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A CGE ANALYSIS OF THE ECONOMIC IMPACT OF OUTPUT-SPECIFIC CARBON TAX ON THE MALAYSIAN ECONOMY

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Abstract: Environmental pollution is an emerging issue in many developing countries and its mitigation is increasingly being integrated into national development policies. One approach to mitigate the problem is by implement pollution control policies in the form of pollution tax or clean technology incentives. Empirical studies for developed countries reveal that imposition of a carbon tax would decrease CO_2 emissions significantly and do not dramatically reduce economic growth. However, the same result may not apply for small-open developing countries such as Malaysia. The objective of this study is to quantify the impact of pollution tax on the Malaysian economy under the backdrop of trade liberalization. To examine the economic impact and effectiveness of carbon tax, a single-country, static Computable General Equilibrium model for Malaysia is constructed. The model is extended to incorporate output-specific carbon tax elements. Three simulations were carried out using a Malaysian 2000 Social Accounting Matrix. The first simulation examines the impact of halving the baseline tariff and export duty while the second solely focused on the impact of output-specific carbon tax. The third simulation combines both former scenarios. The model results indicate that the Malaysian economy is not sensitive to further liberalization. The reason could be attributed to the fact that Malaysian export duty is already low. Additionally, simulation results also indicate that while imposition of carbon tax reduces carbon emission, it also results in lower GDP and trade.

Keywords: Trade, Air Emission, Environmental General Equilibrium, Malaysian Economy.

1. INTRODUCTION

Interest in trade liberalization has been growing during the last two decade. This is in part driven by the postulate that international trade leads to higher welfare via economic growth and development. World Bank data show that between 1990 and 2005 imports and exports of commodities had increased from 20% to 30% share of worldwide Gross Domestic Product. However, production and consumption generates environmental damages, either in the form of air and water pollution or depletion of natural resources. Further, with recent emergence of global environmental issues such as climate change, global warming, ozone depletion and acid rain, the assertion that free trade leads to higher welfare becomes questionable.

Now, there are greater scrutiny being placed on trade policies in order to assess the long-term effects of further economic liberalizations on the environment and its sustainability (for example, see Xing and Kostland (2000), Antweiler et al. (2001), Levinson and Taylor (2004), Cole and Elliot (2003), and Cole and Elliot (2005). Some studies that have addressed the role of international trade and its effects on the environment are Wright (1974), Bullard and Herendeen (1975), Herendeen and Bullard (1976), Herendeen (1978), Stephenson and Saha (1980), Strout (1985), Han and Lakshmanan

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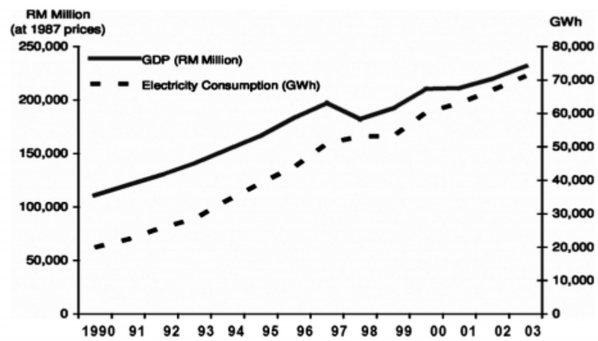
(1994), Wyckoff and Roop (1994), Ferraz and Young (1999), Lenzen (1998), and Wier (1998). Several more recent studies are Antweiler et al. (2001), Machado et al. (2001), Munksgaard and Pedersen (2001), Dietzenbacher and Kakali (2004), Kakali and Debesh (2005), and Al-Amin et al. (2008). The methodologies employed in these studies are wide-ranging; however most results indicate that trade liberalization harms the environment unless accompanied by appropriate mitigation policies. Additionally, these past studies have largely focused on either developed countries or in aggregated world perspective. Little attention has been given to industrializing countries of Southeast Asia, in particular Malaysia.

Malaysia has been experiencing strong economic growth over the last three decades[2]. Among its leading engine of growth is its export-oriented manufacturing sector. Electronics, crude petroleum, palm oil and processed timber are currently among the major foreign exchange earners. Adopting an export-led growth strategy, Malaysia has increasingly diversified its exports in terms of products and markets resulting in large changes in the composition of exports. In consequent to this, Malaysia's total trade expanded by 19.1% per annum during the 7th plan period (1996–2000), 12.6% during the 8th plan period (2001–2005), and is projected to grow at 7.2% during the 9th plan period (2006–2010)[3]. Total trade almost doubled from RM379.3 billion in 1995 to RM685.7 billion in 2000.

Rising income and development in Malaysia also bring about higher energy consumption. In the past two decades, there has been significant growth in the Malaysian energy sector. Primary energy supply in 1991 was 20,611 ktoe (kilo tonnes of oil equivalent) but in 2000 had increased to 50,658 ktoe. In 2003, it further increased to 54,194 ktoe in 2003 (PTM 2003). Final energy demand, which were recorded at 14,560 ktoe and 29,996 ktoe in 1991 and 2000 respectively, increased to 34,586 ktoe in 2003. Electricity demand increased from 22,273 GWh (Giga Watts Hour) in 1991 to 60,299 GWh in 2000 and increased further to 71,159 GWh in 2003 (PTM 2003). Generally, electricity consumption and GDP keep to the same trend. However, as shown in Fig. 1, in recent decades, energy (in particular electricity) intensity per Ringgit of GDP has been rising; all else remaining constant, this implies higher CO2 emission per dollar of GDP. One mitigation method is imposing a carbon tax (carbon dioxide tax) on producers. Since carbon emission is a "bad", a carbon tax is Pigovian if it equals the social cost of carbon emission.

The objective of this paper is to assess the impact of imposing output-specific carbon tax on Malaysian domestic output, trade and income. The impact assessment is done using a static computable general equilibrium (CGE) model of the Malaysian economy based on 2000 social accounting matrix. Three simulations are implemented. The first simulate the impact of a more aggressive liberalization trade policy while the second focused solely on the output-specific carbon tax impact. The third simulation combines both former scenarios.



Source: PTM (2003).

Fig. 1: Trends in GDP and Electricity Consumption in Malaysia, 1990–2003

The organization of this paper is as follows. The next section describes the structure of the CGE model. Section 3 briefly discusses the three scenarios and is followed by discussion on simulation results in Section 4. The final section concludes this paper.

2. THE STRUCTURE OF CGE MODEL FOR THE MALAYSIAN ECONOMY

The basic model consists of ten industries, four institutional agents, two primary factors production, and the rest of the world (ROW). The ten sectors were aggregated from the 2000 Malaysian Input-

[2] Exception was during the Asian financial crisis from 1997 to 2000.

[3] Beginning 1965, Malaysia's overall development goals and broad development strategies are stated in series of 5-year plan books known as the Malaysia Plan. The 1st Malaysia Plan started in 1965. The latest of the sequence is the 9th Malaysia Plan (2006–2010).

Output Table that initially comprised of 94 sectors. Each sector produces a single composite commodity for the domestic market and for ROW. There are four domestic final demand sectors. They are household, enterprise, government and an agent that allocate savings over investment demand from all production sectors. These institutions obtain products from both domestic production sectors and ROW (imports).

All producers are assumed to maximize profits and each faces a two-level nested Leontif/Cobb-Douglas production function. Each commodity is produced by Leontief technology using primary inputs (labour and capital) and intermediate inputs from various production sectors. The primary inputs are determined by Cobb-Douglas production function. To capture features of intra-industry trade for a particular sector, domestic products and products from the ROW within the sector are assumed to be imperfect substitutes and their allocations are determined according to Armington CES (constant elasticity of substitution) function. On the supply side, output allocation between the domestic market and ROW are according to Powell and Gruen's constant elasticity of transformation (CET) function. On the demand side, a single household is assumed. The household is assumed to maximize utility according to Stone-Geary utility function subject to income constraint. Consumption demand for a sector's product is also a CES function of the domestically produced and imported product.

Sectoral capital investment is assumed to be allocated in fixed proportions among various sectors and is exogenously determined. Similarly, government expenditure are also exogenously determined. In terms of macroeconomic closure, factors are assumed mobile across activities, available in fixed supplies, and demanded by producers at market-clearing prices. Factor incomes are distributed on the basis of fixed shares (derived from base-year data) and are passed on in their entirety to the households; Outputs are demanded by the final demand agents at market-clearing prices. Appendix A presents the mathematical structure of the model.

3. SCENARIOS OF TRADE LIBERALIZATION AND CARBON TAX

The simulations carried out are based on year 2000 Social Accounting Matrix of the Malaysian economy where the original 94 production sectors are aggregated into ten sectors. The sectors are: 1. agriculture, 2. mining and quarrying, 3. industry, 4. electricity and gas, 5. buildings and constructions, 6. wholesale and retail trade, 7. hotels, restaurants and entertainment, 8. transport, 9. financial services and real estate, 10. other services. All parameter were calibrated to obtain the actual baseline solution.

Scenario 1 represents a more aggressive liberalization policy where tariff and export duty are halved. This scenario is carried out to see the macroeconomic impacts and environmental effects of trade liberalization. Results from this scenario will show how much environmental impact would arise as a consequent of reducing export duty and import tariff to zero as well as showing the possible gain/losses in government revenues. For the calculation of carbon emission from domestic production activities, due to lack of detail data, it is assumed that CO_2 emission intensity per Ringgit of output for all sectors is 0.14 (toe/RM)(or 0.014 million MT of CO_2 per RM100 million of output) and that CO_2 emission is a linear function of output[4].

Scenario 2 examines the impact of carbon tax without further liberalization. This scenario is implemented with an output-specific carbon tax imposed on domestic products. Implementation of this scenario would allow us to see the possible impact of carbon tax on reduction of CO_2 emission and on various economic variables such as domestic production, exports, imports, private consumption, and GDP. The output-specific carbon tax imposed is RM0.11 per tonne of carbon emission. Derivation of the tax is presented in Appendix B.

Scenario 3 simulates the combined effect of trade liberalization and imposition of carbon tax on the economy. This scenario is simulated see the impact of interaction of between liberalization and carbon tax on the macroeconomic and environmental variables in the Malaysian economy.

4. RESULTS AND DISCUSSION

4.1 Scenario 1

Results from this simulation indicate that total domestic output increased in all production sectors, except "financial services and real estate", "other services", and "building and construction" (Table 1). The industrial sector has the highest increase from the baseline (0.56%) while the hotel, restaurant and entertainment sector has the least increase (0.15%).

[4] Read Abdul Hamid et al. (2008) for explanation.

On the demand side, the model results confirmed the assertion that trade liberalization increased household consumption. The highest consumption increase is in industrial output (0.22 percent or RM74 million), followed by output from the transport sector (0.19% or RM34 million). The total increase in domestic consumption is about RM200 million. On the other hand, the decreased in government's revenue is RM1, 456 million.

The combined effects of tariff and export tax reduction in higher total trade but with small net export due to higher import. At the same time, government revenue and savings, and other macroeconomic variables declined (Table 2). Table 3 presents impacts of liberalization on CO_2 emissions. Figures in the table indicate that, in percentage terms, those sectors that expand as a result of liberalization also emit more CO_2.

Table 1
Impacts of Trade Liberalization on Domestic Output and Household Consumption

Sectors	Baseline (RM100 mill)	Percent change	Baseline (RM100 mill)	Percent change
Agriculture	375.52	0.28	73.39	0.16
Minig and quarrying	438.14	0.25	0.00	–
Industry	4,953.85	0.55	335.31	0.22
Electricity and gas	173.45	0.30	40.72	0.17
Buildings and constructions	450.14	–1.46	2.13	0.09
Wholesale and retail trade	523.32	0.28	24.14	0.17
Hotels, restaurants and entertainment	210.30	0.15	147.84	0.14
Transport	520.00	0.20	179.78	0.19
Financial services and real estate	825.92	–0.34	265.43	0.16
Other services	497.06	–0.03	107.00	0.05

Table 2
Impacts of Trade Liberalization on Income

Sectors	Baseline (RM100 million)	Percent change
GDP	3,500.22	–0.44
Government revenue	356.90	–4.08
Investment	968.24	–1.39
Fixed capital investment	706.32	–1.88
Tariff	40.37	–50.00
Export tax	11.03	–50.00
Enterprise tax	204.86	0.09
Household tax	67.84	–0.04
Enterprise savings	1,162.72	0.09
Household savings	303.70	–0.04

Table 3
Impacts of Liberalization on CO_2 Emission

Sectors	Baseline (million MT)	Percent change
Agriculture	5.26	0.29
Mining and quarrying	6.13	0.25
Industry	69.35	0.55
Electricity and gas	2.43	0.33
Buildings and constructions	6.302	–1.46
Wholesale and retail trade	7.33	0.27
Hotels restaurants and entertainment	2.99	–1.50
Transport	7.28	0.19
Financial services and real estate	11.56	–0.35
Other services	6.96	–0.03

4.2 Scenario 2

Table 4 shows the impact of carbon tax on carbon emission 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 resulting in changes in energy mix and shifting of resources from energy intensive industries to less energy intensive industries or from energy intensive technologies to less energy intensive technologies.

More specifically, imposition of carbon tax result in lower carbon emissions by 1.21% but at the same time GDP decreased by 0.82%, exports by 2.08%, value-added by 2.39% while enterprise savings is lower from the baseline by 1.30%. The simulation results also show that household consumption decreased by 2.32% (or RM2,728 million) from the baseline while household savings decreased by 1.01%. However, government revenue increased from the baseline by 26.67% (RM9,518 million).

4.3 Scenario 3

Relative to the base line, this policy mix results in similar outcome as in Scenario 2. That is, all variables undergo negative change except government revenue (Table 5). Specifically, carbon emission is decreased by almost one percent, GDP decreased by 1.26%. Exports decreased by 1.58% while value-added decreased by 0.84%. The effects of trade liberalization and carbon tax policy result in reduced household consumptions and savings by 2.16% (RM2,540 million) and 1.07% respectively. However, government revenue increased by 22.66% (RM8,087 million).

Table 4
Impacts of Carbon Tax on Domestic Output and Household Consumption

Sectors	Baseline (RM100 million)	Percent change
Domestic production	8,967.69	–1.21
Exports	4,478.43	–2.08
Value added	3,470.87	–2.40
Household consumption	1,175.74	–2.32
GDP	3,500.22	–0.82
Government revenue	356.90	26.67
Investment	968.24	–0.56
Fixed capital investment	706.32	–0.43
Tariff	40.37	–2.18
Export tax	11.03	–2.50
Enterprise tax	204.86	–1.30
Household tax	67.84	–1.01
Enterprise savings	1,162.72	–1.30
Household savings	303.70	–1.01
Carbon dioxide emission*	125.55	–1.21

Note: *Million tonnes.

Table 5
Of Liberalization and Carbon Tax on Domestic Output and Household Consumption

Sectors	Baseline (RM100 million)	Percentage change
Domestic production	8967.69	–0.96
Exports	4478.43	–1.58
Value added	3470.87	–0.84
Household consumption	1175.74	–2.16
GDP	3500.22	–1.26
Government revenue	356.90	22.66
Investment	968.24	–0.85
Fixed capital investment	706.33	–1.46
Tariff	40.37	–50.00
Export tax	11.03	–50.00
Enterprise tax	204.86	–1.22
Household tax	67.84	–1.07
Enterprise savings	1162.72	–1.22
Household savings	303.70	–1.07
Carbon dioxide emission*	125.55	–0.96

Note: *Million tonnes.

4. CONCLUSION AND DISCUSSION

Carbon dioxide in the atmosphere is a greenhouse gas because it traps heat re-radiated from the Earth's surface, thus causing global warming. Since the carbon content of fossil fuel are converted to carbon dioxide when burned, carbon tax essentially is a tax on the carbon content of fossil fuels (coal, petroleum—automobile gasoline, diesel and jet fuel, and gas) that release CO_2 emission into the atmosphere when burned. It an indirect tax because it is imposed at the transaction level and not on income. How much is the tax burden borne by the consumers will depend on the extent that that the market condition allow. The idea behind output-specific carbon tax is similar to the conventional flat rate carbon tax. That is, it will encourage the development of product specific carbon-reducing measures such as increasing energy efficiency (energy efficient light bulbs) and use of renewable energy (for example wind and solar energy) and/or low-carbon fuel (such as biofuel).

In this study, simulation results indicate that although further liberalization results in higher household consumption and lower carbon emissions, other variables such as net export, government revenue, and GDP are lower. In this scenario, most domestic sectors expanded marginally (less than one percent) while three sectors shrank (between 0.03% and 1.46%). Consumption on the other hand, increased by about RM200 million which in turn would become a catalyst for further economy growth.

In the case of imposing carbon tax only, or carbon tax along with liberalization, the simulation results showed that in spite of attaining lower carbon emission and higher government revenue, all other variables are lower. Despite the many negative impacts (especially the negative private consumption and saving effect), administering a carbon tax in Malaysia is still warranted for its long run benefits and still plausible if softening measures were undertaken.

Scenario two and three indicated that revenue raised from the carbon tax is considerable more than the decline in consumption. To soften the impacts and at the same time encourage firms to lower the carbon intensities in their output, the carbon tax should be kept neutral by returning the tax revenue back to consumers dollar-for-dollar via either tax rebate or by reducing/replacing existing tax. Alternatively, the revenue could be spent on promoting conservation-based behavior to consumers; such as encouraging consumers to switch to public transportation, or vehicle that utilize low-carbon fuel or recycling. At the industry side, softening measures could be done in the form of subsidy (or tax rebate) to firms for increasing energy efficiency, or utilization of renewable energy or low-carbon fuel.

APPENDIX A

Mathematical structure of the model

A. The Price Block

A.1 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 PDD_i as follows:

$$PD_i = PDD_i\,(1 + t_i^d) \qquad \text{... (A1)}$$

A.2 Import and Export Price

Domestic price of imported goods PM_i, is the tariff induced market price times exchange rate (ER):

$$PM_i = pwm_i\,(1 + tm_i) \cdot ER \qquad \text{... (A2)}$$

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

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

$$PE_i = pwe_i\,(1 - te_i) \cdot ER \qquad \text{... (A3)}$$

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

A.3 Composite Price

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

$$P_i = \left(\frac{PD_i D_i + PM_i M_i}{Q_i} \right) \qquad \text{... (A4)}$$

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.

A.4 Activity Price

The sales or activity price PX_i is composed of domestic price of domestic sales and the domestic price of exports where:

$$PX_i = \frac{PD_i \,.\, D_i + PE_i \,.\, E_i}{X_i} \qquad \text{... (A5)}$$

where X_i stands for sectoral output.

A.5 Value Added Price

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

$$PV_i = \frac{PX_i \cdot X_i\,(1 - tx_i) - PK_i \cdot IN_i}{VA_i} \qquad \text{... (A6)}$$

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.

A.6 Composite Intermediate Input Price

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

$$PK_i = \sum_j a_{ij} P_j \qquad \text{... (A7)}$$

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

A.7 Numeraire Price Index

Relative price numeraire is:

$$PP = \frac{GDPVA}{RGDP} \quad \text{... (A8)}$$

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

B. Production Block

Sectoral output X_i is express as:

$$X_i = a_i^D \prod_f FDSC_{if}^{\alpha_{if}} \quad \text{... (A9)}$$

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:

$$WF_f . wfdist_{if} = PV_i . \alpha_{if} \frac{X_i}{FDSC_{if}} \quad \text{... (A10)}$$

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 functions of domestic production and defined as follows:

$$IN_i = \sum_j a_{ij} \cdot X_j \quad \text{... (A11)}$$

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

$$X_i = a_i^T [\gamma_i E_i^{\rho_i^T} + (1-\gamma_i) D_i^{\rho_i^T}]^{\frac{1}{\rho_i^T}} \quad \text{... (A12)}$$

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 depends on relative price (P^e/P^d) as follows:

$$E_i = D_i \left[\frac{P_i^e (1-\gamma_i)}{P_i^d . \gamma_i} \right]^{1/\rho_i^T} \quad \text{... (A13)}$$

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

$$E_i = econ_i \left[\frac{pwe_i}{pwse_i} \right]^{\eta_i} \quad \text{... (A14)}$$

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

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

$$Q_i = a_i^C \left[\delta_i M_i^{-\rho_i^C} + (1-\delta_i) D_i^{-\rho_i^C} \right]^{-1/\rho_i^C} \quad \text{... (A15)}$$

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) as follows:

$$M_i = D_i \left[\frac{P_i^d . \delta_i}{P_i^m (1-\delta_i)} \right]^{1/(1+\rho_i^C)} \quad \text{... (A16)}$$

C. Domestic Institution Block

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

$$Y_f^F = \sum_i WF_f \cdot FDSC_{if} \cdot wfdist_{if} \quad \text{... (A17)}$$

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:

$$Y_{capeh}^H = Y_1^F - DEPREC \quad \text{... (A18)}$$

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:

$$Y_{labeh}^H = \sum_{f \neq 1} Y_f^F \quad \text{... (A19)}$$

where Y_f^F is the factor incomes.

Tariff equation TARIFF is expressed as follows:

$$TARIFF = \sum_i pwm_i \cdot M_i \cdot tm_i \cdot ER \quad \text{... (A20)}$$

Similarly, the indirect tax INDTAX is defined as:

$$INDTAX = \sum_i PX_i \cdot X_i \cdot tx_i \quad \text{... (A21)}$$

Likewise, household income tax is expressed as:

$$HHTAX = \sum_h Y_h^H \cdot t_h^H \quad (h = cap, lab) \qquad \text{... (A22)}$$

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

Export subsidy EXPSUB (negative of export revenue) is:

$$EXPSUB = \sum_i pwe_i \cdot E_i \cdot te_i \cdot ER \qquad \text{... (A23)}$$

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

$$GR = TARIFF + INDTAX + HHTAX + EXPSUB \qquad \text{... (A24)}$$

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

$$DEPREC = \sum_i depr_i \cdot PK_i \cdot FDSC_i \qquad \text{... (A25)}$$

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:

$$HHSAV = \sum_h Y_h^H \cdot (1 - t_h^H) \cdot mps_h \qquad \text{... (A26)}$$

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

$$GOVSAV = GR - \sum_i P_i . GD_i \qquad \text{... (A27)}$$

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

$$SAVING = HHSAV + GOVSAV + DEPREP + FSAV \cdot ER \qquad \text{... (A28)}$$

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:

$$CD_i = \sum_h \left[\beta_{ih}^H \cdot Y_h^H \, (1 - mps_h)\,(1 - t_h^H)\right] / P_i \qquad \text{... (A29)}$$

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:

$$GD_i = \beta_i^G \cdot gdtot \qquad \text{... (A30)}$$

where β_i^G is the sectoral government expenditures.

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

$$DST_i = dstr_i . X_i \qquad \text{... (A31)}$$

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:

$$FXDINV = INVEST - \sum_i P_i . DST_i \qquad \text{... (A32)}$$

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

$$DK_i = kshr_i . FXDINV / PK_i \qquad \text{... (A33)}$$

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:

$$ID_i = \sum_j b_{ij} . DK_j \qquad \text{... (A34)}$$

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:

$$GDPVA = \sum_i PV_i . X_i + INDTAX + TARIFF + EXPSUB \qquad \text{... (A35)}$$

$$RGDP = \sum_i \begin{pmatrix} CD_i + GD_i + ID_i + DST_i + E_i - \\ pwm_i \cdot M_i \cdot ER \end{pmatrix} \qquad \text{... (A36)}$$

D. Systems Constraints Block

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

$$Q_i = IN_i + CD_i + GD_i + ID_i + DST_i \quad \text{... (A37)}$$

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 is expressed as follows:

$$\sum_i FDSC_{if} = fs_f \quad \text{... (A38)}$$

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. Equilibrium will be achieved through movements in ER that effect export import price. This balancing equation is expressed as:

$$pwm_i \cdot M_i = pwe_i \cdot E_i + FSAV \quad \text{... (A39)}$$

Lastly the macro-closure rule is given as:

$$SAVING = INVEST \quad \text{... (A40)}$$

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

E. Carbon Emission

The aggregate CO_2 emission is formulated as follows:

$$TQ_{CO_2} = \sum_i \varphi_i X_i \quad \text{... (A41)}$$

where TQ_{CO_2} is the total CO_2 emission and φ_i is the carbon intensity per output.

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

$$T_{CO_2} = \sum_i t_i^d \cdot PD_i \cdot D_i + \sum_i t_i^m \cdot PM_i \cdot M_i \quad \text{... (A42)}$$

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.

APPENDIX B

Carbon tax calculation:

In this paper, the size of carbon tax was calculated as follows:

Let t_i^d (RM/tonne) be the output-specific carbon tax on domestic product by sector i.

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

where P_{CO_2} (RM/tonne) is price of carbon (i.e. the assumed social cost of carbon).

ψ_i^d (RM/toe) is the carbon emission coefficient per unit of fuel use by sector i.

ω_i^d (toe/RM) is a fossil fuel coefficient per unit of domestic goods by sector i.

A. Price of Carbon (P_{CO_2}):

It is assumed that the social cost of carbon is RM752 (US \$ 1 = 3.5 RM) per tonne of carbon.

B. Fossil Fuel Coefficient (ω_i^d)

The fossil fuel coefficient per unit of domestic good is energy use in the sector divided by the sectoral output. Simplifying by averaging across all sectors. Then

$$\omega_i^d = 16{,}500{,}246/896{,}827{,}793 = 0.018398 \text{ (toe/RM)}$$

C. Carbon Emission Coefficient Per Unit of Fuel use (ψ_i^d)

Method of calculation is based on Umed Temurshoev and Kakali Mukhopadhy.

C.1 Carbon Emission from Oil and Gas

Average carbon emission from oil and gas = (carbon emission factor) × (proportion of carbon oxidized) (molecular weight ratio) × (oil-to-RM ratio).

Therefore, average carbon emission from oil and gas = 0.77 × 0.9925 (44.01/12.011) × 0.0017 = 0.0047.

C.2 Carbon Emission from Coal

Carbon emission from coal = (carbon emission factor) × (proportion of carbon oxidized) × (molecular weight ratio) × (oil-to-RM ratio).

Therefore, carbon emission from coal = 0.55 × 0.98 × (44.01/12.011) × 0.0057 = 0.01124462.

Therefore, average carbon emission coefficient per unit of fuel use by sector in the Malaysian economy is (ψ_i^d): (0.0047 + 0.01124462)/2 = 0.0079722.

Finally, $t_i^d = P_{CO_2} \psi_i^d \omega_i^d$
= 752 × 0.0079722 × 0.018398
= 0.110302 (RM/tone of carbon).

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