

A General Equilibrium Model for Energy Policy Evaluation using GTAP-E for Vietnam

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Abstract:

In this paper, a computable general equilibrium model (CGE) using GTAP-E for Vietnam is presented based on the GTAP Data Base version 7. The model is developed following the original structure of GTAP-E model (Burniaux and Truong 2002) and the revised version of the GTAP-E model (Mc Dougall and Golub 2007). Further, as a second step, a dynamic GTAP-E model is developed based on the theoretical structure of dynamic GTAP and the GTAP-E model for Vietnam for the period of 2004-2025. The model is used to simulate the adoption of alternative carbon tax for Vietnam for the based year of 2004 and for the period of 2008-2025. The economy-level and detailed sector-specific effects are also examined considering energy intensive and non-intensive sectors. As a matter of fact, this is the first simulation of energy-environmental policy for Vietnam using the updated version of the GTAP-E.

Key words: *Computable General Equilibrium (CGE), GTAP, GTAP-E, Carbon Tax*

1. Introduction

In the last ten years, several emerging countries including Vietnam experienced dramatic economic growth rate. As a result, energy demand in these economies has been increasing rapidly, which leads to the concern of climate change and the shortage of energy resources. In this context, energy system analysis has become an urgent issue due to the growing concerns related to climate change, land use, differentiation of energy sources and energy prices. The issue related to environmental and energy policies have attracted a lot of studies both in term of technological and economy-wide impacts. There are two approaches to deal with the problem: bottom-up model and top-down model. The bottom-up approach includes technologies in detail, both on the supply side and on the demand side. The top-down model represents micro-economic responsiveness to policies and on this basis, addresses the consequences of policies in terms of public finance, economic competitiveness and employment effect. Due to that difference, in the middle of 90s, a hybrid approach of the two above models has started to emerge.

Among top-down models, Computable General Equilibrium (CGE) models have assumed particular importance. One of the Computable General Equilibrium (CGE) models known as The Global Trade Analysis Project (GTAP) is a global project aiming at facilitating high quality quantitative analysis of the global economic issues. The main products of the GTAP are the global database (the GTAP Data Base) and the global economic model (the standard GTAP model) to conduct policy simulations with the GTAP Data Base. The standard GTAP model is a comparative static multi-regional computable general equilibrium model of the world economy written in the GEMPACK software that was developed by the Centre of Policy Studies, MONASH University. The GTAP-E model is an extension of a standard GTAP model constructed by the Global Trade Analysis Project (GTAP) team. The model incorporated energy substitution both for inter-fuel and fuel-factor substitution into the Standard GTAP model. The new features allow the estimation of sectoral energy consumptions by fuel type - one important step to estimate carbon emission from fuel combustion. The model assumes that capital and energy composite are substitutable to a certain extent and form capital –energy composite. Different types of energy are nested at several levels based on their substitutability. Aside from energy substitution modules, several others modules are also presented.

Since the present of original GTAP-E model developed by Burniaux and Truong (2002), there are number of studies utilized the structure of this model and the revised version for policy analysis of climate change. Nijkamp et al (2005) analyzed the modeling strategies that go beyond the original structure of GTAP-E model in order to incorporate the three climate change instruments¹. Peterson and Schleich (2007) in their paper analyzed the economic and environmental effects of alternative border tax adjustment (BTA) mechanism using an extended version of the GTAP –E model. The results show that the implementation of a BTA has little effect on the marginal abatement costs of achieving the emission reductions in the Kyoto Protocol and does little in reducing carbon leakage. Truong et al. (2007) revised the original paper of GTAP-E model. By incorporating carbon emissions from the combustion of fossil fuels, this revised version of GTAP-E provides a

¹ International Emission Trading (IET), Joint Implementation (JI) and Clean development Mechanism (CDM)

mechanism to trade these emissions internationally as well as domestically. The policy relevance of GTAP-E in the context of existing debate about climate change is illustrated by some simulations of the implementation the European emission trading scheme in 2005. Kemfert et al. (2006) analyzed the effects of emissions trading in European, with special reference to Germany. The analysis is undertaken with a modified version of the GTAP-E using the GTAP version 6 data base. The results shows that Germany, Great Britain and the Czech Republic are the main seller of emissions permits, while Belgium, Denmark, Finland and Sweden are the main buyers. The welfare gains from regional emissions trading are largest for Belgium, Denmark and Great Britain; smallest for Germany. Taking into account the economy-wide and terms –of-trade effects of emissions trading, however, terms-of-trade effects can offset the allocated efficiency gains for the cases of the Netherland and Italy, while all other regions end up with positive net welfare gains. All regions experienced increases in real GDP as a result of regional emissions trading. Tommasino and Martini (2010) introduced carbon tax for Italy using a modified version of GTAP-E with data taken from the GTAP 7 Data Base. The model then would be linked with a bigger model named: Integrating bottom-up and top-down energy models, the case of GTAP-E and Markal – Italy. Niemi and Honkatukia (2011) reported analyses the effects of EU emissions trading schemes on the Nordic energy intensive industries. Based on the modified version of the dynamic GTAP and a long-run baseline, the analysis covers CO₂ mitigation costs and their impacts on industry competitiveness, the risk of carbon leakage, and the combined effects from energy efficiency improvements. The paper also evaluates the effect of subsidies allowed in the EU emission trading directive to industries for compensation of the loss of competitiveness.

The literature survey shows the lack of using dynamic GTAP-E for carbon taxation studies, especially studies applied for Vietnam. In this paper, a new version of GTAP-E model based on the latest GTAP data (GTAP 7, with the base year of 2004) is introduced. The new version is also constructed with a regional mapping where Vietnam is disaggregated. Further, as a second step, a dynamic GTAP-E model is developed based on the theoretical structure of dynamic GTAP and the GTAP-E model for Vietnam for the period of 2004-2025. The model is used to simulate the adoption of alternative carbon tax for Vietnam for the based year of 2004 and for the period of 2008-2025. The economy-level and detailed sector-specific effects are also examined considering energy intensive and non-intensive sectors.

2. The Standard GTAP model and the GTAP-E model

2.1. The Standard GTAP model

The standard GTAP model describes accounting relations and behavioral equations of households and firms in each region as well as in hypothetical global sectors which are introduced to complete the model. In fact, the theory of GTAP model is similar to other Applied General Equilibrium models. The systems of GTAP comprise of two different types of equations. The first system covers the accounting relationship which ensures that receipts and expenditures of every agent in the economy are balanced. The second system consists of behavioral equations based upon microeconomic theory which specify the behavior of optimizing agent (production and demand function).

Figure 1 offers an overview of economic activity of the GTAP model. The regional household is assumed for each region. Its behavior is described by an aggregate utility function. The regional household can earn factor income by providing factors (labor, capital, land and natural resources) to the firms and receive net taxes. Then, it allocates the whole income to composite government purchases, composite private consumption and savings. In the second level of allocation, government demands across composite goods are specified as a Cobb-Douglas function, while private household demands are specified as a constant difference of elasticities function. Company behavior is governed by the zero profit condition that results from profit maximization under the competitive market assumption. Production technologies can be described as a production tree with several levels of nesting. The model assumes two global sectors - the global transportation sector (not included in the figure) and the global banking sector. The global transportation sector provides the international transport service that accounts for the difference between the FOB (free-on-board) value and the CIF (cost, insurance and freight) value of traded commodities. Due to lack of information about the price of international transport services of particular commodities and routes provided by a particular region, the price of the global transport service is a blend of the prices all transport services provided by all the regions. The global banking sector intermediates between global savings and investment. This sector receives net investment from all the regions and offers composite investment at a common price to regional households corresponding to their savings demand. In other word, this global banking sector represents neoclassical macroeconomic closure in which global investment is allowed to adjust to maintain macroeconomic accounting identities at the global level.

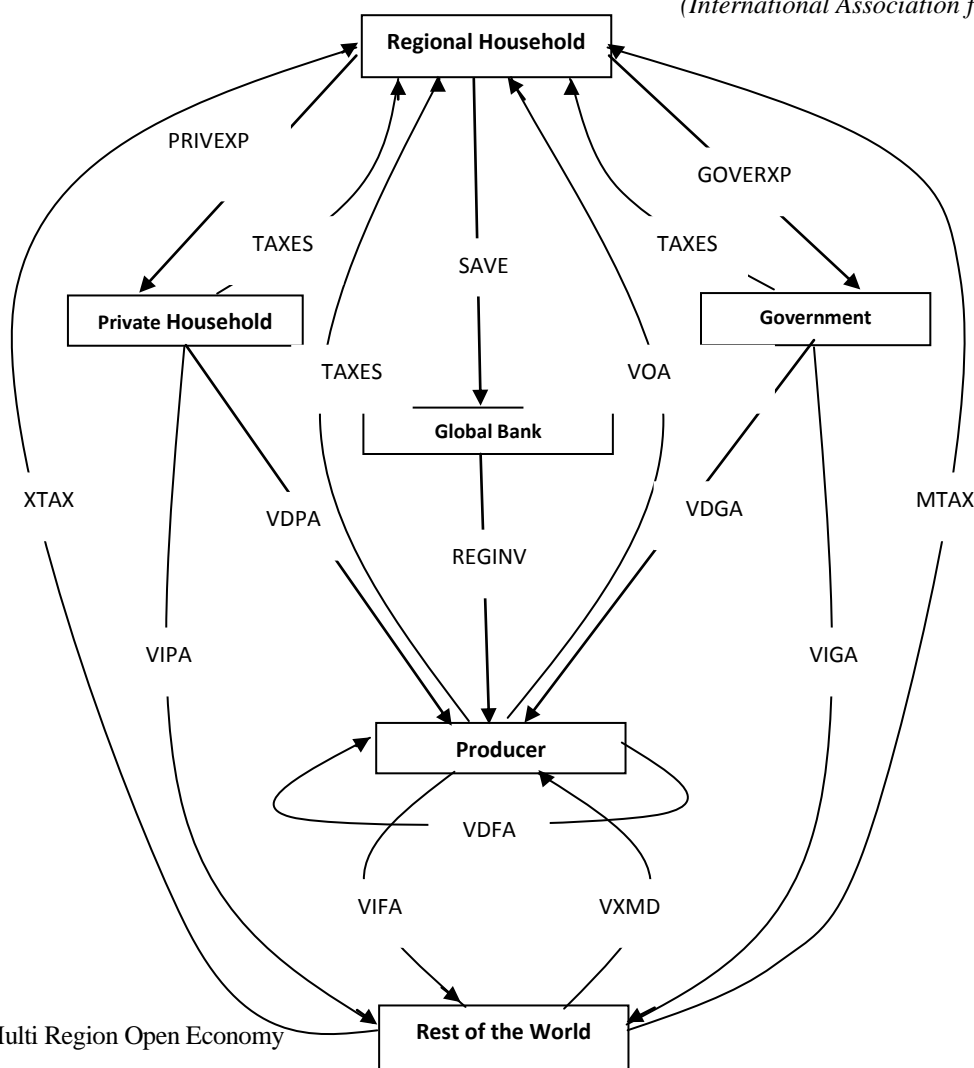


Figure 1. Multi Region Open Economy

Source: Brockmeier, 1996

SAVE	Net saving, by region
PRIVEXP	Private consumption expenditure in region r
TAXES	Different kind of taxes or subsidies
GOVEXP	Government consumption expenditure
VOA	Value of commodity i output in region r at agent price
NETINV	Regional net investment
VDPA	Domestic purchases, by household, at agent's prices
VDGA	Domestic purchases, by government, at agent's prices
MTAX	Tax on imports on good i from source r in destination s
XTAX	Tax on exports on good i from source r in destination s
VIPA	Import purchases, by households, at agent's prices
VIGA	Import purchases, by government, at agent's prices
VDFPA	Domestic purchases, by firms, at agent's prices
VIFA	Import purchases, by firm, at agent's prices
VXMD	Non-margin exports, at market prices

2.2. The GTAP-E model

The GTAP-E model is an energy-environmental version of the standard GTAP model based on the GTAP version 5 data base. The main change in GTAP-E compared with the traditional GTAP model is given by including the possibility of substitution of energy inputs in production and consumption. Energy substitution is incorporated in the structure of the GTAP-E model both in the production and consumption structure. The revised version of the energy environmental

extension of GTAP-E (Burniaux and Truong, 2002) is documented in Research Memorandum No.15 (Mc Dougall and Golub, 2007). The revised model is not only improved but also is adapted to a wider range of energy-environmental policy scenarios. Specifically, emission data, emission trading, carbon taxation, revenue from emission trading, production structure and welfare decomposition are renewed. Those are related to the revisions of the solution program, data, stored input and command files.

3. Using GTAP-E model for the case of Vietnam, the static model

3.1. Methodology

The GTAP-E model for Vietnam utilizes the structure of the original paper of GTAP-E which is developed by Burniaux and Truong (2002) and then revised by Mc Dougall and A. Golub (2007). In fact, the revised version of GTAP-E is the modified version the original GTAP-E and it has several advantages. First, the emissions trading and emission constrains has been modeled based on the newly created trading blocs. Then the CO₂ emissions are calculated following a bottom up approach which is derived from energy consumption. This methodology is different from the way CO₂ emissions are aggregated in the original GTAP-E (2002) which is not closely related to energy consumption. In the revised GTAP-E model, carbon taxation is modeled by introducing trading bloc, nominal carbon tax and real carbon tax as well as the relationship between them. The production structure in the 2007 version of GTAP-E is re-organized, grouping equations by nest. Further, a more effective way to calculate the contribution of permit trading revenue to welfare change is presented in the new version. Based on the arguments above, the revised version of GTAP-E is chosen for the analysis of Vietnamese case.

The determination of the number of sectors and regions to be aggregated is another step in the process of building a GTAP-E version. According to the GTAP-E approach, energy sectors should be presented, including coal, crude oil, gas (natural gas and gas distribution and manufacture), petroleum and refined oil products, and electricity. Energy intensive sectors, non-intensive sectors or sectors which might emit relatively more CO₂ as described on the IEA Energy Balances are also categorized. Specifically, 57 old sectors are mapped over to 17 new sectors. As for regional aggregation, Vietnam is disaggregated from the Data Base. Other regions are similar to the mapped regions in the original GTAP-E model. In fact, 113 old regions are mapped to 9 new regions.

3.2. Data

The data of the model are mainly taken from the GTAP 7 Data Base which is in the file named as BASEDATA.HAR and GSDVOL.HAR. Since the data structure of GTAP-E are not similar to that of the Standard GTAP, GEMPACK program is also utilized to create the aggregated data in addition to Flexagg7 or GTAPAgg7 program (used to make the aggregated data for Vietnam case). As a matter of fact, users can use programs such as TABLO, MOHAR or VIEWHAR to create the data. In this process, WIEWHAR is used to construct the data base for the GTAP-E Vietnam because of its advantages. The most important issue for the GTAP-E model is the inclusion of the energy and CO₂ emission data, which define the differences between standard GTAP and GTAP-E model. The energy data in the revised GTAP-E model bases on the GTAP 6 Data base. It is necessary to update this IEA energy data expressed in MTOE (the base year was 1997) to the more recent GTAP version 7 Data base (whose base year is 2004). The revised GTAP-E model contains the volume of domestic energy production in MTOE for each region under data header named DVOL. In order to obtain the volume of domestic energy production in MTOE using the GTAP Version 7 Data base (file name gsdvole.har), the difference between the volume of energy demand in MTOE (volume purchases by firms and by household) plus the volume of energy commodities export in MTOE minus the volume of import in MTOE for each region are calculated.

In terms of CO₂ emissions, the emissions data is prepared following Ludena (2007) approach, using two main data sources: CO₂ emissions data from Lee (2008) and the GTAP Version 7 Data Base. Specifically, first, the emission data related to consumption of imported energy commodities by firms and household not included in Lee (2008) Data Base is calculated by applying the proportions of the imports and domestic volumes for each commodity. In fact, Lee's CO₂ emissions data are calculated from the energy volume data of the GTAP Version 7 Data Base, categorizing by fuels, region and users (sectors) but with no distinction of emissions from energy consumptions of domestic good or imported good. In this process, natural gas (gas) and gas manufacture and distribution (gdt) are combined in order to avoid the minus numbers which are not possible in reality. Then, the WIEWHAR program in GEMPACK version 10 is utilized to build the data which is suitable for the new version of GTAP-E. Finally, the data has been converted from Giga gram of CO₂ to millions ton of carbon, as required by the GTAP-E revised version following the methodology as described in Lee (2008). The regional and sectoral emissions can also be obtained to fit the requirements of the GTAP-E model.

3.3. Results

The introduction of carbon taxation is simulated under different scenarios: at first the carbon taxation is 10 US dollars per ton of carbon and then, the carbon taxation amounts to 20 US dollars per ton of carbon.

Table 1. Percentage Changes in the real energy price index for Vietnam

Energy commodities	Carbon tax 10 US	Carbon tax 20 US
Coal	13.89	27.77
Oil	3.16	5.62
Gas	5.43	10.86
Oil Products	1.88	3.78
Electricity	1.03	2.02

The results above show that for all scenarios, impacts are greater for coal followed by Gas, Crude Oil and Oil products. Carbon taxation is not levied on electricity because electricity usage does not emit CO₂ while the impacts are driven for the augmentation of fuel utilized in the electricity production from Coal, Oil-products and Natural Gas. Crude oil causes small amounts of CO₂ emission mainly because of the refinery industry. The fact that there is no refinery plant in Vietnam means the utilization of crude oil is for other industries which also emit insignificant amounts of CO₂.

Table 2. Percentage changes in carbon dioxide emission for Vietnam

Energy commodities	Carbon tax 10 US	Carbon tax 20 US
Coal	-6.68	-12.24
Oil	-3.76	-6.42
Gas	-3.44	-6.60
Oil Products	-1.76	-3.45

The implementation of carbon tax impacts positively –as expected – on the reduction of CO₂ emissions. As the carbon tax increases, the impacts are greater for all energy commodities. Impacts of carbon tax are greatest for coal, followed by oil, gas and oil products for the case of carbon taxation 10 US dollars. When carbon tax sets to 20 US dollars, coal still reduces the most, but followed by gas, oil and oil products. Moreover, the impact is relatively bigger with carbon taxation levied to 5 US dollars per ton of carbon²

Table 3. Carbon dioxide emission of Vietnam in Million tons of Carbon

Energy commodities	No carbon tax	Carbon tax 10 US	Carbon tax 20 US
Coal	8.78945	8.202264	7.713202
Oil	0.00037	0.000362	0.000352
Gas	4.07900	3.938731	3.809617
Oil Products	10.77906	10.589793	10.407503
Total	23.64789	22.731150	21.930674
Reduction (%)	-	-3.88 %	-7.26 %

In terms of CO₂ emission reduction in million tons of carbon, CO₂ emission reduction is greatest for coal both in percentage changes and in quantity for all three scenarios. However, the share of CO₂ emissions reduction from coal over total emissions reduction decreases from 64.05 percent with carbon tax 10 US dollars to 62.7 percent with carbon tax 20 US dollars

² All results not included within this table format are available upon request

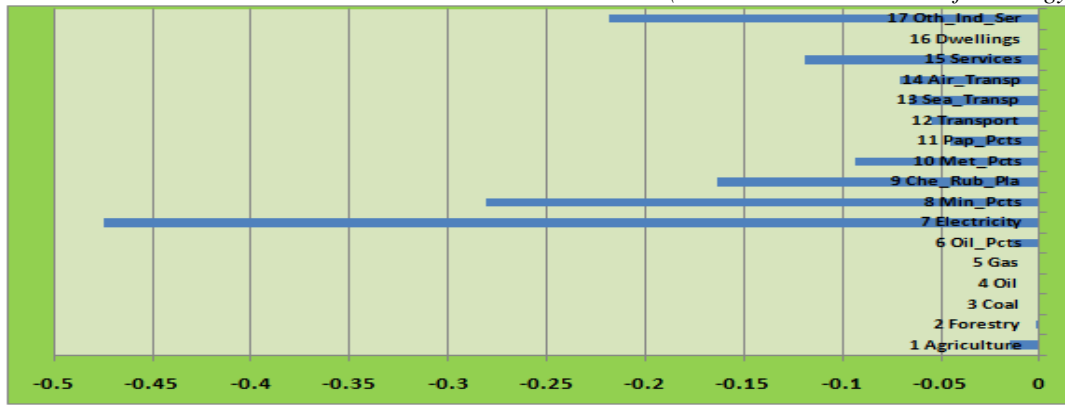


Figure 2. Sectoral emission reduction under carbon tax 20US dollars (M tons of carbon)

As for the sectoral contribution to the overall reduction for the 20US dollars carbon tax levied, the sector in which CO₂ emissions diminishes the most is electricity (-0.47 M tons of Carbon). It is followed by energy intensive sectors such as Mineral Products, Chemical Rubber Plastic product and some of non energy sectors like Services and Other industries and services sectors.

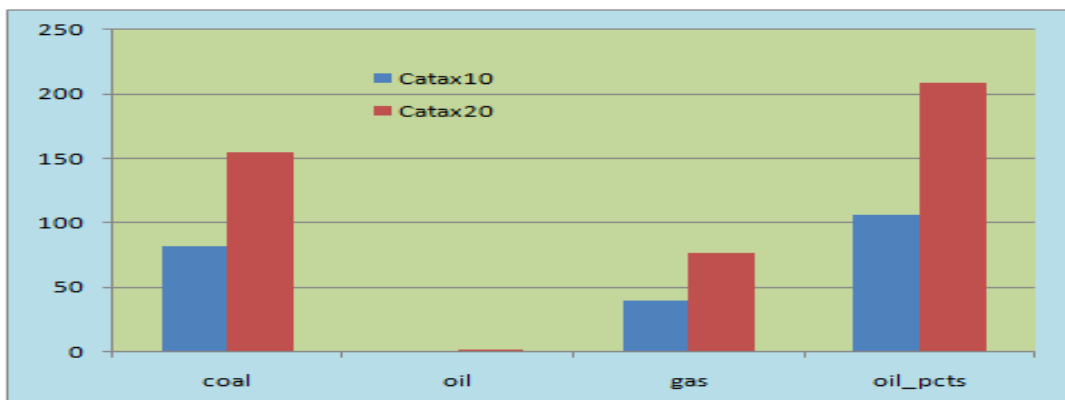


Figure 3. Carbon tax revenue (USD millions)

Figure 3 indicates that the main contribution to carbon tax revenue comes from oil products, followed by coal and gas. In Vietnam's energy production and consumption, coal and oil products account for most of primary energy production and total energy consumption. Therefore, these energy commodities contribute the biggest share to the carbon tax revenue.

Table 4. Percentage change of firm market price expenditure for Vietnam

Energy commodities	Carbon tax 10 US	Carbon tax 20 US
Coal	-7.16	-13.11
Oil	-3.08	-5.32
Gas	-3.18	-6.12
Oil Products	-1.87	-3.66

Both two scenarios imply significant decreases in coal expenditure, followed by gas expenditure, and the decline of oil products and oil is also important. The decrease in coal expenditure is particularly high in energy intensive sectors such as Metal Products, Paper Products. Non energy intensive sectors with significant decreases in coal expenditure are Services sector, and electricity sector. In particular, with 20US dollars carbon tax, metal products reduce emission the most with 16.06 percent, followed by Mineral products, Chemical Rubber and Plastic, Paper products, Sea Transport, Air Transport all around with 14 percent.

Figure 4 shows that output production diminishes the most are gas and oil and transportation sectors (Transport, Sea transport and Air transport) when carbon tax is levied in energy commodities sectors. Gas sector in Vietnam suffers the biggest impact, reducing by 6.58 percent of output. Transportation sectors and then Oil Products and Coal sector are also impacted significantly by the adoption of carbon tax.

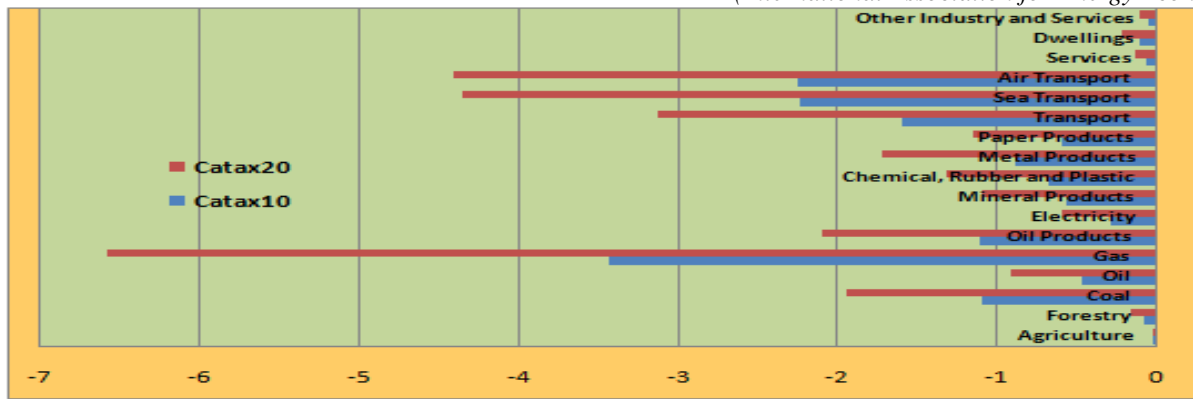


Figure 4. Percentage change in industry output

Table 5 and table 6 show that the impacts on GDP of carbon taxation are significant with carbon tax 20 US dollars per ton. The largest carbon taxation makes GDP decreased by 0.14 percent. Because the GDP of Vietnam is small in comparison with other regions in the model, such percentage changes represent 61.15 and 12.5 million dollars reductions, respectively.

Table 5. Changes of Vietnam's GDP

Scenarios	Percentage change	Changes in volume (2004 USD millions)
Carbon tax 10 US	-0.06	-27.07
Carbon tax 20 US	-0.14	-61.15

GDP decomposition indicates that the greatest reduction is observed for export and import as shown in table 6. Since Vietnam's economy still bases on export of domestic production and natural resources, carbon taxation may have bad impacts on the whole economy. Aside from export and import, consumption, investment and government expenditure also undergo significant decreases. The results show that carbon taxation induces negative influences on Vietnam's economy

Table 6. Percentage changes in GDP decomposition

GDP Decomposition	Carbon tax 10 US	Carbon tax 20 US
Consumption	-0.07	-0.16
Investment	-0.06	-0.12
Government	-0.07	-0.15
Exports	-0.31	-0.61
Imports	-0.29	-0.57

4. Dynamic GTAP-E model

4.1. Methodology

There are two steps to develop a dynamic GTAP-E model for Vietnam. First the data represented the world economy for the year 2008, 2015, 2020 and 2025 are produced based on the standard dynamic GTAP (Gdyn) model. Main macroeconomic indexes are shocked to represent changes of the world's economic in the future included Gross Domestic Product (GDP) growth rate, population, skilled and unskilled labor growth rate. Second, those world's economic data mentioned above are used with the static GTAP-E model for each year in combination with new energy and CO₂ emission data set to simulate for the adoption of carbon tax for Vietnam. In short, the dynamic model of Vietnam is in fact the incorporation of dynamics towards 2025 by solving a series of static equilibria driving by the evolvement of some key exogenous variables.

The dynamic GTAP model which is developed by Ianchovichina and McDougall (2001) is used to project the world's economy in the future. GTAP-Dyn is a recursive-dynamic extension of the standard GTAP, which is a multi region applied general equilibrium model. The dynamic GTAP (GDyn) includes all the special features of the standard GTAP model such as the sophisticated consumer demands and inter-sectoral factor mobility, incorporating a new treatment of investment behavior and additional accounting relations to keep track of foreign ownership of capital.

4.2. Data

4.2.1. The construction of baseline data

Macroeconomic data projection collected are GDP, population, skill and unskilled labor for 2005-2020 period. The world's data is mainly taken from Fouré et al. (2010) and Samir et al. (2010) for a total of 128 countries. Data of Vietnam are based on (GSO, 2010) and (GSO, 2011) which present Statistics data on national accounts of the year 2010 and 2011, published by General Statistics Office of Vietnam (GSO) in combination with data from the Master Plan on Vietnam's energy (MOIT and JICA, 2008). The data are then, combined with the data in "Projections for World CGE Model Baselines" which are collected by Chappuis and Walmsle (2011). Nine regions which are similar to regional aggregation in the previous chapter are disaggregated from the baseline data. The data is then adjusted to be compatible with IEA macroeconomic projection featured in World Energy Outlook 2010 and the master plan on Vietnam's energy sector (MOIT and JICA 2008). The GTAP Satellite data and its aggregation program are also utilized for the standard dynamic GTAP³. Sectoral and Regional aggregation are similar to those of the static model. GTAP Satellite data is constructed by GTAP staff to specially use with the dynamic GTAP model.

4.2.2. Energy and CO₂ emission data

Domestic energy production data for year 2008 are collected from Energy Balance of OECD countries and Energy Balance of Non-OECD countries published by International Energy Agency (2011) for a total of 134 countries (IEA 2011a and IEA 2011b). The data is then aggregated into 9 regions. Sectoral CO₂ emissions data for year 2008 are taken from "CO₂ emissions from fuel combustion" (IEA 2011c) for 146 countries. The data are also aggregated into regional and sectoral to fit the requirements of the GTAP-E model. CO₂ emission is distinguished between imported and domestic sources following the approach of Martini and Tommassino (2010) which is similar to the approach applied for the calculation of the year 2004. In order to do that, energy import and export are also collected both from Energy Balances of OECD and Non-OECD countries 2011 for 138 countries, then the data are aggregated into 9 regions of the model.

Energy and CO₂ data projection for Vietnam from 2015-2025 are taken from Master Plan on Vietnam Energy Sector which was conducted by Ministry of Industry and Trade of Vietnam (MOIT) and Japan International Cooperation Agency (JICA) in 2008. Data of other regions are taken from World Energy Outlook 2010 for the United States, European countries, China and India, Japan. Additional information from International Energy Outlook 2011 (IEA, 2011) and Oil Products Balances (FGE, 2010) has been used for the estimation of energy and CO₂ emission data of the remaining regions.

4.3 Results

The analysis of percentage variations in energy price index values under the 20 US dollars of carbon taxation scenario shows that for the periods of 2008 - 2025, impacts are greater for coal followed by gas and crude oil (table 7). Impacts on real energy price index are smaller oil products and electricity. From the year 2008 to the year 2025, impacts are getting smaller on all energy commodities, especially, decreasing from 32.47 percent to 15.32 percent for coal. Important decreases can also be observed for gas and oil products.

Table 7. Percentage changes in the real energy price index for Vietnam

Energy commodities	2008	2015	2020	2025
Coal	32.47	25.03	19.25	15.32
Oil	4.89	3.05	2.15	1.60
Gas	5.77	3.30	2.73	1.86
Oil Products	2.81	1.85	1.56	1.24
Electricity	1.36	0.90	0.85	0.65

Table 8 displays the implementation of carbon tax impacts positively –as expected – on the reduction of CO₂ emissions. However, the impact on crude oil for the year 2008 is largest but greater decrease can be observed for coal, gas and oil products since CO₂ emission from crude oil is insignificant. For the year 2015, 2020 and 2025, CO₂ emission from gas reduce the most, followed by the emission reduction from coal and oil products. This is because household and imported gas seems to be very sensitive to the changes of gas price index. Except for the case of natural gas, it can be observed that impacts of carbon tax on energy commodities price index are smaller over time while CO₂ emission reduction are larger from 2008 to 2025.

³ GTAP Satellite data is constructed by GTAP staff to specially use with the dynamic GTAP model. The main data of GTAP version 7 Satellite data base is similar to the GTAP version 7 data base but it incorporates some more data which are then utilized for the standard dynamic GTAP

Table 8. Percentage of carbon dioxide emission reduction

Energy commodities	2008	2015	2020	2025
Coal	-19.48	-17.04	-18.81	-27.18
Oil	-25.28	-3.80	-3.73	-4.06
Gas	-20.39	-20.76	-18.86	-33.98
Oil Products	-2.74	-15.44	-7.53	-3.75
Total	-13.04	-16.93	-14.27	-19.43

Table 9 presents carbon dioxide reduction in million tons of carbon. Emission from coal diminishes the most it is because the carbon content of coal is the largest among energy commodities. Total carbon reduction from 3.6 million tons in 2008 amounts to approximately 18 million tons in 2025 of which coal accounts for 61.9 and 65.86 percent, respectively. Even carbon dioxide emission of crude oil reduce greatly in terms of percentage, the amount of carbon reduction is insignificant for 2008 – 2025 periods. The two tables show that impacts of carbon tax are greater for the year 2008 and the year 2015, becoming smaller for the year 2020 and 2025.

Table 9. CO₂ emission reduction in million tons of carbon

Energy commodities	2008	2015	2020	2025
Coal	2.52	3.53	5.38	11.83
Oil ⁴	0.00	0.00	0.00	0.00
Gas	0.81	1.35	1.78	4.83
Oil Products	0.30	2.82	1.93	1.30
Total	3.63	7.70	9.09	17.96

Figure 5 presents sectoral emission reduction under carbon tax 20US dollars for 2008-2025 periods. The patterns are almost the same as the year 2004. For the year 2008, the sector in which CO₂ emissions diminish the most is electricity (-0.66 million tons of Carbon). CO₂ emission reduction is reduced the most in Mineral Products, Chemical, Rubber and Plastic sectors. Except for Forestry, Coal, Oil and Gas sectors (the emission reduction is small), CO₂ emission reduction is significant for energy intensive sectors such as Paper Products, Mineral Products and non energy intensive sectors such as Other industries and services sector and Services sector. The year 2015 and 2020 concern on Mineral Products sector as it reduce the most CO₂ emissions (-1.5 million tons of carbon, followed by electricity sector and Other Industries and Services sector (1.4 and 1.2 million tons of carbon, respectively). For the year 2025, electricity sector again, diminishes the most (-5.7 million), almost doubled that of Mineral Products sector (-3.1 million tons of carbon). Important contribution to the overall emission reduction are marked for Other industries and services sector, Chemical Rubber and Plastic sector, and Services sector. It is worth noticing that sectoral emissions in 2025 is almost double that of the year 2020.

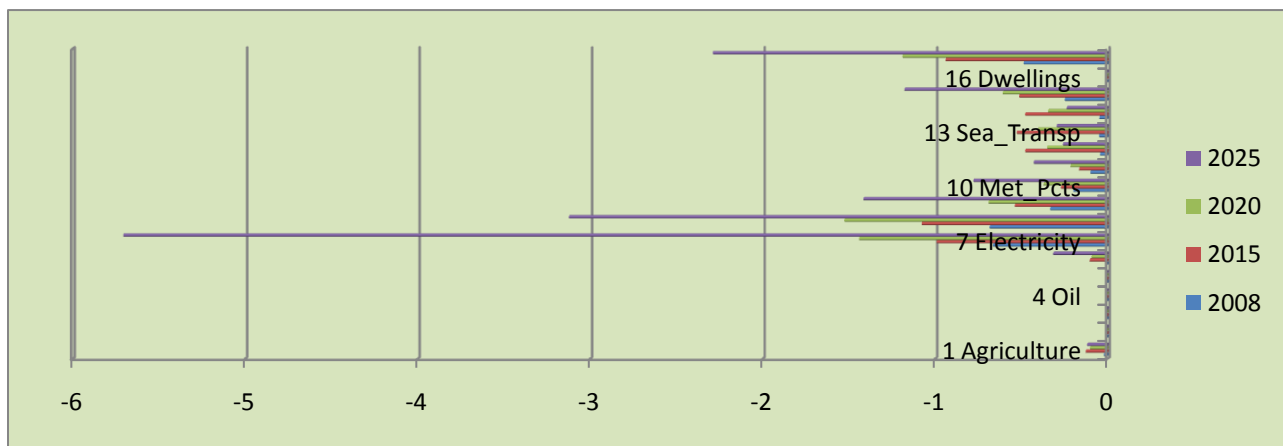


Figure 5. Sectoral emission reduction under carbon tax 20 US dollar for 2008 -2025 periods

Figure 6 indicates that the main contribution to carbon tax revenue comes from oil products, following by coal and gas. The figure also shows that the contribution to carbon tax revenue from coal increase rapidly. This is compatible with

⁴ CO₂ emission reduction in million ton of carbon for crude oil is insignificant. The numbers are 0.000112, 0.00000237, 0.00000307, 0.00000327, 0.00000516 million tons of carbon for the year of 2008, 215, 2020 and 2025, respectively

the fact that coal demand will take a bigger share in Vietnam primary energy demand in the future. Carbon tax revenue from crude oil remains insignificant while revenue from gas is much smaller than that from coal and oil products.

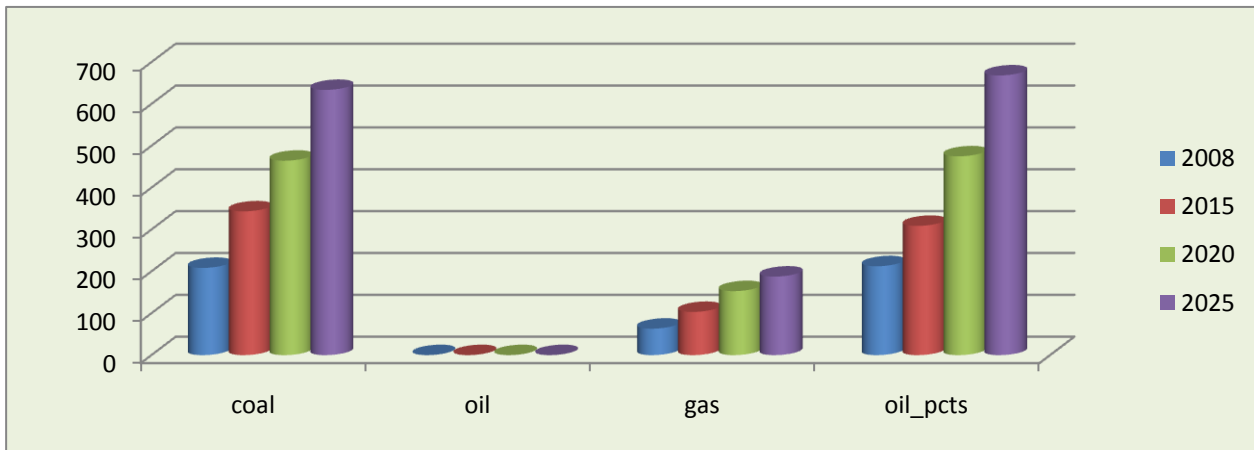


Figure 6. Carbon tax revenue for 2008 – 2025 periods (million US dollars)

Table 10 presents percentage change of firm market expenditure on energy commodities for Vietnam. All the four year imply significant decreases in coal expenditure, following by oil expenditure, the decline of oil products and gas is also important. Towards the year 2025, the decreases of firm expenditures on energy commodities are smaller.

Table 10. Percentage change of firm market price expenditure for Vietnam

Year	Coal	Oil	Gas	Oil Products
2008	-13.22	-5.07	-3.24	-3.01
2015	-10.41	-5.34	-4.74	-1.89
2020	-8.42	-3.95	-3.79	-1.58
2025	-6.96	-2.99	-2.78	-1.30

As shown in Figure 7, for the case with carbon tax of US dollars 20 per ton of carbon, industrial output decreases are getting bigger over time. However, the greater decrease can be seen for the year 2015 of which oil products and coal sectors diminish the most with - 22.42 and -15.71 percent, respectively. Impacts of US 20 dollars of carbon taxation scenario seem to be smaller for the year 2020 and 2025 for the two sectors. In general, output production diminishes the most after carbon tax in energy commodities sectors such as oil products, coal, and gas. Important decreases can also be observed for transportation sector such as transport, sea transport and air transport, especially for the year 2008.

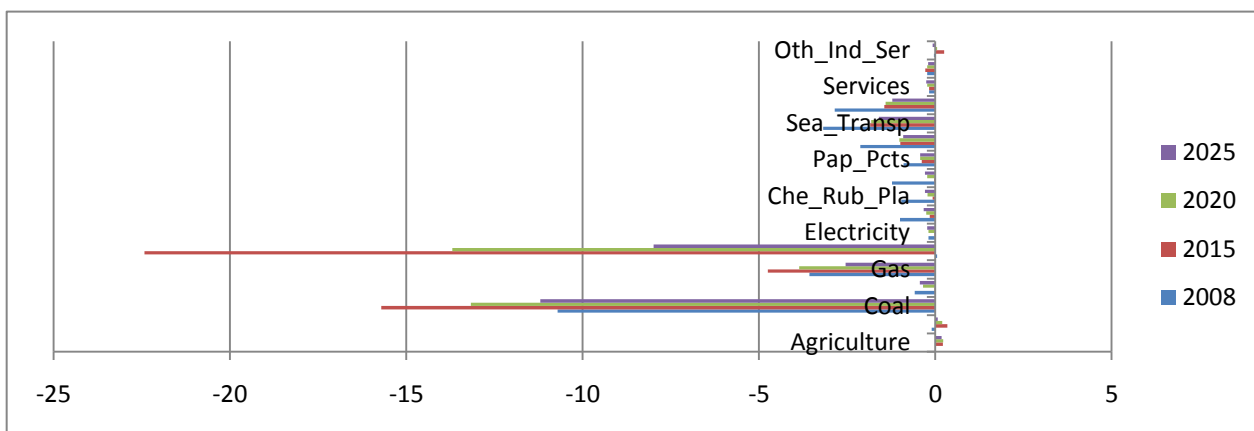


Figure 7. Percentage changes in industry output for 2008-2025 periods

Table 11 and table 12 show that the impacts on GDP of carbon taxation are getting smaller from 2008 – 2025 with carbon tax of 20 US dollars per ton. Toward the year 2025, impacts of carbon tax decreases from 0.14 percent in 2008 to 0.09 percent in 2025. Such small changes represents 68.27, 126.80, 174.81, 247.34 million US dollars reduction, respectively

Table11. The changes of Vietnam's GDP

Year	Percentage changes	Changes in 2004 US dollars millions
2008	-0.14	-82.70
2015	-0.11	-126.80
2020	-0.10	-174.81
2025	-0.09	-247.34

Percentage changes of GDP composition varies over time. Greatest changes can be observed for export and import in 2008, then they are for consumption, government expenditure and imports for the year 2025. The results indicate that the adoption of carbon tax US dollars 20 US cause greater CO₂ emission reduction in the future, increasing in both percentage and quantity (-13 percent of the year 2008 to 19.43 percent reduction in 2025). However, its impacts on the whole economy is getting smaller, decreasing from -0.14 percent to - 0.09 percent reduction of GDP.

Table12. Percentage changes of GDP Decomposition

Scenarios	Consumption	Investment	Government	Exports	Imports
2008	-0.16	-0.11	-0.16	-0.45	-0.41
2015	-0.14	-0.05	-0.15	0.27	0.19
2020	-0.12	-0.06	-0.13	0.08	0.05
2025	-0.11	-0.08	-0.11	-0.07	-0.08

5. Conclusion

The results of dynamic GTAP-E model under 20 US dollars of carbon taxation scenario indicate some results: First, percentage changes in real energy price index have the same pattern as those of the year 2004 such as coal price increase the most, followed by gas, oil, oil products and electricity. Meanwhile, the increase in price of energy commodities is smaller from the year 2004 to the year 2025. It shows that impacts of carbon tax are getting smaller in the future. Despite of this, CO₂ emission reduction tends to increase over time. Actually, percentage change of CO₂ emission reduction is smaller for the year 2020, but reaches the highest for the year 2025 (-19.43 percent). Second, carbon tax of 20 US dollars impacts greatly on industry output for the year 2015⁵, the most contraction can be observed for oil products sector and coal sector. However, its impact on GDP and GDP decomposition is smaller than that of 2004 - 2008 periods. The explanation is the rapid expansion of Vietnam's economy which mitigates the negative impact of carbon tax. Third, the results of dynamic model for the period 2008-2025 shows that impacts of carbon tax on the GDP is smaller than that of the year 2004, diminishing GDP to -0.09 percent in 2025 comparing to -0.14 percent of the base year. It seems the impact of carbon tax on GDP reaches the highest point for the period of 2004-2008, and then it is decreasing towards the year 2025. In short, the adoption of carbon tax of 20 US dollars per ton of carbon has strong impact on carbon dioxide emission reduction, reducing carbon from 7.26 percent in 2004 to 19.43 percent in 2025 with a little negative impact on economic growth. It is worth noticing that energy intensive sectors still account for larger reduce of carbon dioxide while oil products sector and coal sector is the most vulnerable one among 17 sectors of the model in term of total output simply because using coal would emit a lot of carbon dioxide compared with other energy commodities.

The results of this study show that in the future (toward the year 2025) impact of carbon tax policy on GDP and on Investment, Consumption, Import and Export are relatively small, but the reduction of carbon taxation is relatively large. The results suggest the carbon tax is an effective policy tool in mitigating CO₂ emission and ensure sustainable development for Vietnam

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⁵ All results not included in this paper will be available upon request

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