (scenario 1b) reduce the nominal GDP by 1.90%, domestic production by 2.35%, exports by 3.97%, fixed capital investment by 0.25%, household savings by 2.36% and enterprise savings by 2.92%. And, more reductions of pollution emission such as a 3.40% reduction of carbon emissions (scenario 1c) reduce the nominal GDP by 3.17%, domestic production by 3.40%, exports by 5.71%, household consumptions by 7.48%, household savings by 3.94% and enterprise savings by 4.80%.

While evaluating the simulation results from environmental policies, one should notice that the model only measures the economic gain or loss of an environmental policy. No non-monetary environmental benefits from pollution reduction have been captured by the model. However, the simulation results from this model can be very useful to policy makers for evaluating the economic impacts and pollution reduction effects of a pollution control policy. According to our policy findings, policy-makers could consider first carbon tax policy (scenario 1a). Initial carbon tax reforms (1% CO_2 reduction) results in decrease real GDP 0.82%, however it increases fixed capital investment by 0.43% and investment share of nominal GDP by 1.39% and government revenue by 26.66. And, revenues from the carbon tax can be used for the following purposes: a) the revenue can be used to offset the negative effect on consumption welfare levels; b) they can be financed to adoption of technological change in the long run. This policy results in achieving reasonably good environmental impacts without losing the investment, fixed capital investment, investment share of nominal GDP and government revenue.

This study suggests that an initial carbon tax can be applied for the central purpose of reducing the rate of growth of carbon emissions. Even in the absence of technological change on the Malaysian economy a carbon tax induces general equilibrium effects that offset the further negative effects on the economy. Our findings provide several suggestions and message to policy makers, who are considering carbon taxation policy together with economic development. This study serves as a guide to selection of more feasible and appealing environmental policies, the responses of the Malaysian economy to each policy changes and the relative merits of the range of policies that might be considered for reducing emissions. It may be useful to conclude this study by discussing briefly a variety of interesting future research area which is not analyzed in this study. This model did not consider other

[7] The carbon tax also falls of domestic production, exports, value-added, real GDP, tariff revenue, export tax revenue, enterprise tax, household tax, and enterprise savings.

various pollutants (nitrogen dioxide, sulfur dioxide, methane, and other particulates) which are also related with environmental pollution. An extension of the model offered in this study is to include other pollutants associated with environmental concerns. On the other hand, because of the data limitations (capital composition matrix) this study did not consider the dynamic general equilibrium. The applied approach focuses on structural and causal mechanism at work due to a policy change, but cannot be used to make unconditional projections or forecasts. Dynamic general equilibrium model is incredibly important for forecasting purpose of environment and it is very fruitful for future mitigation and adaptation policy. The dynamic modeling also focuses on the importance of indirect effects based on a large number of cause and effect circles. Further investigation of various capital composition matrices would provide better information to construct dynamic modeling about the economic consequences of environmental policies in the near future.

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Appendix A

The equations, variables and parameters of the CGE model of Malaysia are as follows:

A.1. Price Block

$$PD_i = \widetilde{PD_i}(1+t_i^d)$$
$$PM_i = pwm_i(1+tm_i).ER$$
$$PE_i = pwe_i(1-te_i).ER$$
$$P_i = \left(\frac{PD_iD_i + PM_iM_i}{Q_i}\right)$$
$$PX_i = \frac{PD_i.D_i + PE_i.E_i}{X_i}$$
$$PV_i = \frac{PX_i.X_i(1-tx_i) - PK_i.IN_i}{VA_i}$$
$$PK_i = \sum_j a_{ij}.P_j$$
$$PP = \frac{GDPVA}{RGDP}$$

A.2. Production Block

$$X_i = a_i^D \prod_f FDSC_{if}^{\alpha if}$$
$$WF_f.wfdist_{if} = PV_i.\alpha_{if}\frac{X_i}{FDSC_{if}}$$
$$IN_i = \sum_j a_{ij}.X_j$$
$$X_i = a_i^T[\gamma_i E_i^{\rho_i^T} + (1-\gamma_i)D_i^{\rho_i^T}]^{\frac{1}{\rho_i^T}}$$
$$E_i = D_i\left[P_i^e(1-\gamma_i) \big/ P_i^d.\gamma_i\right]^{1/\rho_i^T}$$
$$E_i = econ_i\left[pwe_i \big/ pwse_i\right]^{\eta_i}$$
$$Q_i = a_i^C\left[\delta_i M_i^{-\rho_i^C} + (1-\delta_i)D_i^{-\rho_i^C}\right]^{-1/\rho_i^C}$$
$$M_i = D_i\left[P_i^d.\delta_i \big/ P_i^m(1-\delta_i)\right]^{1/1+\rho_i^C}$$

A.3. Domestic Institution and Income Block

$$Y_f^F = \sum_i WF_f .FDSC_{if} .wfdist_{if}$$
$$Y_{capeh}^H = Y_1^F - DEPREC$$
$$Y_{labeh}^H = \sum_{f \neq 1} Y_f^F$$
$$TARIFF = \sum_i pwm_i .M_i .tm_i .ER$$
$$INDTAX = \sum_i PX_i .X_i .tx_i$$
$$HHTAX = \sum_h Y_h^H .t_h^H \quad h = cap, lab$$
$$EXPSUB = \sum_i pwe_i .E_i .te_i .ER$$
$$GR = TARIFF + INDTAX + HHTAX + EXPSUB *$$
$$DEPREC = \sum_i depr^i .PK_i .FDSC_i$$
$$HHSAV = \sum_h Y_h^H .(1 - t_h^H).mps_h$$
$$GOVSAV = GR - \sum_i P_i .GD_i$$
$$SAVING = HHSAV + GOVSAV + DEPREP + FSAV .ER$$

A.4. Domestic Institution and Expenditure Block

$$CD_i = \sum_h \left[\beta_{ih}^H .Y_h^H .(1 - mps_h).(1 - t_h^H) \right] / P_i$$
$$GD_i = \beta_i^G .gdtot$$
$$DST_i = dstr_i .X_i$$
$$FXDINV = INVEST - \sum_i P_i .DST_i$$
$$DK_i = kshr_i .FXDINV / PK_i$$
$$ID_i = \sum_j b_{ij} .DK_j$$
$$GDPVA = \sum_i PV_i .X_i + INDTAX + TARIFF + EXPSUB$$
$$RGDP = \sum_i \left(CD_i + GD_i + ID_i + DST_i + E_i - pwm_i .M_i .ER \right)$$

A.5. Systems Constraints Block

$$Q_i = IN_i + CD_i + GD_i + ID_i + DST_i$$
$$\sum_i FDSC_{if} = fs_f$$
$$pwm_i .M_i = pwe_i .E_i + FSAV$$
$$SAVING = INVEST$$

A.6. Carbon Emission Block

$$TQ_{CO_2} = \varphi_{coal} X_{coal} + \varphi_{oil} X_{oil} + \varphi_{gas} X_{gas} \text{ or } TQ_{CO_2} = \sum_i \varphi_i X_i$$

$$T_{CO_2} = \sum_i t_i^d \widetilde{PD}_i D_i + \sum_i t_i^m \widetilde{PM}_i M_i$$

$$P_{CO_2} \geq 0$$

$$t_i^d = P_{CO_2} \psi_i^d \omega_i^d$$

$$t_i^m = P_{CO_2} \psi_i^m \omega_i^m$$

A.7. Indices

i, j	Production sectors
h	Household

A.8. Variables

Variables	Definitions
G_i	Government final demand
D_i	Domestic sales of domestic output
C_i	Final demand for private consumption
E_i	Exports
DEPREC	Total depreciation rate
DK_i	Investment by sector of destination
DST_i	Inventory investment by sector
EXPSUB	Total export taxes or export subsidy
$FDSC_{if}$	Factor demand
FSAV	Foreign savings
FXDINV	Fixed capital investment
GDPVA	Nominal GDP in factor price
GOVSAV	Government savings
GR	Total government revenue
HHSAV	Total household savings
HHTAX	Household tax revenue
ID_i	Final demand for investment goods
INDTAX	Total indirect tax revenue
INT_i	Intermediate input demand
INVEST	Total investment
Y_h^H	Household income
Y_f^F	Factor income
X_i	Domestic output
WF_f	Average output price

TARIFF	Tariff revenue
SAVING	Total saving
RGDP	Real GDP
R	Exchange rate
Q_i	Composite goods supply
PINDEX	GDP deflator
P_i^x	Output price
PW_i^e	World price of export
P_i^v	Value added price
P_i^q	Price of composite goods
P_i^m	Domestic price of imports
P_i^k	Price of a unit of capital in each sector
P_i^d	Domestic sales price
P_i^e	Domestic price of exports
T_{CO_2}	Total carbon tax revenues
TQ_{CO_2}	Total carbon emissions
P_{CO_2}	Carbon price ($/ton)
t_i^d	Carbon tax of domestic product by sector
t_i^m	Carbon tax of import product by sector

A.9. Parameters

Ψ_i^d	Carbon emission coefficient per unit of domestic fuel use by sector
Ψ_i^m	Carbon emission coefficient per unit of import fuel use by sector
ω_i^d	Fossil fuel coefficient per unit of domestic goods by sector
ω_i^m	Fossil fuel coefficient per unit of import goods by sector
a_{ij}	Input output coefficients
a_i^C	CES function shift parameter
a_i^D	Production function shift parameter
a_i^T	CET function shift parameter
$alpha_{if}$	Production function share parameter
b_{ij}	Capital composition matrix
$depr_i$	Depreciation rate
$dstr_i$	Inventory investment ratio
$econ_i$	Export demand shift parameter
$X_{i(coal)}$	Coal by sector
$X_{i(oil)}$	Oil by sector

$X_{i(gas)}$	Gas by sector
fs_f	Aggregate factor supply
$gdtot$	Real government consumption
$kshr_i$	Investment destination share
mps_h	Household savings rate
pw_i^m	World price of imports
$pwse_i$	World price of export substitutes
t_h^H	Household income tax rate
t_i^e	Export tax/subsidy rate
t_i^m	Tariff rate on imports
t_i^x	Indirect tax rate
$wfdist_{if}$	Factor market distortion parameter
α_{ij}	Production function exponent
β_i^G	Government expenditure share
β_{ih}^H	Household expenditure shares
δ_i	CES function share parameter
η_i	Export demand price elasticity
γ_i	CET function share parameter
ρ_i^C	CES function exponent
ρ_i^T	CET function exponent