The Economic Projection and Policy Analysis Model for Taiwan: A Global Computable General Equilibrium Analysis

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Abstract

In this study we build a global computable general equilibrium (CGE) model for Taiwan to analyze climate policy implications on Taiwan's economy based on the GTAP 9 database, which provides economic data of three reference years that allows us to explore questions including: 1) for a counterfactual simulation, what could be the effects of using economic data with distinct reference years? 2) Based on the same data and sectorial classification, could various model settings result in drastically different simulation outcomes? 3) What would be the economic implications on Taiwan when Taiwan accomplishes its INDC target unilaterally versus when emissions reduction becomes a global effort? We find that under a global carbon reduction scenario, mitigation costs across regions tend to be higher when using data for the year of 2011, as oppose to cases of using the 2007 and 2004 data, due to increasing energy cost shares over time. Besides, with the same reference year, sectorial aggregation and policy scenario, when comparing our results with those from the CGE component of GTAP9inGAMS, our model shows lower GDP losses for energy exporting counties since our production technologies allow more substitution possibilities among inputs. We also find that when when only Taiwan carries out the reduction target, due to the existence of carbon leakage, the CO_2 price is lower and the GDP impact is slightly smaller than the case where emissions reduction becomes a global effort.

Keywords: Global Computable General Equilibrium Analysis, CO_2 Reduction Policy, Energy

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CONTENTS

1. INTRODUCTION

The economy of Taiwan is highly dependent on international trade and imports of fossil fuels, which currently account for around 98% of Taiwan's energy supply (Bureau of Energy, 2015). In the context of global efforts to cut greenhouse gas (GHG) emissions, a global general equilibrium model with energy use and emissions details where Taiwan is explicitly represented is essential for the analyses of policy impacts on the economy, energy use, and environment of Taiwan. The Economic Projection and Policy Analysis (EPPA)-Taiwan is a version of the MIT EPPA model developed jointly by the Institution of Nuclear Energy Research (IENR) of Taiwan and the MIT Joint Program on the Science and Policy of Global Change (MIT JP).

EPPA-Taiwan is a multi-region and multi-sector computable general equilibrium (CGE) model of the world economy. While the dynamic version of the model with capital vintaging, power sector details and backstop technologies is under development, the static version without these elements presented in this study will be enough for the current research purpose. Compared to other versions of EPPA, a new feature of EPPA-Taiwan is the adoption of the Global Trade Analysis Project database version 9 (GTAP 9) (Aguiar, 2016; GTAP, 2016), which provides three reference years that allows us to study an interesting yet unanswered question, that is, when conducting a climate mitigation simulation, other things being equal, what could be the effects of using data with distinct reference years? Since the underlying economic condition of one reference year may be quite different from that of another, is there anything modelers should be aware of in updating the economic data?

In EPPA-Taiwan, we use the aggregation routine provided in GTAP9inGAMS (Lanz and Rutherford, 2016) to produce a database that represents the world economy with the desired regional and sectorial aggregation levels. Since GTAP9inGAMS also provides a stylized CGE component (henceforth GTAP9inGAMS-CGE) for running the database, the second question we would like to study is: based on the same aggregated GTAP data, what could be the role of different model settings, in terms of production, preference, and elasticity of substitution among inputs, in determining the simulation results under the same policy shock? More specifically, when conducting the same carbon mitigation scenario, will results from EPPA-Taiwan and GTAP9inGAMS-CGE look more or less the same, or will they turn out to be quite different, and why?

A key focus of EPPA-Taiwan is to study the implications of carbon mitigation policy on Taiwan's economy. This is especially important since in its Intended National Determined Contribution (INDC), Taiwan has agreed to aggressively cut its GHG emissions by 50% from the business-as-usual level by 2030 (EPA, 2015). As the Paris Agreement has entered into force in November 2016 (UNFCCC, 2016), cutting GHG emissions to mitigate the climate change is expected to become a global effort. Currently relevant studies on Taiwan are essentially based on a single-country modeling framework (Chen, 2013; Lin et al., 2012, Lin et al., 2009; Li, 2000). A single-country framework, however, is ill-equipped for representing international trade, which is a crucial part of Taiwan's economic activities (exports and imports currently account for 62% and 50% of Taiwan's GDP, respectively (NDC, 2016)). Because of this limitation, issues such as carbon leakage and foreign policy impacts on domestic economy cannot be addressed appropriately. Therefore, the third question we would like to explore in this study is: what would be the implications on Taiwan's economy when its INDC is carried out as planned, and how different the policy impacts on Taiwan could be if the reduction targets are enforced in the context of a global effort, versus if Taiwan accomplishes its INDC unilaterally?

In this study, our focus will be to answer these questions, which have not been studied extensively, but are interesting and crucial from both the modeling and policy perspectives. For example, if policy makers target on a global CO_2 emission target but based on each country's self-evaluation, the expected contributions for each country may be estimated from different model setting with databases of different years. Unilateral climate policy can be detrimental to global, thus, this could be a source of overestimation/underestimation in meeting the global emission target. Furthermore, the results from our study also reveal that the projected economic impact of climate policy could be different if we ignore other countries' climate policy.

The rest of the paper is organized as follows: Section 2 presents the model structure and data; Section 3 discusses the scenario considered in each simulation and analyzes simulation results; and Section 4 provides a conclusion.

2. MODEL STRUCTURE AND DATA

In EPPA-Taiwan, there are three types of agents in each region: household, producers, and government. The household provides primary factors (labor, capital, and natural resources) to producers, receives income in return, and allocates income to consumption and savings. Producers convert primary factors and intermediate inputs into goods and services, sell them domestically or abroad to other producers, households, or governments. The government collects taxes from household and producers to finance government consumption and transfers. These activities can be represented by a series of circular flow diagrams connecting to each other via international trade as shown in **Figure 1** (Paltsev et al. 2005). The model is formulated in a series of mixed complementary problems (MCP) (Mathiesen, 1985; Rutherford, 1995; Ferris and Peng, 1997), and is written and solved using the modeling languages of GAMS and MPSGE (Rutherford, 1999). In the Appendix A we provide the core computer code of EPPA-Taiwan written in MPSGE for interested readers .

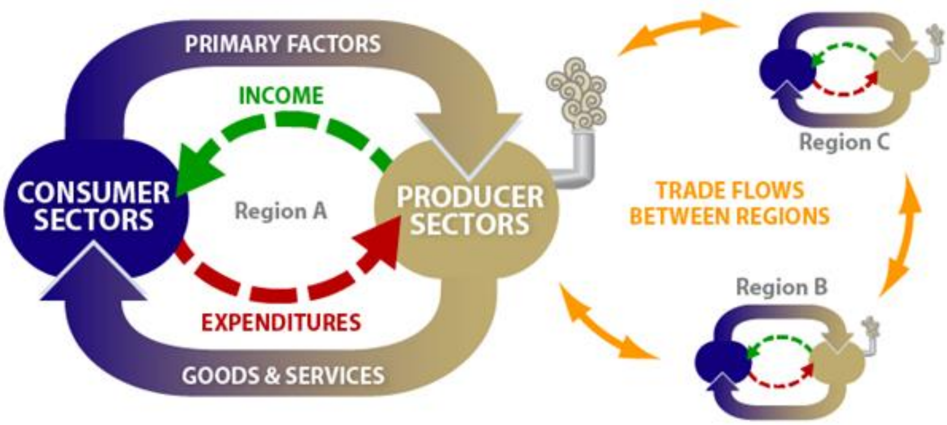

Figure 1. Schematic representation of EPPA-Taiwan**.**

2.1 Model structure

The development of EPPA-Taiwan is based on GTAP9inGAMS-CGE (Lanz and Rutherford, 2016), with the production structure and elasticities substantially revised so they are similar to the settings presented in the static component of EPPA6 (Chen et al., 2015). Specifically, in our model, activities of different agents and their interactions are described by: 1) zero-profit conditions; 2) market-clearing conditions; and 3) income-balance conditions. For the household and producer, the associated economic activities are utility and output, respectively. A typical zero-profit condition expressed in MCP format is:

$$MC - MB \geq 0; Q \geq 0\,; [MC - MB\,] \cdot Q = 0 \tag{1}$$

For instance, when a zero-profit condition is applied on a production activity, if the equilibrium output is Q positive, the marginal cost MC must equal the marginal benefit MB, and if MC is greater than MB in equilibrium, Q will be zero because the producer has no reason to produce. Note that MC less than MB is not an equilibrium state since in that case Q will increase until MC equals MB. Other activities such as investment, imports, exports, and commodity aggregation modeled using the Armington assumption (Armington, 1969) have their own zero-profit conditions.

For each market-clearing condition, the price level is determined based on market demand and supply. A typical market-clearing condition in MCP format is:

$$S \geq D; P \geq 0\,; [S - D\,] \cdot \mathrm{P} = 0 \tag{2}$$

The market-clearing condition states that for each market, if there is a positive equilibrium price P, then P must equalize supply S and demand D. If S is greater than D in equilibrium, then the commodity price is zero. Similarly, S less than D is not an equilibrium state because in that case, P will continue to increase until the market is cleared (S equals D).

Income-balance conditions specify income levels of household and government that support their spending levels. A typical income-balance condition in MCP format can be written as:

$$E \geq I; E \geq 0\,; [E - I\,] \cdot E = 0 \tag{3}$$

The expenditure E equals income I always holds in CGE models. In EPPA-Taiwan, the price of utility for Taiwan is chosen as the numeraire of the model, so all other prices are measured relative to it.

2.2 Technology, preference, and international trade

In EPPA-Taiwan, we use Constant Elasticity of Substitution (CES) functions (and the special cases of Leontief and Cobb-Douglas functions) to characterize both production technology and consumer preference. To provide an example of CES function applied to represent a production activity, let us consider a technology that uses energy and non-energy inputs, and denote the rental prices of energy input Q_e and non-energy input Q_n by P_e and P_n, respectively. Following the calibrated share form for CES functions (Rutherford, 1998), the unit cost C for converting Q_e and Q_n into output Q, as represented by **Figure 2**, can be formulated as:

$$C = \left[\alpha \left(\frac{P_e}{\bar{P}_e}\right)^{1-\sigma} + (1-\alpha)\left(\frac{P_n}{\bar{P}_n}\right)^{1-\sigma}\right]^{1/(1-\sigma)} \tag{4}$$

where α is the cost share of energy, $\bar{P}_e$ and $\bar{P}_n$ are the base year (pre-shock) levels of P_e and P_n, respectively, and σ is the elasticity of substitution between the energy and non-energy inputs defined as:

$$\sigma = [\frac{\frac{\partial Q_e}{Q_e}}{\frac{\partial Q_n}{Q_n}}]/[\frac{\frac{\partial P_n}{P_n}}{\frac{\partial P_e}{P_e}}] \tag{5}$$

Based on Condition (1) and Equation (4), if one denotes the equilibrium price of Q by P, which has a base year level of $\bar{P}$, the output of this technology is determined by the following MCP, which is simply the cost-benefit analysis for the production activity:

$$C \geq \frac{P}{\bar{P}}; Q \geq 0; \left(C - \frac{P}{\bar{P}}\right) \cdot Q = 0 \tag{6}$$

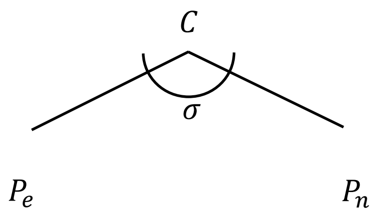

Figure 2. Nesting structure of the two-input CES cost function**.**

While the two-input example above can be generalized to a N-input case ($N > 2$), a caveat for a single-nest CES function with N inputs is that all pairs of inputs have identical elasticities of substitution. Nevertheless, one can adopt a nested CES function to overcome this restriction, and this is the strategy used in our model. For instance, **Figure 3** presents the nesting structure for the cost function of the energy-intensive sector in EPPA-Taiwan (details for sectorial definition will be presented in Section 2.3), which consists of seven nests. The elasticity of substitution for each nest, which is defined in Equation (5), is the value beside the arc, and P, PA, PF, and PS are price indices for domestic, Armington goods, non-sector-specific primary factor, and sector-specific primary factor, respectively. Specifically, the notation $PA("coal", r)$ at the bottom nest in **Figure 3** represents the price index for coal as an Armington good in region r, i.e., coal (either domestic or imported) is one of the inputs to the production activity of the energy-intensive sector in that region. **Figure 4**, on the other hand, provides the nesting structure for the expenditure function of the representative consumer (household), where PW is the price index for utility. The nesting structure for the expenditure function demonstrates that household consumption includes energy, dwelling service, and other Armington goods. As in EPPA6 (Chen et al., 2015), the incentive for savings is taking into account in the expenditure function, and savings equal investment in the model. While this treatment may not be necessary in a static CGE, it provides the ground for developing the dynamic version of EPPA-Taiwan in the future.

In a global CGE such as EPPA-Taiwan, besides interactions among sectors through inter-industry transactions, interactions among regions are considered via bilateral trade flows. Particularly, in our model, each region may export part of its domestic outputs in exchange for imported commodities in a way such that any additional imports relative to the base year levels must be achieved by an increase in exports with similar market values. Additionally, crude oil in our model is treated as perfect substitutes in global trade. For most goods, the Armington assumption mentioned in Section 2.1 and widely used in modeling international trade is adopted. Under this formulation, imported goods from a production sector and region are treated as imperfect substitutes for goods from the same sector but is produced domestically or in another regions. Therefore, the Armington assumption allows a region to be both an importer and exporter of similar products, which reflects the observed patterns. On the other hand, when goods are perfect substitutes, there is a single global price. With the Armington assumption, goods from the same sectors but different regions each have a separate price since they are not homogeneous from the household's perspective. **Figure 5** provides the Armington aggregations for imported goods from different regions, and for domestic and imported goods. PM, PT, and P are price indices for imports, international transportation service, domestic production respectively. crude oil is modeled as an internationally homogenous good, thus the elasticity substitution between imported and domestic oil is unlimited. PCO_2 in **Figure 5** is for adding a carbon penalty to the consumer price of various energy consumptions, which in place only if there is an emission reduction policy. The nesting of structures for the cost functions of other sectors or activities are presented in Appendix B.

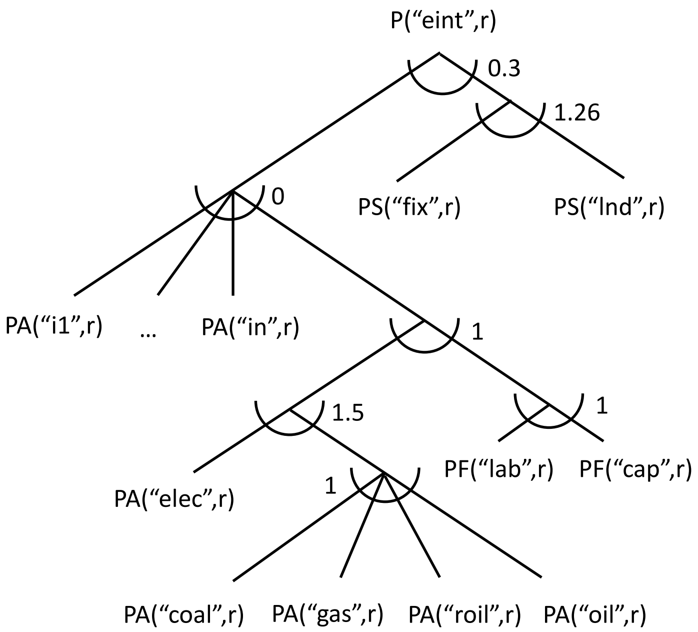

Figure 3. Nesting structure for the cost function of the energy-intensive sector.

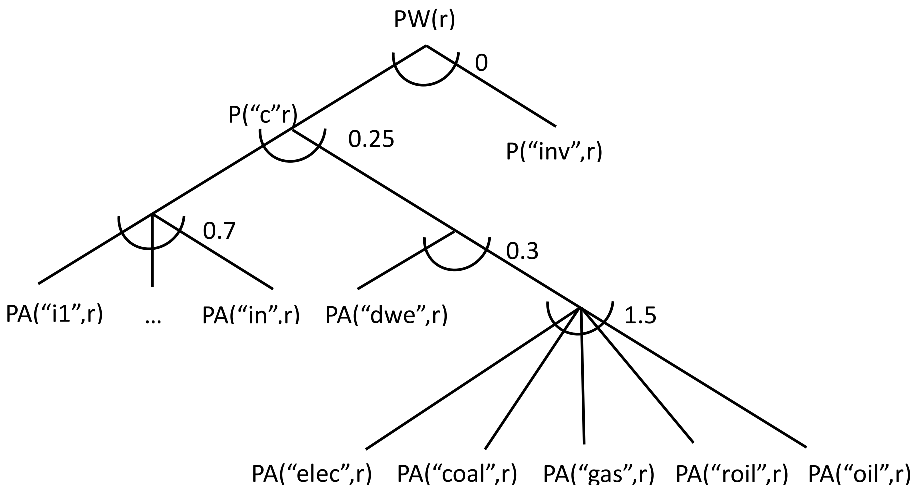

Figure 4. Nesting structure for the expenditure function of the household.

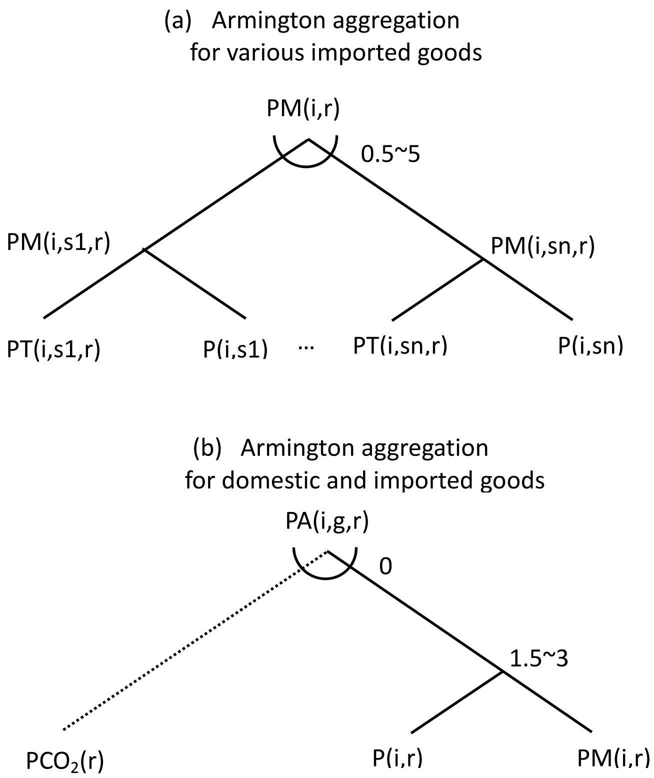

Figure 5. Nesting structure for the cost function of Armington goods.

2.3 Social Accounting Matrix

A social accounting matrix (SAM) contains the base year input-output and supply-demand structures of the economy. It provides a consistent picture of production activities, market transactions, and income-expenditure flows between different agents in the economy. **Table 1** provides the structure for the SAM of each region in EPPA-Taiwan, which is constructed based on the micro-consistent format of SAM presented in Rutherford (1999)—each row corresponds to a market-clearing condition (Condition 2 in Section 2.1), and columns characterize the zero-profit condition of an activity (Condition 1 in Section 2.1), except for the last column which represents the income-balance condition of the economy (Condition 3 in Section 2.1). Variables in blue/italic/bold denote output of each activity, supply of each market, or endowment of the representative agent (those in the last column); variables in red are input of each activity, demand of each market, or aggregate consumption of the representative agent (those in the last column). To keep the symbols clean, regional indices of each variable are dropped.

Domestic production activities $Y(i)$ are presented in Columns 1, where sector set i includs subset i^* and subset $x. Y(i^*)$ and $Y(x)$ denote production activities of non-homogeneous goods and homogeneous goods respectively. In EPPA-Taiwan, crude oil is a homogeneous product globally, thus, there is a single world market price for crude oil. $vom(i^*)$ and $vom(x)$ denote outputs by production activities $Y(i^*)$ and $Y(x)$ respectively. The inputs of domestic production include: $vfm(sf,i)$ are land and natural (fix) resource inputs; $vfm(mf,i)$ are labor and capital inputs; and $voam(i,i)$ are energy and non-energy inputs of Armington aggregate goods (the Armington aggregate good is the aggregation of domestic produced product $vdfm$ and imports $vifm$); and lastly, rto, $rtfa$ and rtf are taxes on output, intermediate input, and primary input, respectively.

Columns 2–4 are for activities of total household consumption $Y(C)$, the government activity govt $Y(G)$, and capital formation $Y(Inv)$. Total household consumption $Y(C)$ includes Armington goods $voam(i,C)$ (sum of domestic produced commodities $vdfm(i,C)$ and imported commodities $vifm(i,C)$) and the associated tax payment $rto(C)$ are converted into the household output $vom(C)$. The government activity $Y(G)$ represents how the goverment's Armington consumption $voam(i,G)$ and the associated tax payment $rto(G)$ are converted into the government output $vom(G)$. The inputs of capital formation include $voam(i,Inv)$ and $rto(Inv)$ with the output $vom(Inv)$.

Column 5 is the activity for Sluggish primary factor including land and natural/fix resouces through a CET function, the input is region's total land and natural resources endowment $evom(sf)$, while the output $vfm(sf,j)$ is land and natural resources for each sector.

Columns 6-8 are activities for international transportation service $YT(j)$, trade M, and Armington aggregation A. The regional input for international transportation service $YT(j)$ is denoted by $vst(j)$, while the total global output is $vtw(j)$. Armington output $voam(i,g)$ is the aggregation of domestic non-homogeneous products $vdfm(i^*,g)$, domestic homogeneous products $vdfm(x,g)$, non-homogeneous imports $vifm(i^*,g)$, and homogeneous imports

$vifm(x,g)$. Imports $vim(i^*)$ come from exports of other regions $vxmd(i^*,s)$, plus the international transportation service $vtwr(j,i^*,s)$ which is the same as $vtw(j)$.

Columns 9-10 are activities for net export $HOMX$ and net import $HOMM$ of homogeneous good- crude oil. There is a single world market price PWH. Crude oil is imported and exported as a homogeneous product, which subject to tariffs, export taxes, and international transport margins. Value of net export and net import are $vhomx(x)$ and $vhomm(x)$ respectively.

Columns 11 and 12 are for the welfare (utility) function W and the income balance condition of the representative household RA. the welfare W is derived from consumption $vom(C)$ and saving $vom(Inv)$ with output vum. The total (gross) household income is constituted of net labor income and net capital income (denoted as e$vom(mf)$), resource rents including e$vom(sf)$, the tax payment (GRG), (and the emission quote $\mathrm{CO2lim}$ exist only if there is an emission reduction policy). vb is current account balance, which is a constant in this static version of EPPA-Taiwan. ($homadj$ and $trnadj$ are adjustment for homogenous treatment and adjustment for homogenous treatment respectively) The household expenditure is allocated to purchasing utility vum and spending on government output which is exogenously determined since the government is treated as a passive entity in EPPA-Taiwan.

Table 1. SAM/MCM for EPPA-Taiwan

		Columns in this matrix correspond to Activities and their corresponding Zero-profit Conditions											Income-Balance
		Domestic Production Activity	Consumer Activity	Goverment Activity	Investment Activity (Capital)	Sluggish Primary Factor	International Transportation	Import Activity	Armington Goods	Homogeneous good export	Homogeneous good import	Utility	Representative consumer
Rows in this matrix correspond toMarket-clearing conditions		Y(i)	Y(C)	Y(G)	Y(Inv)	FT	YT	M	A	HOMX	[HOMM]	W	RA
Domestic Production	P(i*)	*+vom(i*)*					vst(j)	vxmd(i*,s)	vdfm(i*,g)				
	P(x)	*+vom(x)*							vdfm(x,g) [vifm(x,g)]	vhomx(x)	*[+vhomm(x)]*		*+homadj(x)*
HH consump	P(C)		*+vom(C)*									vom(C)	
Gov. consump.	P(G)			*+vom(G)*									vom(G)
Loanable Funds	P(Inv)				*+vom(Inv)*							vom(I)	
Primary Factors	PS	vfm(sf,i)	vfm(sf,C)	vfm(sf,G)	vfm(sf,Inv)	*+vfm(sf,j)*							
	PF(mf)	vfm(mf,i)	vfm(mf,C)	vfm(mf,G)	vfm(mf,Inv)								*+evom(mf)*
	PF(sf)					evom (sf)							*+evom(sf)*
Intl. Transp.	PT						*+vtw(j)*	vtwr (j,i*,s)			[homt(x)]		*+trnadj*
Imports	PM							*+vim(i*)*	vifm(i*,g)				
Armington Good	PA(i)	voam(i,i)	voam(i,C)	voam(i,G)	voam(i,Inv)				*+voam(i,g)*				
	PCO_2								CO_2				*+CO2lim*
Homogeneous good	PWH									*+homx(x)*	[homm(x)]		
Total HH consump.	PW											*+vum*	vum
Resources for Tax payment	TAX	rto, rtf	rto	rto	rto			rtms,rtxs	rtfd,rtfi	txhom	[tmhom]		*GRG*
Current Account	PC												*+vb*

Note: i* denotes sector set i excluding item x, x denotes crude oil which is an homogeneous good in the EPPA-Taiwan.

2.4 Data

GTAP 9, the main economic database of EPPA-Taiwan, classifies the world economy into 140 regions, 57 sectors, and 8 primary factors, and provides three reference years: 2004, 2007, and 2011. In our model we aggregate the database into 19 regions (**Table 1**), 14 sectors (**Table 2**), and 4 primary factors (**Table 3**)—these settings are the same as EPPA6 (Chen et al., 2015), except that Taiwan is explicitly identified as another EPPA region. The complete mappings for regions, sectors, and primary factors from GTAP 9 to our model are provided in Appendix C. Besides, the elasticities of substitution are drawn from EPPA6, and those elasticity values are based on literature review (**Table 4**). On the other hand, the energy use data (in terms of energy units) are from the International Energy Agency (IEA) (McDougall and Lee, 2006), which are also included in the GTAP 9 database. In addition, the reference year CO_2 emissions of our model are derived from the fossil fuel consumption levels in GTAP 9 through emission factors for each type of fossil fuels. Coefficient of carbon contents (100 million tons per exa-joule) of coal, gas and refined oil are 0.247, 0.137, and 0.199 respectively (IEA, 2011). While the economic data in SAM drawn from GTAP 9 are expenditure in terms of a monetary unit, based on the energy use data (in energy units) provided in GTAP 9, we are able to link to base year energy consumption and production (in terms of exa-joule (EJ) or tera-watt-hour (TWh)) to the corresponding expenditure level (US dollar), and therefore keep track of the evolution of both under a counterfactual simulation.

Table 2. Regions in EPPA-Taiwan.

EPPA-Taiwan region	Symbol	EPPA-Taiwan region	Symbol
United States	USA	Indonesia	IDZ
Canada	CAN	China	CHN
Mexico	MEX	India	IND
Japan	JPN	Brazil	BRA
Australia, New Zealand & Oceania	ANZ	Africa	AFR
The European Union+	EUR	Middle East	MES
Eastern Europe and Central Asia	ROE	Latin America	LAM
Russia	RUS	Rest of Asia	REA
East Asia	ASI	Taiwan	TWN
South Korea	KOR		

Note:+ The European Union (EU-27) plus Croatia, Norway, Switzerland, Iceland, and Liechtenstein.

Table 3. Sectors in EPPA-Taiwan.

EPPA-Taiwan sector	Symbol	Subgroup	EPPA-Taiwan sector	Symbol	Subgroup
Crops	CROP	agri	Gas	GAS	enoe
Livestock	LIVE	agri	Electricity	ELEC	elec
Forestry	FORS	agri	Energy-Intensive Industries	EINT	eint
Food Products	FOOD	naenoe	Other Industries	OTHR	naenoe
Coal	COAL	enoe	Ownership of Dwellings	DWE	naenoe
Crude Oil	OIL	enoe	Services	SERV	naenoe
Refined Oil	ROIL	enoe	Transport	TRAN	naenoe

Table 4. Primary factors in EPPA-Taiwan.

Sector	Symbol	Subgroup
Capital	CAP	mf
Labor	LAB	mf
Land	LND	sf
Natural resources	FIX	sf

Table 5. Substitution elasticities in EPPA-Taiwan.

Type of substitution elasticity	Notation	Value
between domestic and imported goods	sdm	1.0–3.0
between imported goods	smm	0.5–5.0
between energy and non-energy (labor-capital bundle) inputs	e_kl	0.6–1.0
between labor and capital	l_k	1.0
between electricity and fossil energy bundle for the aggregated energy	noe_el	1.5
between fossil energy inputs for the fossil energy bundle	esube	1.0
between natural resource and other inputs	esup	0.3–0.5
between natural resources and land	esubva	0.2–1.7
Final consumption (consumer)	enoe_el; eed; d_elas; delas	0.25~1.5

Source: Cossa (2004)

3. SIMULATIONS

To answer the questions raised in Section 1, three simulations are presented. As a starting point, we focus on cutting CO_2 emissions throughout the paper. In the first simulation, we study the response of EPPA-Taiwan using three different base year data provided in GTAP 9 under the same policy shock. The next simulation compares the economic impacts of global CO_2 constraint from two models under the same policy scenario, input-output data, and sectorial resolution, but with different functional forms and elasticities for representing activities of consumption and production—EPPA-Taiwan and GTAP9inGAMS-CGE. Lastly, based on our model, two scenarios are considered in the third simulation: 1) Taiwan implements a CO_2 reduction policy unilaterally, and 2) Taiwan pursues the reduction goal when a global emissions mitigation efforts exist.

3.1 Simulations with distinct base year data

We impose a sample carbon reduction policy globally on each region of EPPA-Taiwan while changing the database settings of the model with each setting using one of the three base year data (for 2004, 2007, and 2011, respectively) aggregated from GTAP 9. For each region, the sample policy considered cuts 40% of CO_2 emissions of the reference (no policy) case. We find that in general, CO_2 prices are higher when using the 2011 data, as compared with cases of using 2007 and 2004 data. For instance, as shown in **Figure 6**, the CO_2 prices in four EPPA regions including Taiwan are higher for later years. Note that CO_2 emissions in GTAP 9 are from IEA data, which are for combusted emissions resulting from burning fossil fuels. Therefore, the main reason for higher CO_2 prices for later years is because of the increasing prices for fossil fuels over time (**Figure 7**).

More specifically, the higher fossil fuel prices in 2011, of course, are incorporated into the data of that year in GTAP 9, and while a higher prices for fossil fuels would induce more significant energy-saving measures or innovation in the long-run, the energy consumption structure in terms of physical unit is unlikely to change substantially in the short-run due to technology constraints. Therefore, higher prices for fossil fuels in 2011 would translate to higher fossil fuels cost shares in that year, and lower fossil fuels prices in earlier years result in lower fossil fuels cost shares for corresponding years (**Figure 8** shows the economy-wide average fossil fuel cost share for each type of fossil fuels for each base year. We find that the cost share of crude oil has increased significantly from 2004 to 2011). Therefore, using a higher fossil fuel cost share to represent the same technology suggests that emissions reduction becomes more expensive.

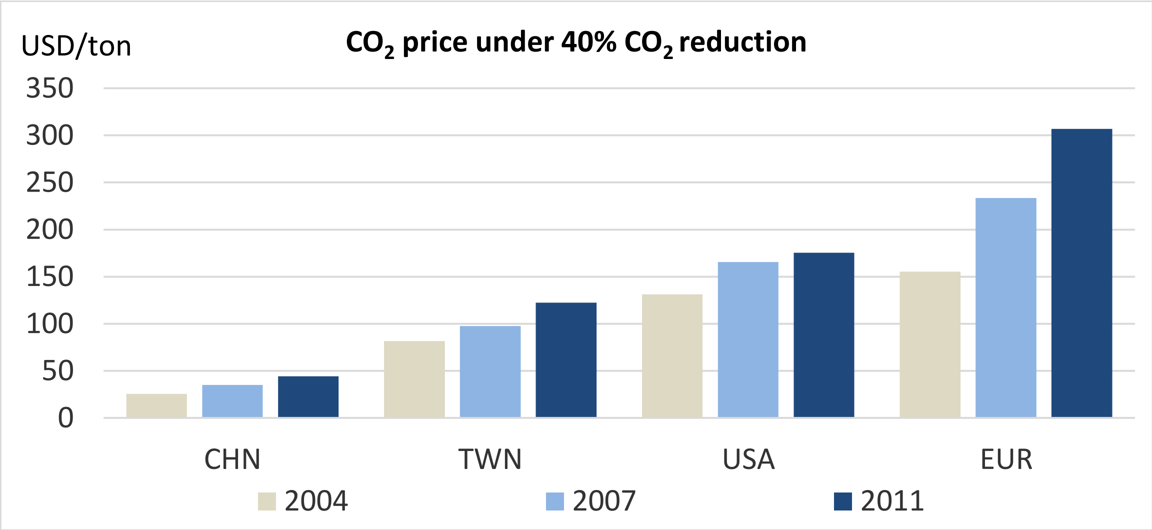

Figure 6. CO_2 prices based on the same model with databases of different years.

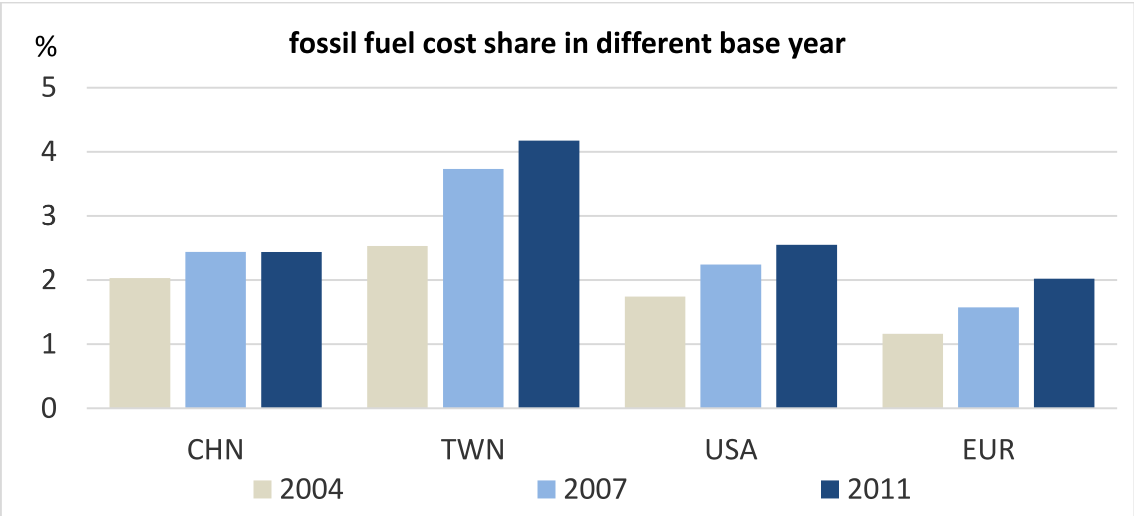

Figure 7. energy cost share of different years.

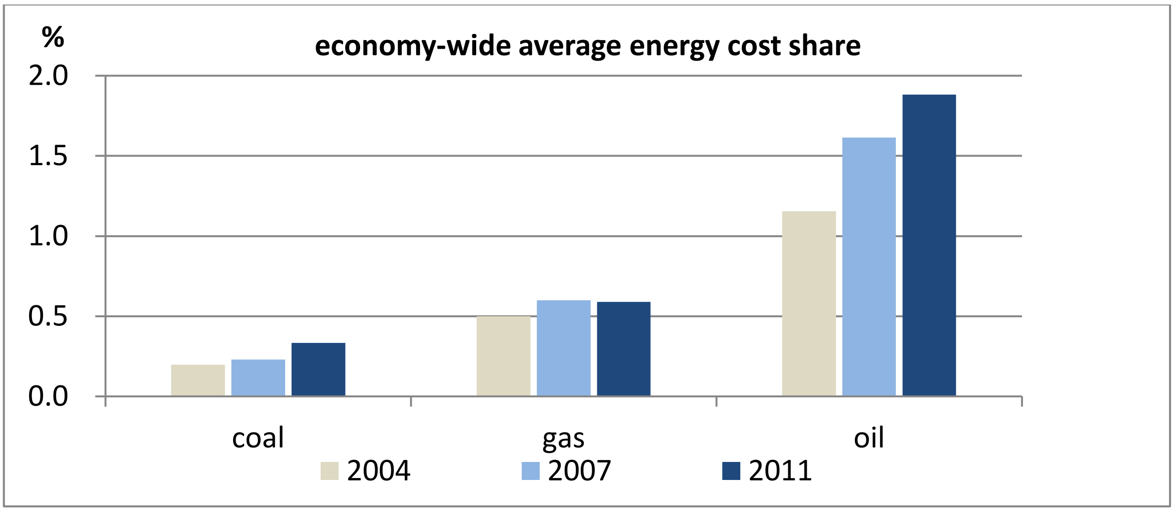

Figure 8. economy-wide average cost share for fossil fuels of different years.

3.2 Simulations with different models

In this simulation we focus on comparing the economic impacts of global CO_2 constraint from two models using the same database—the EPPA Taiwan and GTAP9inGAMS-CGE. We choose the input-output data of 2011, the latest reference year of GTAP 9. The nesting structure and substitution elasticities of the two models are quite different in many ways (see **Figure 9** for the structures of cost and expenditure functions of GTAP9inGAMS-CGE; and see **Table 6** for the substitution elasticities of the two models). In particular, GTAP9inGAMS-CGE has a zero substitution elasticity between energy and non-energy inputs, and similarly, there is no substitution possibility among various types of fossil fuel.

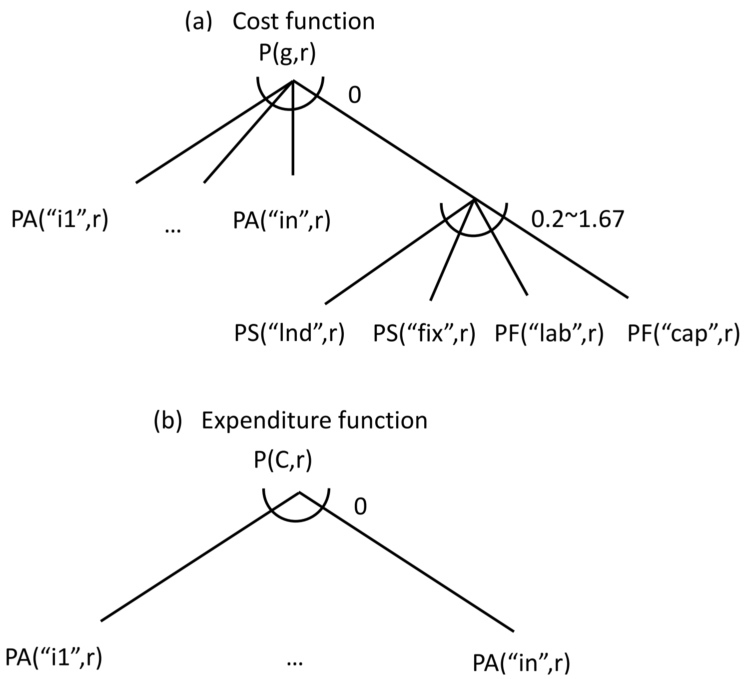

Figure 9. Nesting structure in GTAP9inGAMS-CGE.

Table 6. Substitution elasticities in EPPA-Taiwan and in GTAP9inGAMS-CGE

	Notation in EPPA-Taiwan	Value	Notation in GTPA9inGAMS-CGE	Value
between domestic and imported goods	sdm	1.0–3.0 (elec=1;enoe=1.5; the rest=3)	esubd	1.89~12
between imported goods	smm	0.5–5.0 (elec=0.5;enoe=3; the rest=5)	esubm	3.57~31
between energy and non-energy (labor-capital bundle) inputs	e_kl	0.1–1.0 (elec=0.1;agri=0.6;enoe=0.8; the rest=1)	esub	0 (only in c is 1)
between electricity and fossil energy bundle for the aggregated energy	noe_el	1.5	esub	0 (only in c is 1)
between labor and capital	l_k	1	esubva	0.2~1.67 (gas=0.5;)
between fossil energy inputs for the fossil energy bundle	esube	1	esub	0 (only in c is 1)
between natural resource and other inputs	esup	0.3–0.5 (oil,gas,coal=0.5; the rest=0.3)	esub	0 (only in c is 1)
between natural resources and land	esubva	0.2~1.67 (gas=0.5)	esubva	0.2~1.67 (gas=0.5;)
Final consumption (consumer)	enoe_el; eed; d_elas; delas	*0.25~1.5 (enoe_el=1.5; z_dw=0.3; d_elas=0.3~0.69; delas=0.25)	esub	1

Note:(1) In EPPA-Taiwan, enoe including coal, gas, roil, and oil; (2)In GTAP9inGAMS-CGE there is only two layers CES function. Source: (1) Chen, et al. (2015) The MIT EPPA6 Model: Economic Growth, Energy Use, and Food Consumption; (2) Lanz and Rutherford (2016) GTAPinGAMS: Multiregional and Small Open Economy Models.

We consider a policy scenario where each EPPA region cuts its CO_2 emissions by 20%. The results reveal that compared with outputs from GTAP9inGAMS-CGE, our model generally demonstrates a lower GDP losses (**Figure 10** presents a figure with a global GDP change profile for the two models, and **Figure D1**. in the Appendix D presents a figure with regional GDP change profile for all regions) except for regions including JPN, USA, EUR, and ASI. The main reason behind this is because unlike GTAP9inGAMS-CGE, our model allows some substitution possibilities between energy and non-energy inputs and also among fossil fuel inputs. In our model, cutting CO_2 emissions can be achieved not only by reducing output, as in the case of GTAP9inGAMS-CGE, but also by either energy efficiency improvement or switching to a less carbon-intensive energy source, which are not allowed in GTAP9inGAMS-CGE. We also find that under the same policy shock, the (producer) price of crude oil is higher in our model. The lower crude oil price in GTAP9inGAMS-CGE constitutes a double whammy to the GDP loess of the region MES, which includes many oil exporting countries, through the terms of trade effect. **Figure 11** also shows that demand of oil drops more in the GTAP9inGAMS-CGE since that the model does not allow substitution between oil and higher carbon-intensive energy inputs (coal or gas), which explains the lower crude oil price in GTAP9inGAMS-CGE. At the same time, lower crude oil prices in GTAP9inGAMS-CGE mitigate the negative GDP impact of oil importing regions, and for regions including JPN, USA, EUR, and ASI, they outweigh other factors that pull down their GDP levels. (more detailed impact of substitution possibilities can be found in **Figure D2.** in the Appendix D. It shows that the result could be significant difference while GTAP9inGAMS-CGE allows more substitution possibilities between various energy inputs, and between the energy bundle and the capital-labor bundle).

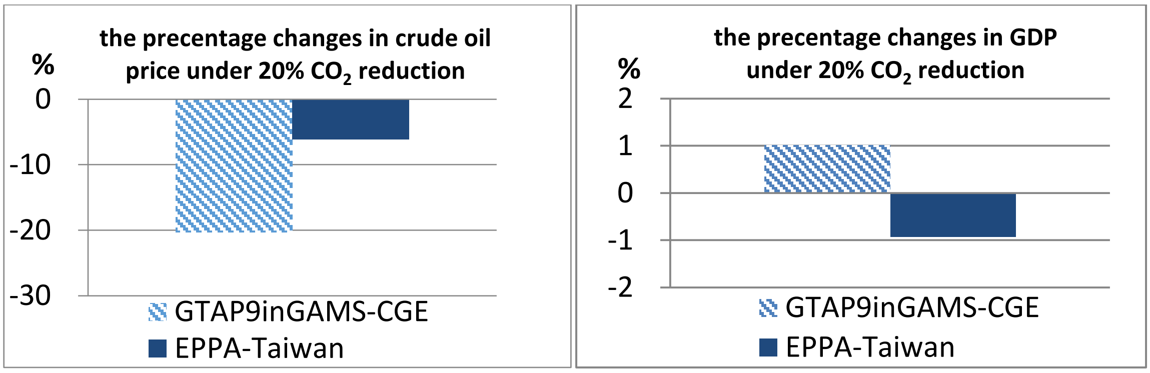

Figure 10. Changes in crude oil prices and GDP based on two different models.

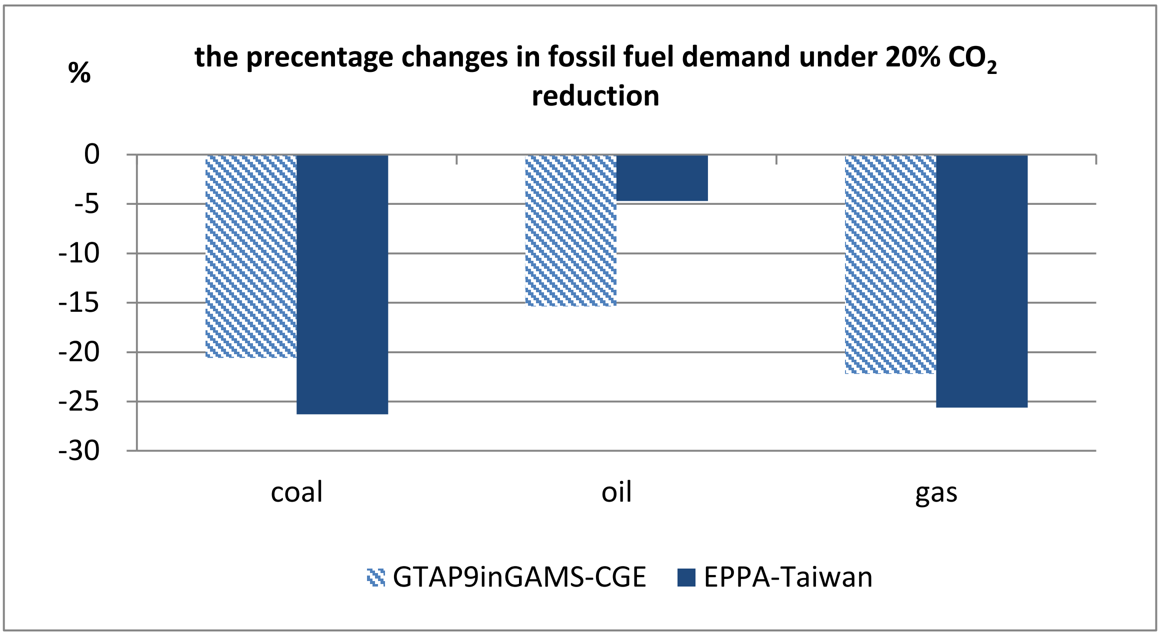

Figure 11. Changes in demand of fossil fuels in GTAP9inGAMS-CGE and in EPPA-Taiwan.

3.3 Unilateral mitigation versus global effort

To explore the implications on Taiwan's economy when it pursues an emissions mitigation measure, we take into account two scenarios: the first is that Taiwan implements a CO_2 reduction policy unilaterally, and the second is that Taiwan carries out the reduction goal when the global emissions mitigation efforts exist. Inspired by Taiwan's INDC target, which will cut 50% of Taiwan's business-as-usual (BAU) GHG emissions by 2030 (EPA, 2015), in both scenarios, we consider that Taiwan will cut its CO_2 emissions down to 50% of the BAU level, and for the second scenario, we follow the expected emissions reduction profiles considered in Jacoby et al. (2017) to represent INDCs of other EPPA regions and use the BAU emissions and GDP in 2030 from the EPPA6 model. The expected emission targets for each region are listed in Appendix E. A caveat to this exercise is that it is only intended to compare the economic impacts between the two scenarios discussed above. A dynamic CGE will be necessary if one would like to explore issues such as the potential implications of Paris agreement. Nevertheless, the current exercise may still shed some light in revealing the very different economic consequences for the emissions reduction of Taiwan, due to whether there will be a global mitigation effort.

We find that compared to the scenario where Taiwan implements the reduction policy unilaterally, with the existence of a global effort, as shown in **Figure 12**, when only Taiwan carries out the reduction target, due to the due to the existence of carbon leakage, the CO_2 price is lower and the GDP impact is slightly smaller than the case where emissions reduction becomes a global effort. The GDP loss in Taiwan seems not to become larger under a global emission constraint, the reason is due to the fact that the emission reduction becomes globally, producer prices for fossil fuels are suppressed when other countries also participate in the mitigation efforts.

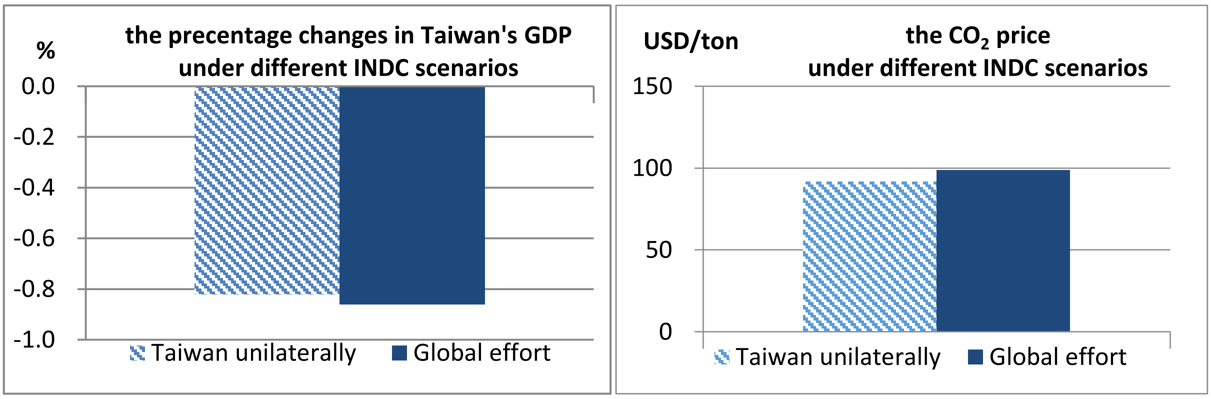

Fig. 12 CO_2 price and Changes in Taiwan's GDP and under different INDC pledge scenarios.

4. CONCLUSIONS

Global CGE models have been used extensively by researchers in many countries to assess the effects of energy or climate policies, where sectorial and regional interactions need to be taken into account carefully. For Taiwan, which depends heavily on international trade and energy imports, existing studies had been conducted solely within the single-country CGE framework. To bridge this gap, in this study we build a version of EPPA where Taiwan is explicitly represented. Our model is the first global CGE model for Taiwan as the energy-environmental policy simulation tool, and it allows us to answer questions raised by this study, including the implications of 1) using input-output data with different base years; 2) applying the input-output data with the same base year, sectorial, and regional definition on distinct models; and 3) pursuing Taiwan's emissions reduction with or without a global mitigation effort. Answering these questions helps researchers and policy makers understand potential sources that could affect simulation results under the same policy shock due to the update of input-output data. It also demonstrates the importance of model setting and highlights the roles of policies taken by rest of the world in determining the domestic policy implications of Taiwan.

Continuous effort is necessary to refine the model structure and keep the underlying data up to date. Improvement on current EPPA-Taiwan can be done in several aspects. For instance, in many countries power sector is a major carbon source. However, the standard GTAP 9 database our model is based only provides an aggregated power sector. As a result, one may disaggregate the power sector in current EPPA-Taiwan into different generation options based on, for example, GTAP 9-Power, a special version of the GTAP 9 with a more detailed representation for the power sector. At the same time, one may also incorporate some engineering data into the model to represent "backstop technologies" that are usually not economically feasible in the base year, but may play crucial roles once energy or climate policies come in. Furthermore, besides the static version of EPPA-Taiwan we build for this study, future research may turn the static model into a dynamic one, so that the model is eligible to address issues where changes in economic condition and policy stringency level over time are a crucial dimension that needs to be taken into account.

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APPENDIX A. EPPA-Taiwan Code

```
$title this is a static version of the EPPA-Taiwan in MPSGE

**the eppacore file for the EPPA-Taiwan is derived from both the file "mrtmge" in GTAP9inGAMS-CGE (Lanz and Rutherford, 2016) a-
nd EPPA6
**the author have greatly benefited from GTAPinGAMS package by Bruno Lanz and Thomas F. Rutherford, the author would like to ex-
press acknowledgement to them.


*$if not set yr $set yr 11
$if not set source $set source 2011eppaTaiwan_19

$set ds %source%
$include .\readgtap
$include .\transhomo
*$include ..\parameters\elas_alignGTAPinGAMS
Set rnum2(r) /TWN/;

$ontext
$model:eppaTaiwan

$sectors:
        Y(g,r)$vom(g,r)                         ! Supply-billion us dollars
        M(i,r)$(vim(i,r) and not x(i))          ! Imports
        YT(j)$vtw(j)                            ! Transportation services
        FT(f,r)$(sf(f) and evom(f,r))           ! Specific factor transformation
        A(i,g,r)$voam(i,g,r)                    ! Armington aggregation- g sector uses the product of i sector
        W(r)$w0(r)                              ! Utility
        HOMM(i,r)$homm0(i,r)$x(i)               ! import sector for homogenious goods
        HOMX(i,r)$homx0(i,r)$x(i)               ! export sector for homogenious goods
$commodities:
        P(g,r)$(vom(g,r) or x(g))               ! Domestic output price
        PM(j,r)$(vim(j,r) and not x(j))         ! Import price
        PT(j)$vtw(j)                            ! Transportation services
        PF(f,r)$evom(f,r)                       ! Primary factors rent
        PS(f,g,r)$(sf(f) and vfm(f,g,r))        ! Sector-specific primary factors
        PA(i,g,r)$voam(i,g,r)                   ! Armington goods price
        PW(r)$w0(r)                             ! Utility price
        PCO2(r)$sclim(r)                        ! co2 price(us dollars per ton)
        PWH(i)$x(i)                             ! world price for homogenious googs
$consumers:
        RA(r)                                   ! Representative agent

*armington goods
$prod:A(i,g,r)$(voam(i,g,r))    s:0  esu:selas(i,"sdm",r)
        o:PA(i,g,r)             q:voam(i,g,r)   p:(1+rtfa0(i,g,r))
        i:P(i,r)$(not x(i))     q:vdfm(i,g,r)   p:(1+rtfd0(i,g,r))      esu:    a:RA(r) t:rtfd(i,g,r) a:RA(r) t:co2tax(i,g,r)




        i:PM(i,r)$(not x(i))    q:vifm(i,g,r)   p:(1+rtfi0(i,g,r))      esu:    a:RA(r) t:rtfi(i,g,r) a:RA(r) t:co2tax(i,g,r)
        i:P(i,r)$(x(i))         q:vdfm(i,g,r)   p:(1+rtfd0(i,g,r))      esu:    a:RA(r) t:rtfd(i,g,r) a:RA(r) t:co2tax(i,g,r)
        i:P(i,r)$(x(i))         q:vifm(i,g,r)   p:(1+rtfi0(i,g,r))      esu:    a:RA(r) t:rtfi(i,g,r) a:RA(r) t:co2tax(i,g,r)
        i:PCO2(r)$sclim(r)      q:eco2(i,g,r)


* government and investment index
$prod:Y(g,r)$vom(g,r)$gi(g)     s:esub(g)
        o:P(g,r)                q:vom(g,r)      P:(1-rto0(g,r))                 a:RA(r) t:rto(g,r)
        i:PA(i,g,r)             q:voam(i,g,r)

* consumption index
$prod:Y(g,r)$vom(g,r)$con(g)    u:delas     a(u):d_elas(r)  dw(u):eed(r)    en(dw):selas("hh","noe_el",r)
        o:P(g,r)                q:vom(g,r)      P:(1-rto0(g,r))                 a:RA(r) t:rto(g,r)
        i:PA(i,g,r)$nend(i)     q:voam(i,g,r)                           a:
        i:PA(i,g,r)$dwe(i)      q:voam(i,g,r)                           dw:
        i:PA(i,g,r)$e(i)        q:voam(i,g,r)                           en:

* set agri = {crop live fors}
$prod:Y(g,r)$(vom(g,r) and agri(g))     a:pnesta(g,r)           va(a):selas(g,"l_k",r)  fx(a):esup(g,r)  e(fx):selas(g,"e_kl-
",r) ne(e):ene(g,r)
+                               en(e):selas(g,"noe_el",r)  en1(en):esube(g,r)       bva(fx):esubva(g)
        o:P(g,r)                q:vom(g,r)      P:(1-rto0(g,r))                 a:RA(r) t:rto(g,r)
        i:PA(i,g,r)$enoe(i)     q:voam(i,g,r)                           en1:
        i:PA(i,g,r)$elec(i)     q:voam(i,g,r)                           en:
        i:PA(i,g,r)$ne(i)       q:voam(i,g,r)                           ne:
        i:PS(sf,g,r)            q:vfm(sf,g,r)   p:(1+rtf0(sf,g,r))      bva:    a:RA(r) t:rtf(sf,g,r)
        i:PF(mf,r)              q:vfm(mf,g,r)   p:(1+rtf0(mf,g,r))      va:     a:RA(r) t:rtf(mf,g,r)

* set eint = {eint}
$prod:Y(g,r)$(vom(g,r) and eint(g))     b:esup(g,r)         a(b):pnesta(g,r)        ee(a):selas(g,"e_kl",r)   va(ee):sela-
s(g,"l_k",r)  en(ee):selas(g,"noe_el",r)
+                                       en1(en):esube(g,r)  bva(b):esubva(g)
        o:P(g,r)                q:vom(g,r)      P:(1-rto0(g,r))                 a:RA(r) t:rto(g,r)
        i:PA(i,g,r)$enoe(i)     q:voam(i,g,r)                           en1:
        i:PA(i,g,r)$elec(i)     q:voam(i,g,r)                           en:
        i:PA(i,g,r)$ne(i)       q:voam(i,g,r)                           a:
        i:PS(sf,g,r)            q:vfm(sf,g,r)   p:(1+rtf0(sf,g,r))      bva:    a:RA(r) t:rtf(sf,g,r)
        i:PF(mf,r)              q:vfm(mf,g,r)   p:(1+rtf0(mf,g,r))      va:     a:RA(r) t:rtf(mf,g,r)


* domestic production index
* note the negation of aenoe.  set aenoe = {crop live fors coal oil roil gas elec eint}
* so this block is for set Naenoe ={food othr serv tran dwe}
```

```
$prod:Y(g,r)$(vom(g,r)$(Naenoe(g)))        b:esup(g,r)           a(b):pnesta(g,r)    ee(a):selas(g,"e_kl",r)    va(ee):selas(g,"l_
k",r)  en(ee):selas(g,"noe_el",r)
+                                          enl(en):esube(g,r)    bva(b):esubva(g)
        o:P(g,r)                q:vom(g,r)      P:(1-rto0(g,r))                 a:RA(r)  t:rto(g,r)
        i:PA(i,g,r)$enoe(i)     q:voam(i,g,r)                          enl:
        i:PA(i,g,r)$elec(i)     q:voam(i,g,r)                          en:
        i:PA(i,g,r)$ne(i)       q:voam(i,g,r)                          a:
        i:PS(sf,g,r)            q:vfm(sf,g,r)   p:(1+rtf0(sf,g,r))     bva:     a:RA(r)  t:rtf(sf,g,r)
        i:PF(mf,r)              q:vfm(mf,g,r)   p:(1+rtf0(mf,g,r))     va:      a:RA(r)  t:rtf(mf,g,r)

* set enoe = {coal oil roil gas}
$prod:Y(g,r)$(vom(g,r)$(enoe(g)))        b:esup(g,r)             a(b):pnesta(g,r)    va(a):selas(g, "l_k",r)    en(a):selas(g,"noe
_el",r)
+                                        enl(en):esube(g,r)      bva(b):esubva(g)
        o:P(g,r)                q:vom(g,r)      P:(1-rto0(g,r))                 a:RA(r)  t:rto(g,r)
        i:PA(i,g,r)$enoe(i)     q:voam(i,g,r)                          enl:
        i:PA(i,g,r)$elec(i)     q:voam(i,g,r)                          en:
        i:PA(i,g,r)$ne(i)       q:voam(i,g,r)                          a:
        i:PS(sf,g,r)            q:vfm(sf,g,r)   p:(1+rtf0(sf,g,r))     bva:     a:RA(r)  t:rtf(sf,g,r)
        i:PF(mf,r)              q:vfm(mf,g,r)   p:(1+rtf0(mf,g,r))     va:      a:RA(r)  t:rtf(mf,g,r)

* set elec = {elec}
$prod:Y(g,r)$(vom(g,r) and elec(g))      s:esub(g)     va:esubva(g)
        o:P(g,r)                q:vom(g,r)      P:(1-rto0(g,r))                 a:RA(r)  t:rto(g,r)
        i:PA(i,g,r)             q:voam(i,g,r)
        i:PS(sf,g,r)            q:vfm(sf,g,r)   p:(1+rtf0(sf,g,r))     va:      a:RA(r)  t:rtf(sf,g,r)
        i:PF(mf,r)              q:vfm(mf,g,r)   p:(1+rtf0(mf,g,r))     va:      a:RA(r)  t:rtf(mf,g,r)

* net imports of homogenous goods
* vhomm0(x,r) = (homm0(x,r)+homt0(x,r))*(1+tmhom(x,r))
* homt0: value of homogenous goods transport cost; tmhom: tariff on homogenous goods
$prod:HOMM(i,r)$homm0(i,r)$x(i)  s:0
        o:P(i,R)                q:vhomm0(i,r)
        i:PWH(i)                q:homm0(i,r)    p:(1+tmhom0(i,r))      a:RA(r)   t:tmhom(i,r)
        i:PT(j)                 q:homt0(j,i,r)  p:(1+tmhom0(i,r))      a:RA(r)   t:tmhom(i,r)

* net exports of homogenous goods
* vhomx0(x,r) = homx0(x,r)/(1+txhom(x,r))
* txhom: export tax on homogenous goods
$prod:HOMX(i,r)$homx0(i,r)$x(i)
        o:PWH(i)                q:homx0(i,r)
        i:P(i,r)                q:vhomx0(i,r)   p:(1+txhom0(i,r))      a:RA(r)   t:txhom(i,r)

*utility index
$prod:W(r)$w0(r)        s:ew(r)
        o:PW(r)                 q:w0(r)


        i:P("i",r)              q:vom("i",r)
        i:P(con,r)              q:vom(con,r)

$prod:YT(j)$vtw(j)       s:eyt
        o:PT(j)                 q:vtw(j)
        i:P(j,r)                q:vst(j,r)

$prod:M(i,r)$(vim(i,r) and not x(i))    s:selas(i,"smm",r)   s.tl:0
        o:PM(i,r)               q:vim(i,r)
        i:P(i,s)                q:vxmd(i,s,r)   p:pvxmd(i,s,r) s.tl: a:RA(s) t:(-rtxs(i,s,r)) a:RA(r) t:(rtms(i,s,r)*(1-rtxs(i,
s,r)))
        i:PT(j)#(s)             q:vtwr(j,i,s,r) p:pvtwr(i,s,r) s.tl: a:RA(r) t:rtms(i,s,r)

$prod:FT(sf,r)$evom(sf,r)   t:etrae(sf)
        o:PS(sf,j,r)            q:vfm(sf,j,r)
        i:PF(sf,r)              q:evom(sf,r)

$demand:RA(r)
        d:PW(r)                 q:w0(r)
        e:P(con,rnum)           q:vb(r)
        e:P("g",r)              q:(-vom("g",r))
        e:PF(f,r)               q:evom(f,r)
        e:PCO2(r)$sclim(r)      q:clim(r)
        e:P(g,r)$x(g)           q:homadj(g,r)
        e:PT(j)                 q:trnadj(j,r)


$report:

         v:R_ARM(i,g,r)          o:PA(i,g,r)       prod:A(i,g,r)    ! realized vafm (Armington good output in billion US$)
         v:R_VOMg(g,r)           o:P(g,r)          prod:y(g,r)      ! realized vom (sectoral output in billion US$)
         v:R_CO2(i,g,r)          i:PCO2(r)         prod:A(i,g,r)    ! realized (sectoral CO2 emission in billion ton)
         v:R_CONS(r)             o:PW(r)           prod:W(r)        ! realized vum (total final consumption in billion US$)
         v:R_VDFM(i,g,r)         i:P(i,r)          prod:A(i,g,r)    ! Realized vdfm (domestic supply in billion US$)
         v:R_VIFM(i,g,r)         i:PM(i,r)         prod:A(i,g,r)    ! Realized vifm (import supply in billion US$)
         v:R_VFMSF(f,g,r)        i:PS(f,g,r)       prod:Y(g,r)      ! Realized vfm_sf (supply of sluggish factor in billion US$)
         v:R_VFMMF(f,g,r)        i:PF(f,r)         prod:Y(g,r)      ! Realized vfm_mf (supply of mobile factor in billion US$)
         v:R_VXMD(i,s,r)         i:P(i,s)          prod:M(i,r)      ! Realized vxmd (region r's importing from region s in billion
 US$)
         v:R_VST(j,r)            i:P(j,r)          prod:YT(j)       ! Realized vst (Transportation services in billion US$)

$offtext
$sysinclude mpsgeset eppaTaiwan


 PA.L(i,g,r)      = 1+rtfa0(i,g,r);


 *PCO2.L(r)$sclim(r)=1e-6;
 P.FX("c",rnum2)   = 1;
 *==========
 sclim(r)=no;
 eppaTaiwan.workspace = 256;
 eppaTaiwan.iterlim = 0;
 eppaTaiwan.optfile = 1;
 $include eppaTaiwan.gen
 solve eppaTaiwan using mcp;


 $set sim base

 $include .\report.gms
 $include ..\active\INDCshock.gms

 $exit
```

APPENDIX B. Nesting structures

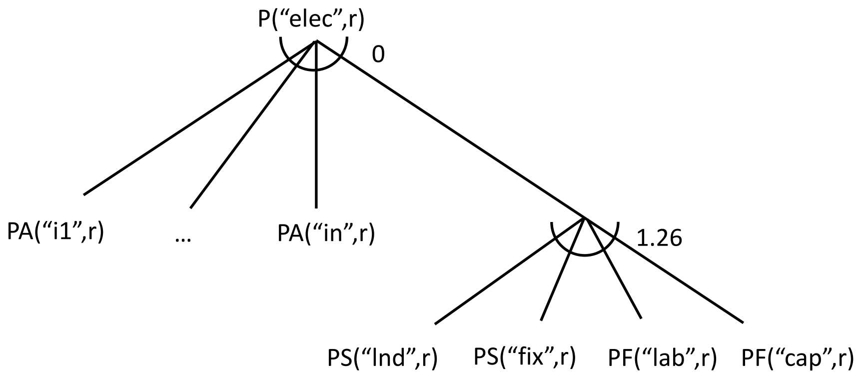

Figure B1. Nesting structure of electricity sector.

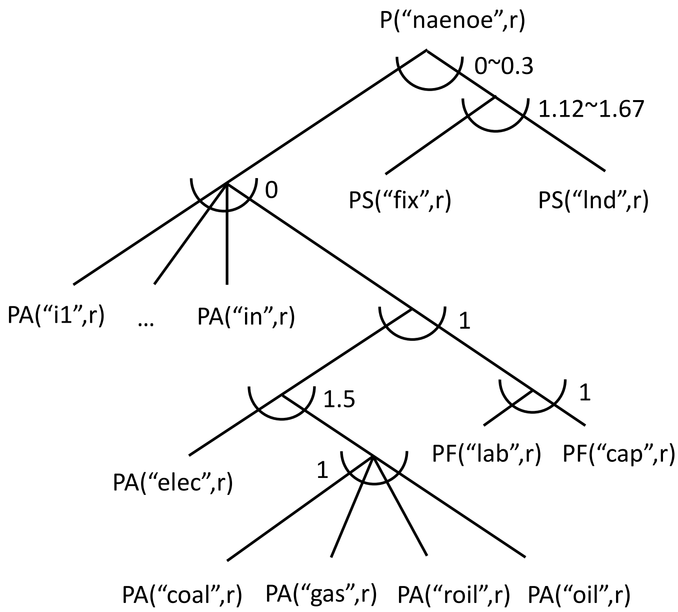

Figure B2. Nesting structure of dwelling, food, other, service, and transportation sector.

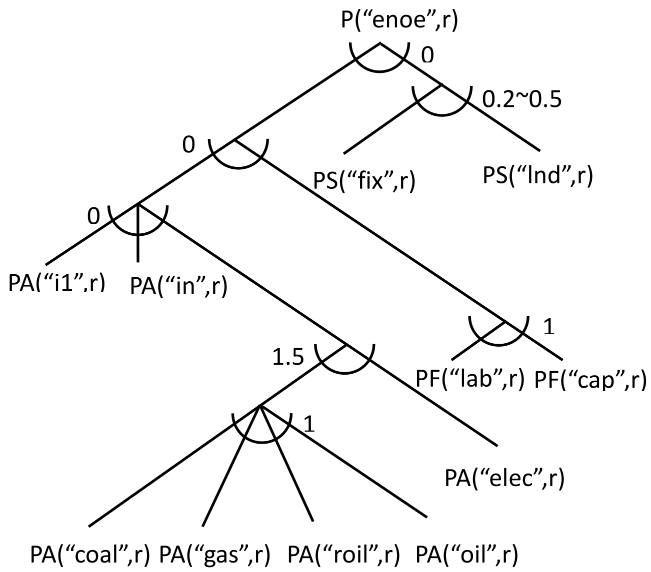

Figure B3. Nesting structure of oil, gas, refined oil and coal sector.

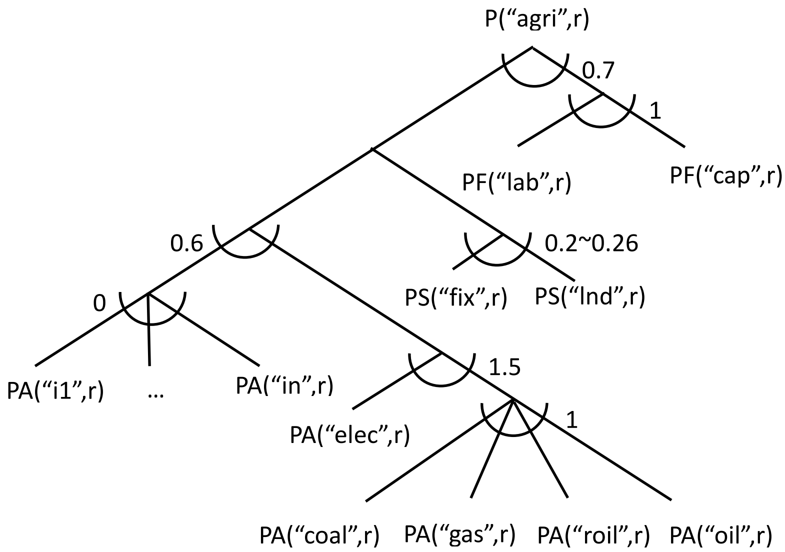

Figure B4. Nesting structure of crop, live, and forest sector.

APPENDIX C. Mapping from GTAP9 to EPPA-Taiwan

Table C1. Mapping for regions from GTAP 9 to EPPA-Taiwan.

	GTAP 9 region	EPPA-Taiwan region		GTAP 9 region	EPPA-Taiwan region		GTAP 9 region	EPPA-Taiwan region
1	Albania	ROE	51	Kazakhstan	ROE	101	Ukraine	ROE
2	United Arab Emirates	MES	52	Kenya	AFR	102	Uruguay	LAM
3	Argentina	LAM	53	Kyrgyzstan	ROE	103	United States of America	USA
4	Armenia	ROE	54	Cambodia	REA	104	Venezuela	LAM
5	Australia	ANZ	55	Korea Republic of	KOR	105	Viet Nam	REA
6	Austria	EUR	56	Kuwait	MES	106	South Central Africa	AFR
7	Azerbaijan	ROE	57	Lao People's Democratic Republic	REA	107	Rest of Central America	LAM
8	Belgium	EUR	58	Sri Lanka	REA	108	Caribbean	LAM
9	Bangladesh	REA	59	Lithuania	EUR	109	Central Africa	AFR
10	Bulgaria	EUR	60	Luxembourg	EUR	110	Rest of East Asia	REA
11	Bahrain	MES	61	Latvia	EUR	111	Rest of Eastern Africa	AFR
12	Belarus	ROE	62	Morocco	AFR	112	Rest of Eastern Europe	ROE
13	Plurinational Republic of Bolivia	LAM	63	Madagascar	AFR	113	Rest of EFTA	EUR
14	Brazil	BRA	64	Mexico	MEX	114	Rest of Europe	ROE
15	Botswana	AFR	65	Malta	EUR	115	Rest of North America	LAM
16	Canada	CAN	66	Mongolia	REA	116	Rest of North Africa	AFR
17	Switzerland	EUR	67	Mozambique	AFR	117	Rest of Oceania	ANZ
18	Chile	LAM	68	Mauritius	AFR	118	Rest of South Asia	REA
19	China	CHN	69	Malawi	AFR	119	Rest of South African Customs Union	AFR
20	Cote d'Ivoire	AFR	70	Malaysia	ASI	120	Rest of Southeast Asia	REA
21	Cameroon	AFR	71	Namibia	AFR	121	Rest of South America	LAM
22	Colombia	LAM	72	Nigeria	AFR	122	Rest of Former Soviet Union	ROE
23	Costa Rica	LAM	73	Nicaragua	LAM	123	Rest of the World	ANZ
24	Cyprus	EUR	74	Netherlands	EUR	124	Rest of Western Africa	AFR
25	Czech Republic	EUR	75	Norway	EUR	125	Rest of Western Asia	MES
26	Germany	EUR	76	Nepal	REA	126	South Africa	AFR
27	Denmark	EUR	77	New Zealand	ANZ	127	Zambia	AFR
28	Ecuador	LAM	78	Oman	MES	128	Zimbabwe	AFR
29	Egypt	AFR	79	Pakistan	REA	129	Benin	AFR
30	Spain	EUR	80	Panama	LAM	130	Burkina Faso	AFR
31	Estonia	EUR	81	Peru	LAM	131	Brunei Darussalam	REA
32	Ethiopia	AFR	82	Philippines	ASI	132	Dominican Republic	LAM
33	Finland	EUR	83	Poland	EUR	133	Guinea	AFR
34	France	EUR	84	Portugal	EUR	134	Jamaica	LAM
35	United Kingdom	EUR	85	Paraguay	LAM	135	Jordan	MES
36	Georgia	ROE	86	Qatar	MES	136	Puerto Rico	LAM
37	Ghana	AFR	87	Romania	EUR	137	Rwanda	AFR
38	Greece	EUR	88	Russian Federation	RUS	138	Togo	AFR
39	Guatemala	LAM	89	Saudi Arabia	MES	139	Trinidad and Tobago	LAM
40	Hong Kong	CHN	90	Senegal	AFR	140	Taiwan	TWN
41	Honduras	LAM	91	Singapore	ASI			
42	Croatia	EUR	92	El Salvador	LAM			
43	Hungary	EUR	93	Slovakia	EUR			
44	Indonesia	IDZ	94	Slovenia	EUR			
45	India	IND	95	Sweden	EUR			
46	Ireland	EUR	96	Thailand	ASI			
47	Iran Islamic Republic of	MES	97	Tunisia	AFR			
48	Israel	MES	98	Turkey	ROE			
49	Italy	EUR	99	Tanzania United Republic of	AFR			
50	Japan	JPN	100	Uganda	AFR			

Table C2. Mapping for sectors from GTAP 9 to EPPA-Taiwan.

	GTAP 9 sector	EPPA-Taiwan sector		GTAP 9 sector	EPPA-Taiwan sector
1	paddy rice	CROP	31	paper products - publishing	EINT
2	wheat	CROP	32	petroleum - coal products	ROIL
3	cereal grains nec	CROP	33	chemical - rubber - plastic products	EINT
4	vegetables - fruit - nuts	CROP	34	mineral products nec	EINT
5	oil seeds	CROP	35	ferrous metals	EINT
6	sugar cane - sugar beet	CROP	36	metals nec	EINT
7	plant-based fibers	CROP	37	metal products	EINT
8	crops nec	CROP	38	motor vehicles and parts	OTHR
9	bo horses	LIVE	39	transport equipment nec	OTHR
10	animal products nec	LIVE	40	electronic equipment	OTHR
11	raw milk	LIVE	41	machinery and equipment nec	OTHR
12	wool - silk-worm cocoons	LIVE	42	manufactures nec	OTHR
13	forestry	FORS	43	electricity	ELEC
14	fishing	LIVE	44	gas manufacture - distribution	GAS
15	coal	COAL	45	water	OTHR
16	oil	OIL	46	construction	OTHR
17	gas	GAS	47	trade	SERV
18	minerals nec	OTHR	48	transport nec	TRAN
19	bo meat products	FOOD	49	water transport	TRAN
20	meat products	FOOD	50	air transport	TRAN
21	vegetable oils and fats	FOOD	51	communication	SERV
22	dairy products	FOOD	52	financial services nec	SERV
23	processed rice	FOOD	53	insurance	SERV
24	sugar	FOOD	54	business services nec	SERV
25	food products nec	FOOD	55	recreational and other services	SERV
26	beverages and tobacco products	FOOD	56	public admin - and defence - education - health	SERV
27	textiles	OTHR	57	ownership of dwellings	DWE
28	wearing apparel	OTHR			
29	leather products	OTHR			
30	wood products	OTHR			

Table C3. Mapping for primary factors from GTAP 9 to EPPA-Taiwan.

	GTAP 9 primary factor	EPPA-Taiwan primary factor
1	Officials and Mangers legislators (ISCO-88 Major Groups 1-2)	LAB
2	Technicians technicians and associate professionals	LAB
3	Clerks	LAB
4	Service and market sales workers	LAB
5	Agricultural and unskilled workers (Major Groups 6-9)	LAB
6	Land,	LND
7	Capital,	CAP
8	Natural resources	FIX

APPENDIX D. Simulation results

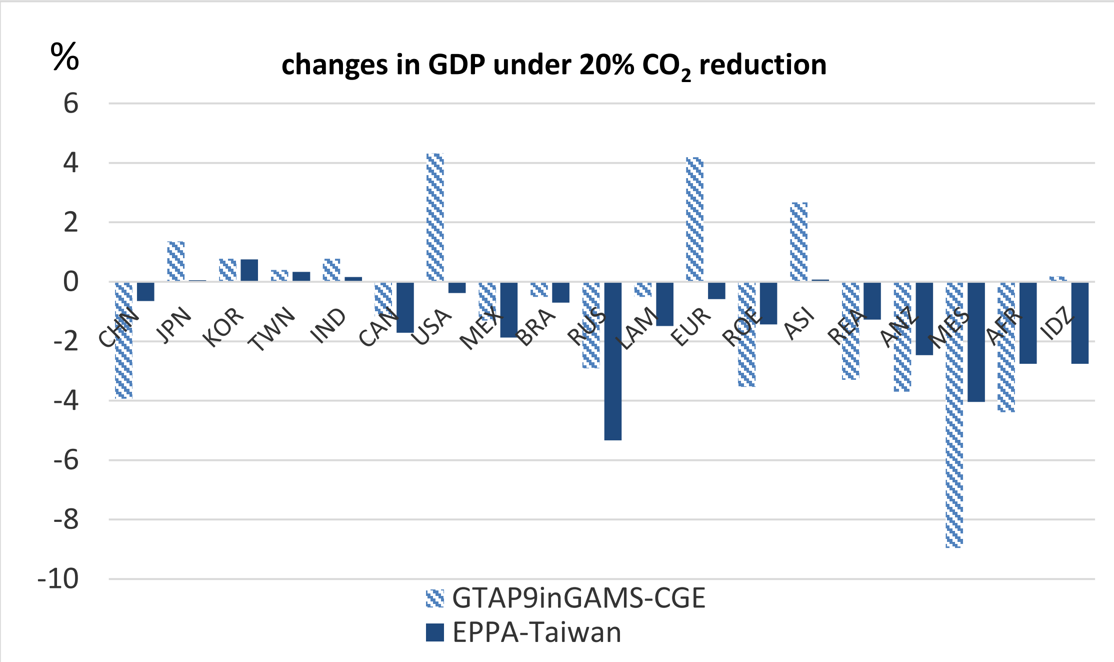

Figure D1. Changes in GDP in GTAP9inGAMS-CGE and in the EPPA-Taiwan.

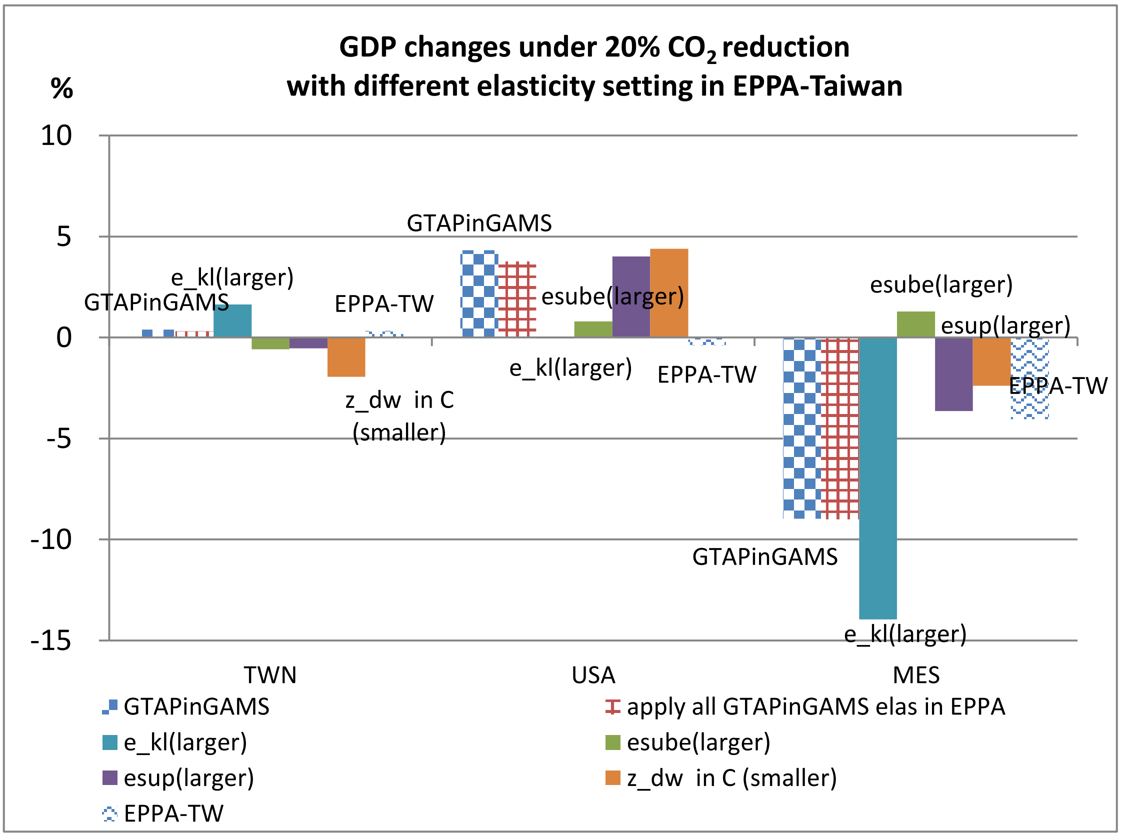

Figure D2. Replacing single elasticity by EPPA elasticity.
(the rest elasticities are align with GTAP9inGAMS-CGE)

APPENDIX E. Emission targets under INDC commitments

Table E1. Emission Targets for each region under INDC commitments.

Region	Policy type	2030 CO_2 trajectory (million ton)	2030 GDP trajectory (billion USD)	2011 CO_2 (million ton)	Emission target
USA	ABS	5942	21943	5831	4965
CAN	ABS	1014	2231	656	592
MEX	BAU	1099	1869	494	824
BRA	ABS	1182	2143	515	202
LAM	BAU	964	2778	885	868
EUR	ABS	4048	24032	4781	3222
RUS	ABS	1491	1747	1863	2400
ROE	BAU	1609	2331	1363	1448
CHN	CO_2 INT	13235	14536	9269	16680
IND	CO_2 INT	3709	5257	1995	8427
JPN	ABS	1110	5240	1438	1008
ASI	BAU	2301	2449	759	2071
REA	BAU	861	1332	457	775
ANZ	BAU	640	1841	481	477
MES	BAU	2097	2985	1956	1887
AFR	BAU	2564	3308	1163	2436
KOR	BAU	1666	2043	791	1249
IDZ	BAU	1212	1315	436	848
TWN	BAU	428		350	214