The Introduction and Economic Implications by using EPPA-Taiwan model

Cheng-Da Yuan[1]
Wei-Hong Hong [1]
Hui-Chih Chai [1]
Y.-H. Henry Chen[2]

1. Center of Energy Economy and Strategy Research, Institute of Nuclear Energy Research, INER
2. Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology

09/29/2017

MIT JOINT PROGRAM ON THE SCIENCE AND POLICY of GLOBAL CHANGE

核能研究所
能源經濟及策略研究中心
Center of Energy Economics and Strategy Research

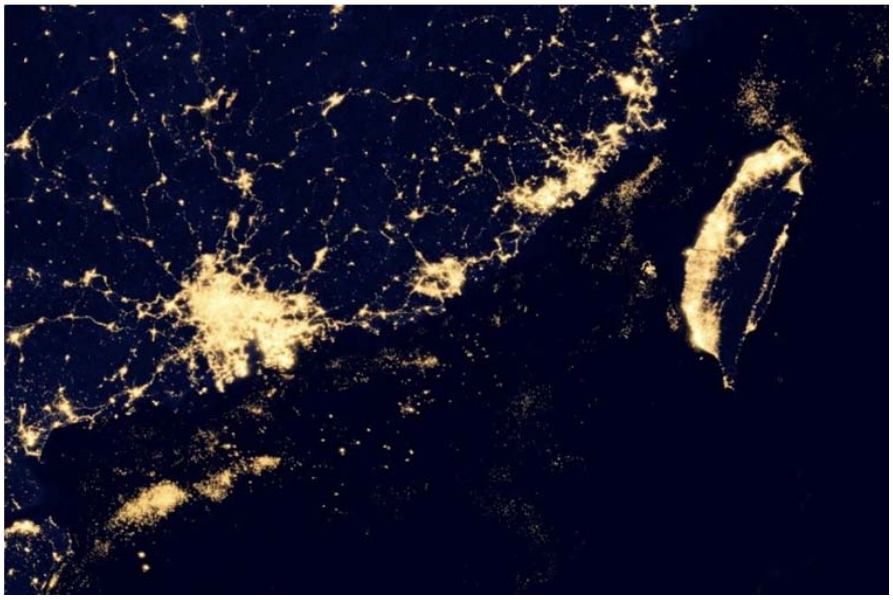
Outline

- **Introduction**
  - Overview
  - Nesting structure
  - Dynamic mechanisms
- **Economic Implication-static model**
  - MRT v.s SOE
  - Results
  - Conclusion, limit and further research

Introduction

Why we need to build EPPA-Taiwan?

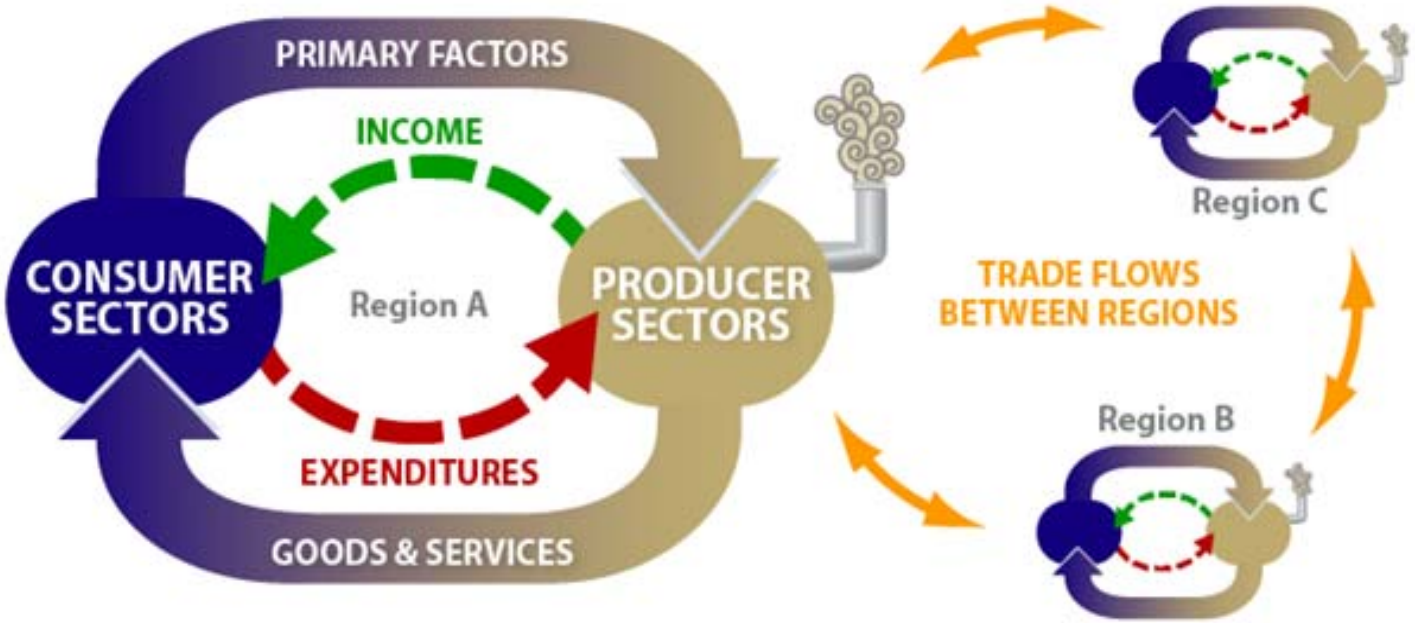
- Taiwan relies heavily on imports of fossil fuels
- Taiwan is highly dependent on international trade



Source: NASA

Model structure & Equilibrium condition

- Schematic representation of EPPA-Taiwan



source: Paltsev (2005)

Features of the EPPA-Taiwan

- A member of MIT EPPA family models
- The dynamic version of the model is under development

	EPPA-Taiwan
modeling language	the GAMS/MPSGE
Database	GTAP9 (more easily to adjust sectors and regions)
Region	19 (Taiwan)
Sector	21 sectors with detailed Electricity sector
Substitution Elasticity	aligned with MIT EPPA 6
Function form	CES with multiple layers Stone-Geary
Nesting structure	1) Detailed Electricity sector 2) Backstop technology 3) GHG emissions

reference years: 2011

Data: Regions and Sectors

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		

In the EPPA6 model Taiwan's data is aggregated with Malaysia, Philippines, Thailand, and Singapore as one region named Dynamic Asian (ASI).

EPPA-Taiwan sector	Symbol	Subgroup	EPPA-Taiwan sector	Symbol	Subgroup
Crops	CROP	Agri	Gas	GAS	enoe
Livestock	LIVE	Agri	Energy-Intensive Industries	EINT	eint
Forestry	FORS	Agri	Other Industries	OTHR	naenoe
Food Products	FOOD	naenoe	Ownership of Dwellings	DWE	naenoe
Coal	COAL	Enoe	Services	SERV	naenoe
Crude Oil	OIL	Enoe	Transport	TRAN	naenoe
Refined Oil	ROIL	Enoe			
Coal-fired	**COALG**	**Elec**	**Gas-fired**	**GASG**	**elec**
Oil-fired	**OILG**	**Elec**	**Hydro**	**HYDRO**	**elec**
Nuclear	**NUCLEAR**	**Elec**	**Wind**	**WIND**	**elec**
Solar	**SOLAR**	**Elec**	**Other**	**ReG**	**elec**

The electricity sector is aggregated by fossil fuel and renewables

Model structure & Equilibrium condition

- Activities of different agents are described by three conditions
- Formulate a CGE model as Mixed Complementarity Problems (MCP)

  - Zero profit condition: $[MC - MR \geq 0; Q \geq 0; (MC - MR) \cdot Q = 0]$
  - Market clearing condition: $[\mathrm{S}{-}D \geq 0; P \geq 0; (S - D) \cdot P = 0]$
  - Income balance condition: $[E - I \geq 0; E \geq 0; (E - I) \cdot E = 0]$

The structure of micro-consistent matrix

Table 1. SAM/MCM for EPPA-Taiwan

			Columns in this matrix correspond to Activities and their corresponding Zero-profit Conditions												Income-Balance Conditions
			Domestic Production Activity	Electricty 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
			Y(i,r)	EL(g,r)	Y(C,r)	Y(G,r)	Y(INV,r)	FT(sf,r)	YT(i)	M(i*,r)	A(i,g,r)	HOMX(x,r)	[HOMM(x,r)]	W(r)	RA(r)
Rows in this matrix correspond toMarket-clearing conditions	Domestic Production	P(i*,r)	*+vom(i*,r)*						vst(i*,r)	vxmd(i*,s,r)	vdfm(i*,g,r)				
		P(elec,r)	*+vom(elec,r)*	+voe(g,r)											
		P(x,r)	*+vom(x,r)*						vst(x,r)		vdfm(x,g,r) [vifm(x,g,r)]	vhomx(x,r)	*[+vhomm(x,r)]*		*+homadj(x,r)*
	HH consump	P(C,r)			*+vom(C,r)*									vom(C,r)	
	Gov. consump.	P(G)r				*+vom(G,r)*									vom(G,r)
	Loanable Funds	P(INV,r)					*+vom(INV,r)*							vom(INV,r)	
	Primary Factors	PS(sf,j,r)	vfm(sf,i,r)					*+vfm(sf,j,r)*							
		PF(mf,r)	vfm(mf,i,r)												*+evom(mf,r)*
		PF(sf,r)						evom (sf,r)							*+evom(sf,r)*
	Intl. Transp.	PT(j)							*+vtw(j)*	vtwr (j,i*,s,r)			[homt(j,x,r)]		*+trnadj(j,x,r)*
	Imports	PM(i,r)								*+vim(i*,r)*	vifm(i*,g,r)				
	Armington Good	PA(i,g,r))	voam(j,i,r)		voam(i,C,r)	voam(i,G,r)	voam(i,INV,r)				*+voam(i,g,r)*				
		PCO_2(r)									CO_2(i,g,r)				*+CO2lim(r)*
	Aggregated Electricity	PE(g,r)	+voe(i,r)	*+voe(g,r)*	+voe(C,r)	+voe(G,r)	+voe(INV,r)								
	Homogeneous good	PWH(x)										*+homx(x,r)*	[homm(x,r)]		
	Total HH consump.	PW(r)												*+vum(r)*	vum(r)
	Resources for Tax payment	TAX(i,g,r)	rto(i,r), rtf(f,i,r)		rto(C,r)	rto(G,r)	rto(INV,r)			rtms(i*,s,r), rtxs(i*,s,r)	rtfd(i,g,r),rtfi(i,g,r)	txhom(x,r)	[tmhom(x,r)]		*tax revenue(r)*
	Current Account	P(C,TWN)													*+vb(r)*

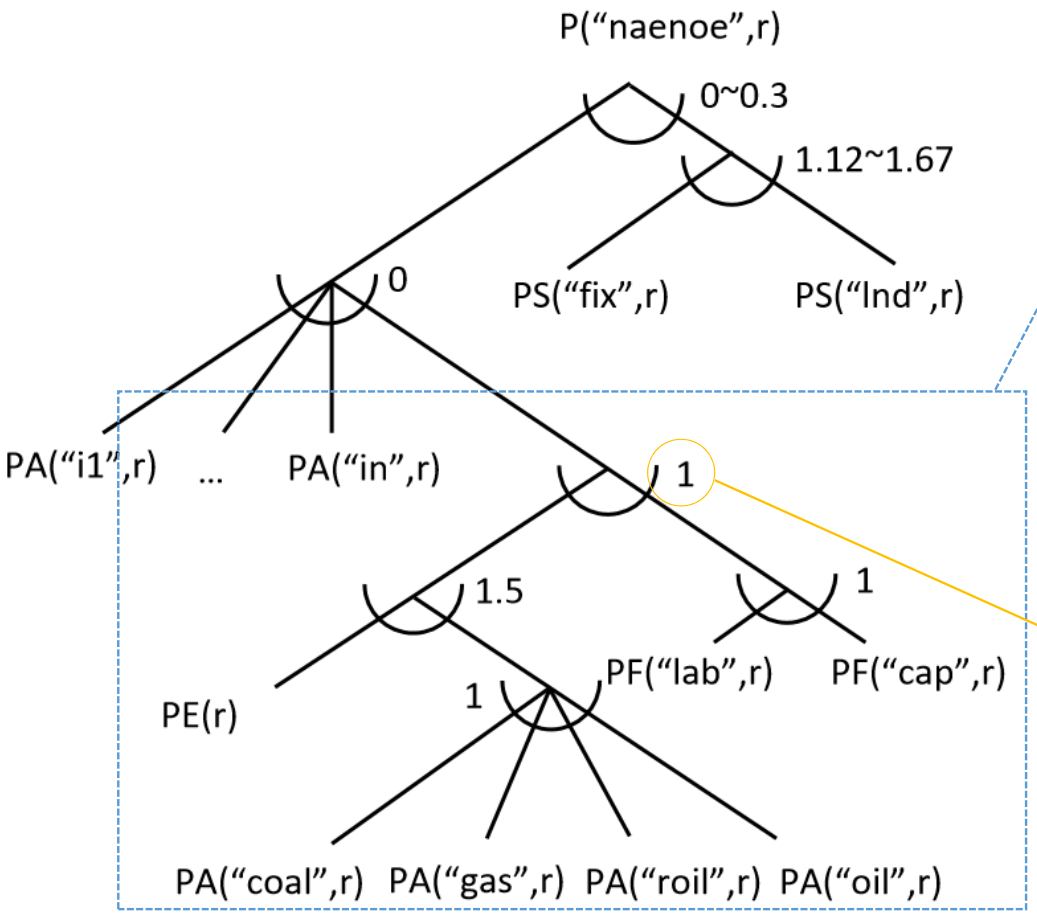
Note: i* denotes sector set i excluding item x and el. Where x denotes crude oil which is an homogeneous good and elec denotes various power generations, includes nuclear, hydro, fossil fule generation, wind, hydro and other renewable power generations in the EPPA-Taiwan.

Market clearing

Zero profit

Income balance

Nesting structures: production sectors- naenoe
(dwelling, food, other, service, and transportation sector)



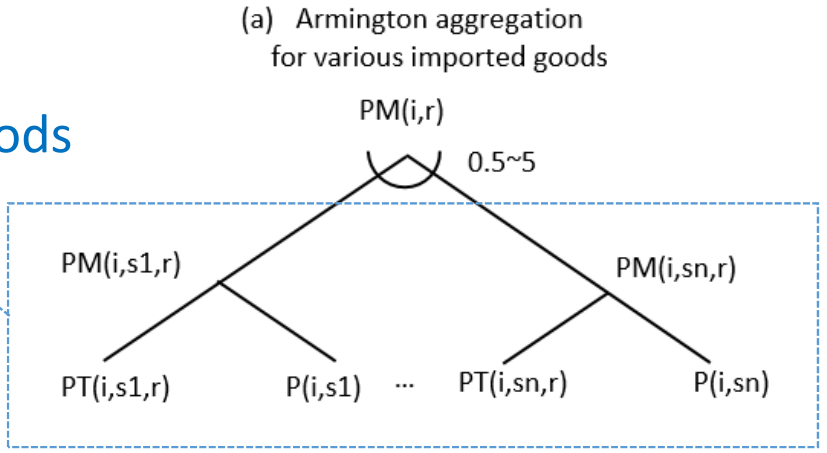
KLE(capital-labor-energy) bundle

Elasticity of substitution

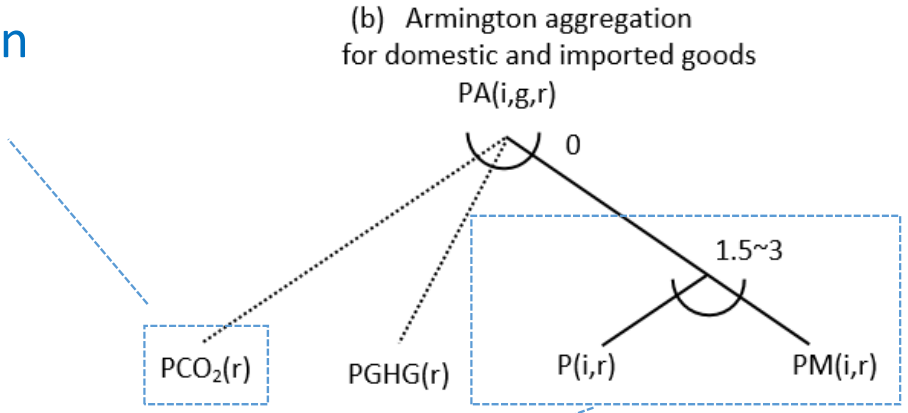
$$\sigma = \left[\frac{\frac{\partial Q_e}{Q_e}}{\frac{\partial Q_n}{Q_n}}\right] \Big/ \left[\frac{\frac{\partial P_n}{P_n}}{\frac{\partial P_e}{P_e}}\right]$$

Nesting structures:
International Trade & Armington goods

S1~Sn: Sources of importing goods



PCO_2 represents a carbon penalty to energy consumptions



aggregation of domestic and imported goods, except for crude oil

Dynamic mechanisms

- Investment I should be added to capital stock KS rather than capital return K

- Convert stock to flow based on some assumptions
  - Value of capital stock $KS = \sum_{t=1}^{\infty} \frac{K}{(1+r)^t} = \frac{K}{r}$
  - Value of capital return $K = r \cdot KS$
  - $KS_{t+1} = I_t + (1-\delta) \cdot KS_t$
  - $K_{t+1} = r \cdot I_t + (1-\delta) \cdot K_t$

Dynamic mechanisms

- Resource depletion
  - The depletion mechanism allows nature resource such as nature gas, coal and oil deplete with time.

- AEEI
  - The technologies improvement can enhance the efficiency for energy use, thus reduce the energy input in production activities. Our model assumption for AEEI allows efficiency improvement for different energy uses such as the electricity, oil, refined oil, coal and gas.

Dynamic mechanisms

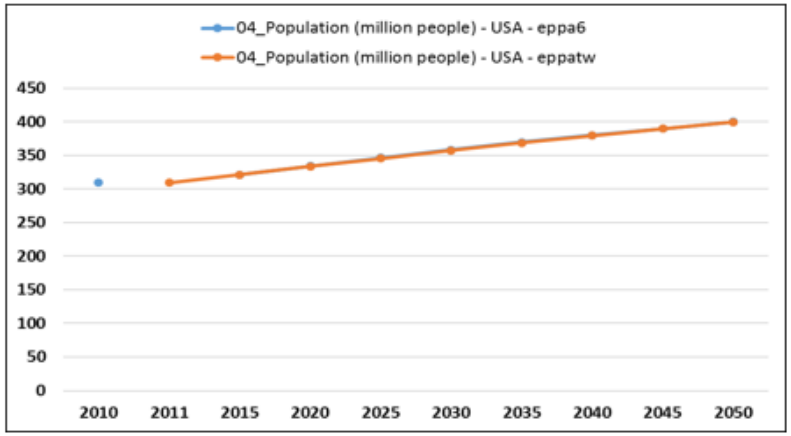
- GDP
  - The GDP trajectory is newly updated from IMF's World Economic Outlook (WEO, 2017) and used to calibrate the factor-augmented productivity growth https://www.imf.org/external/pubs/ft/weo/2017/01/weodata/index.aspx

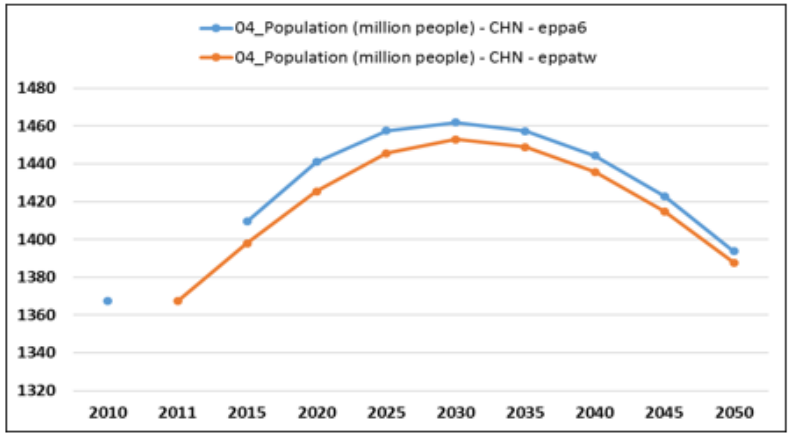
- Population
  - The population data is based on the forecasting statistics of 2017 Revision of World Population Prospects (WPP, 2017). For more information can visit: https://esa.un.org/unpd/wpp/

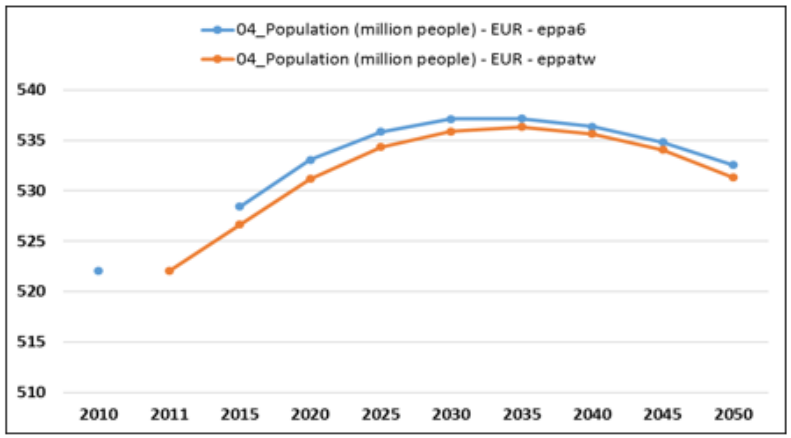
- GHG
  - To adequately calculate mitigation target for specific regions (see Jacoby *et al*., 2017), we calibrate the GHG emissions from Emission Database for Global Atmospheric Research (EDGAR) since most countries meet mitigation target in GHG base.

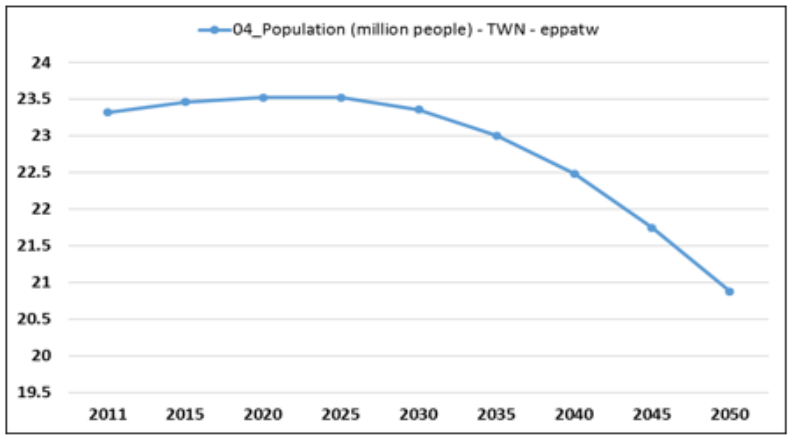
  - The GHG emissions of EDGAR database is based on the energy balance statistics of IEA (2013) and provides sectoral GHG emissions include CH_4, N_2O, SF_6, PFCs and HFCs and contributed to either in combustion or non-combustion. For more information can visit: http://edgar.jrc.ec.europe.eu, 2013

Population projection for selected regions (US, China, EU and Taiwan)

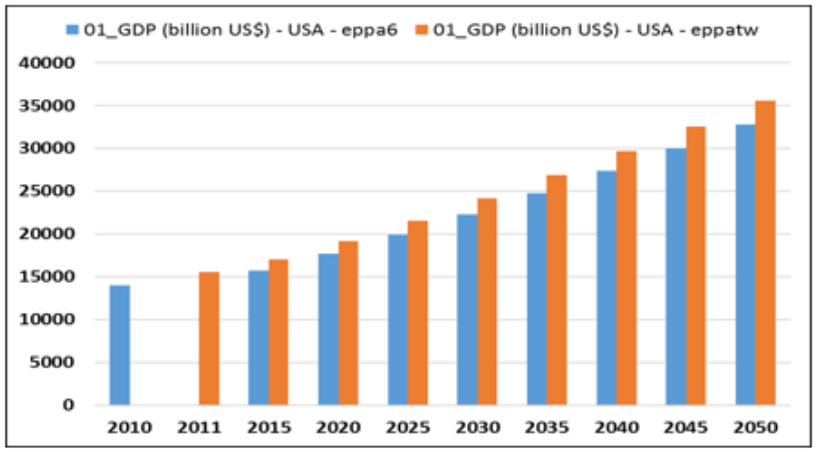


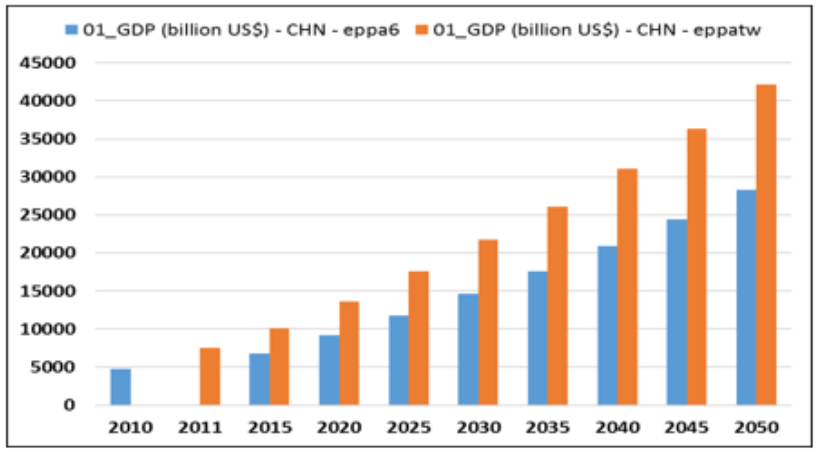


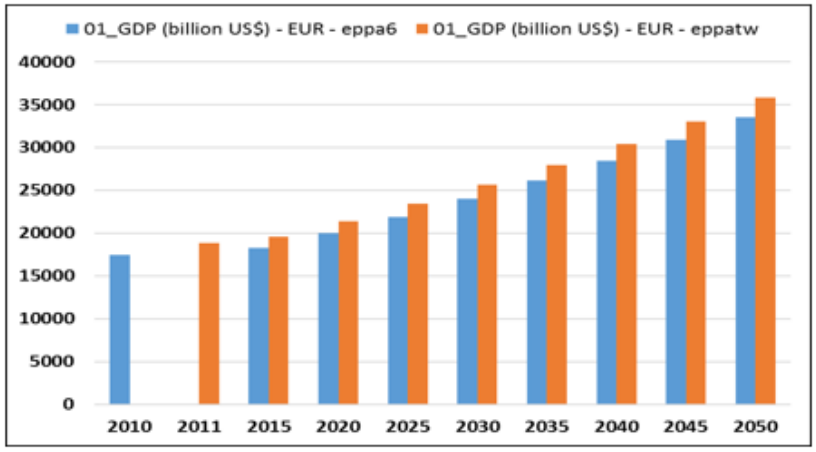


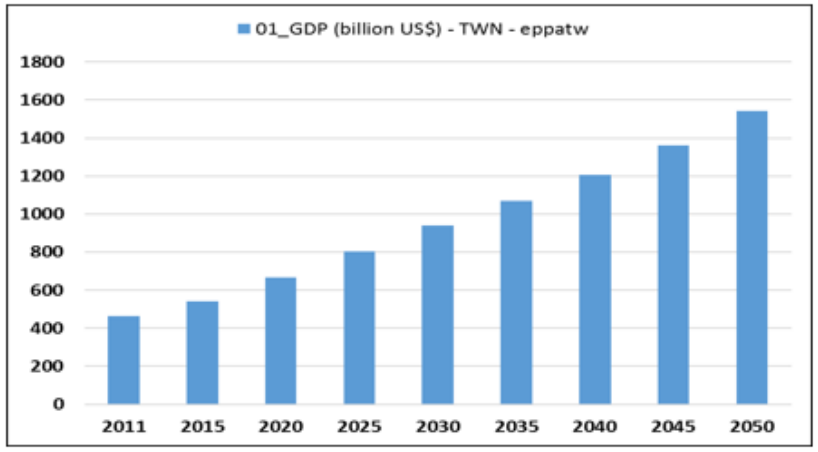


GDP projection for selected regions (US, China, EU and Taiwan)

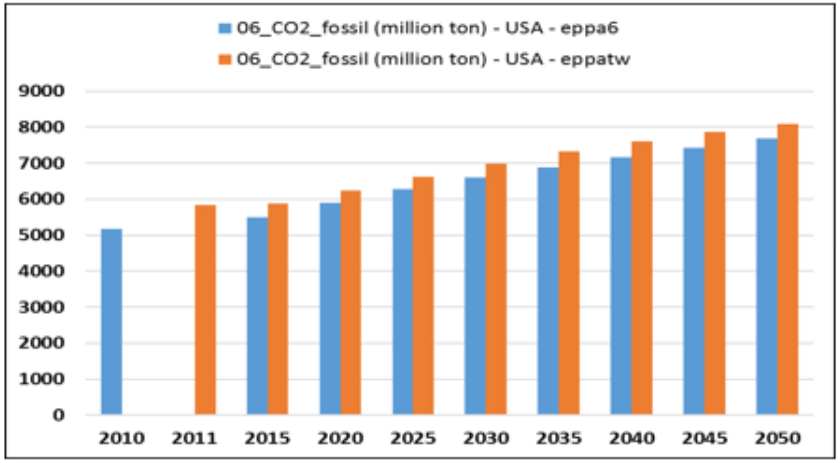


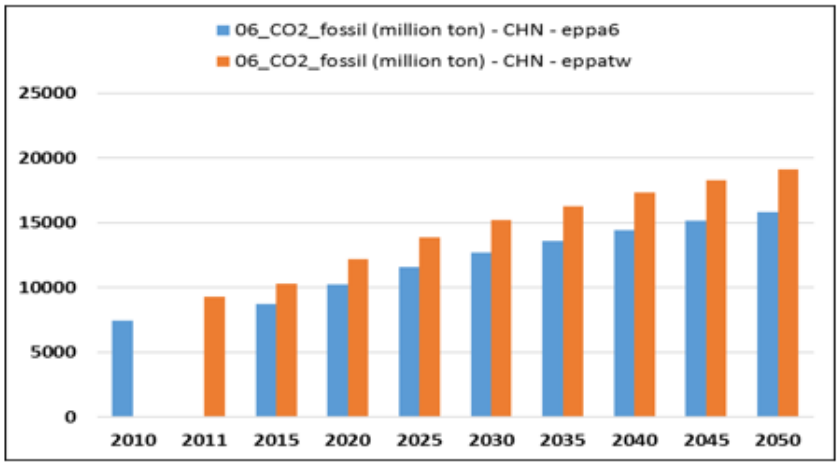


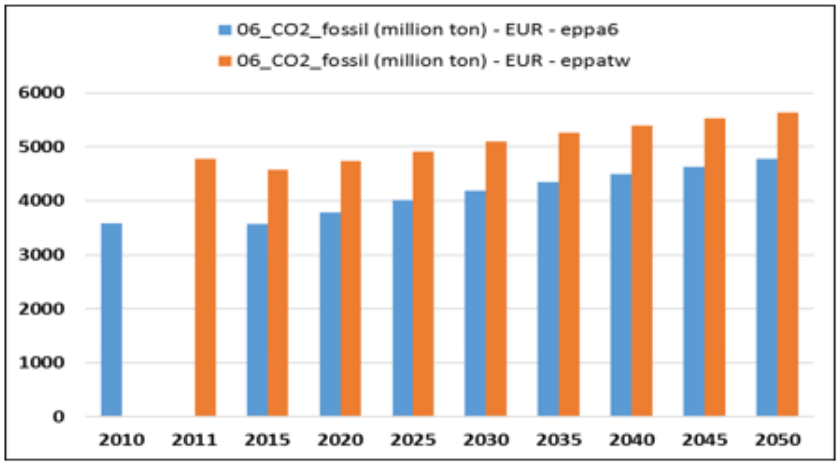


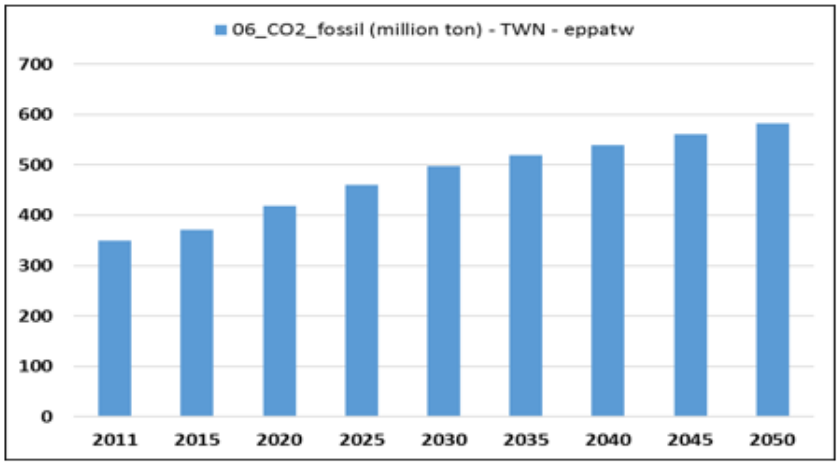


CO_2 projection for selected regions (US, China, EU and Taiwan)





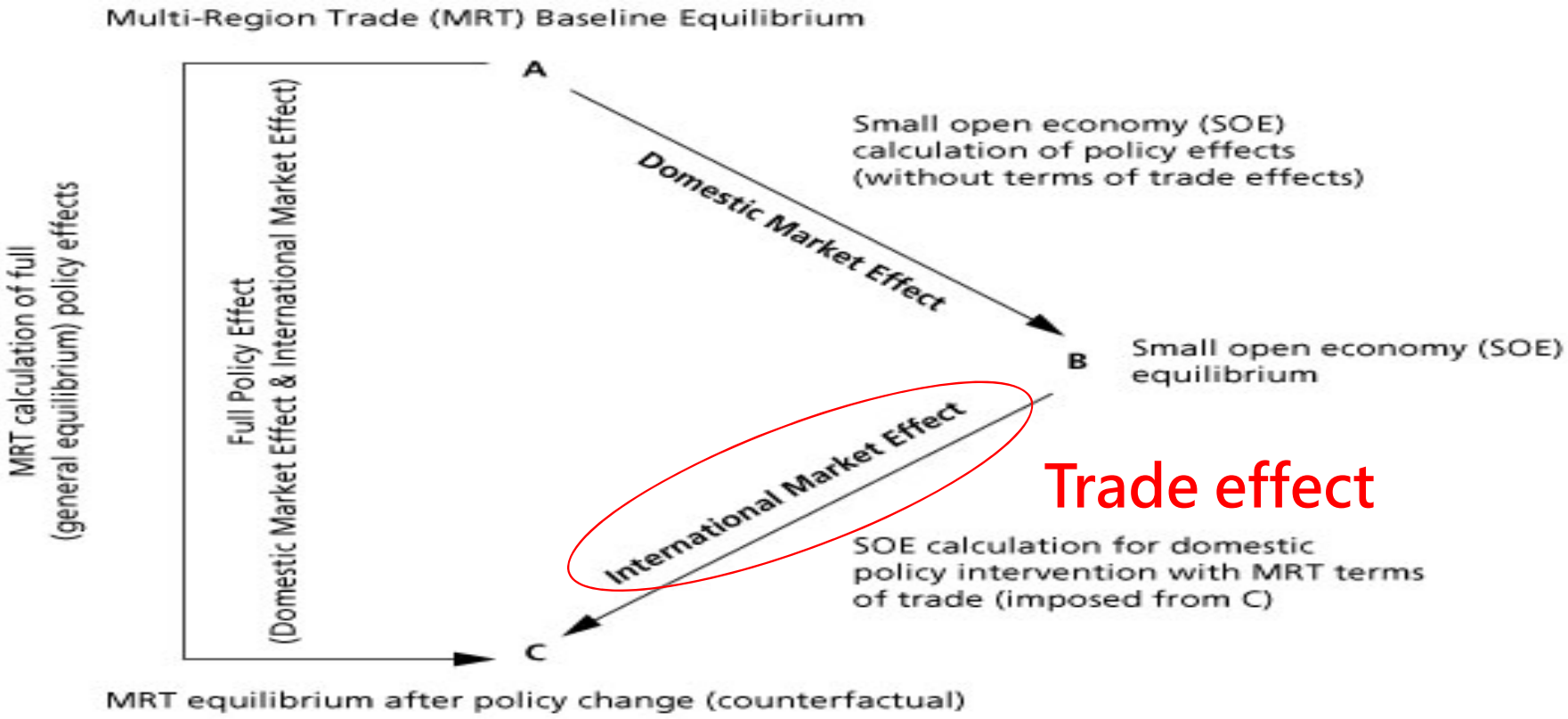




Economic Implication-static model

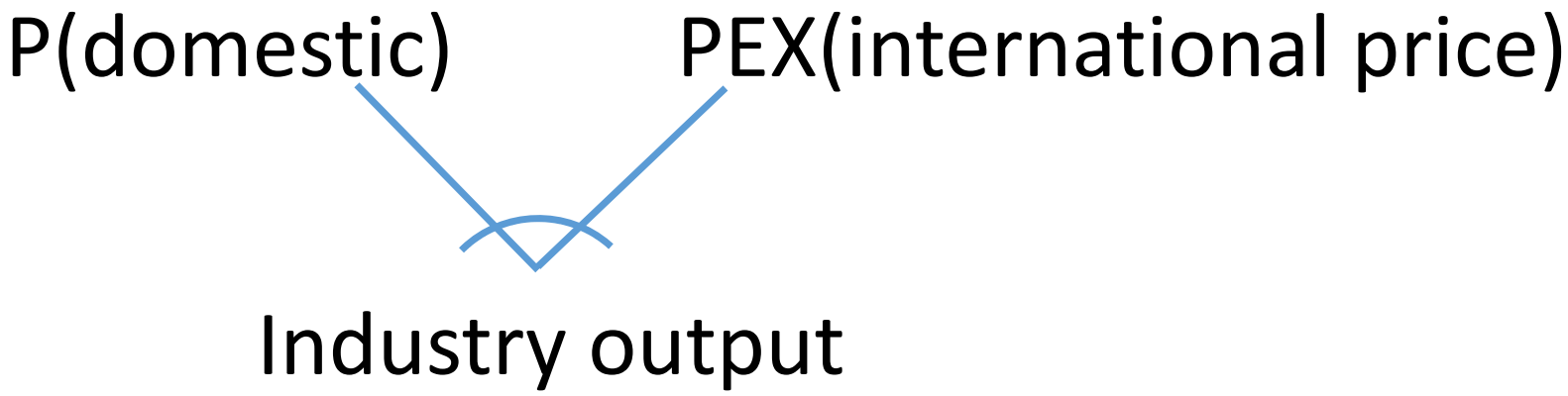
Multi-region Trade (MRT) v.s. Small open economy (SOE)

- SOE : keep international prices fixed when impose the domestic policy on the specific country



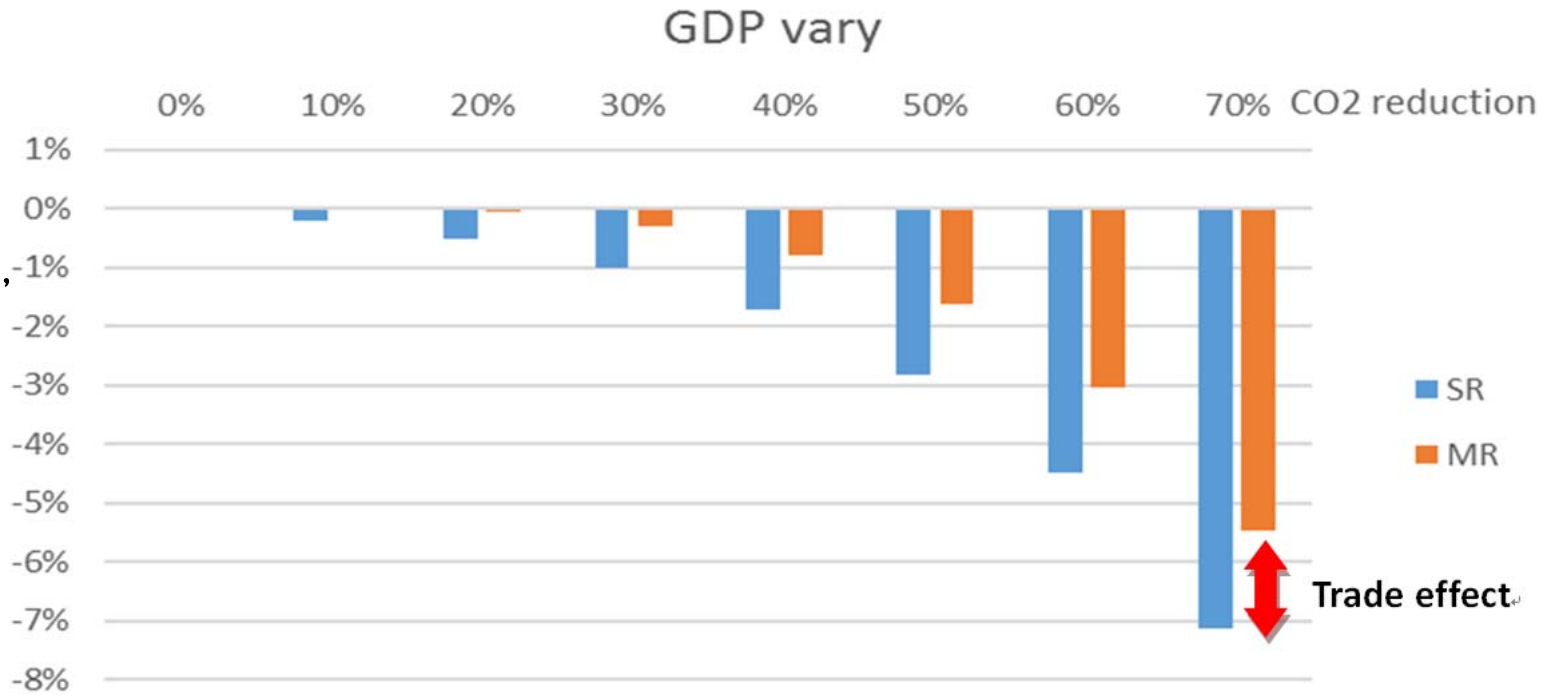
Source: Böhringer and Rutherford, 2002

Closure Conditions



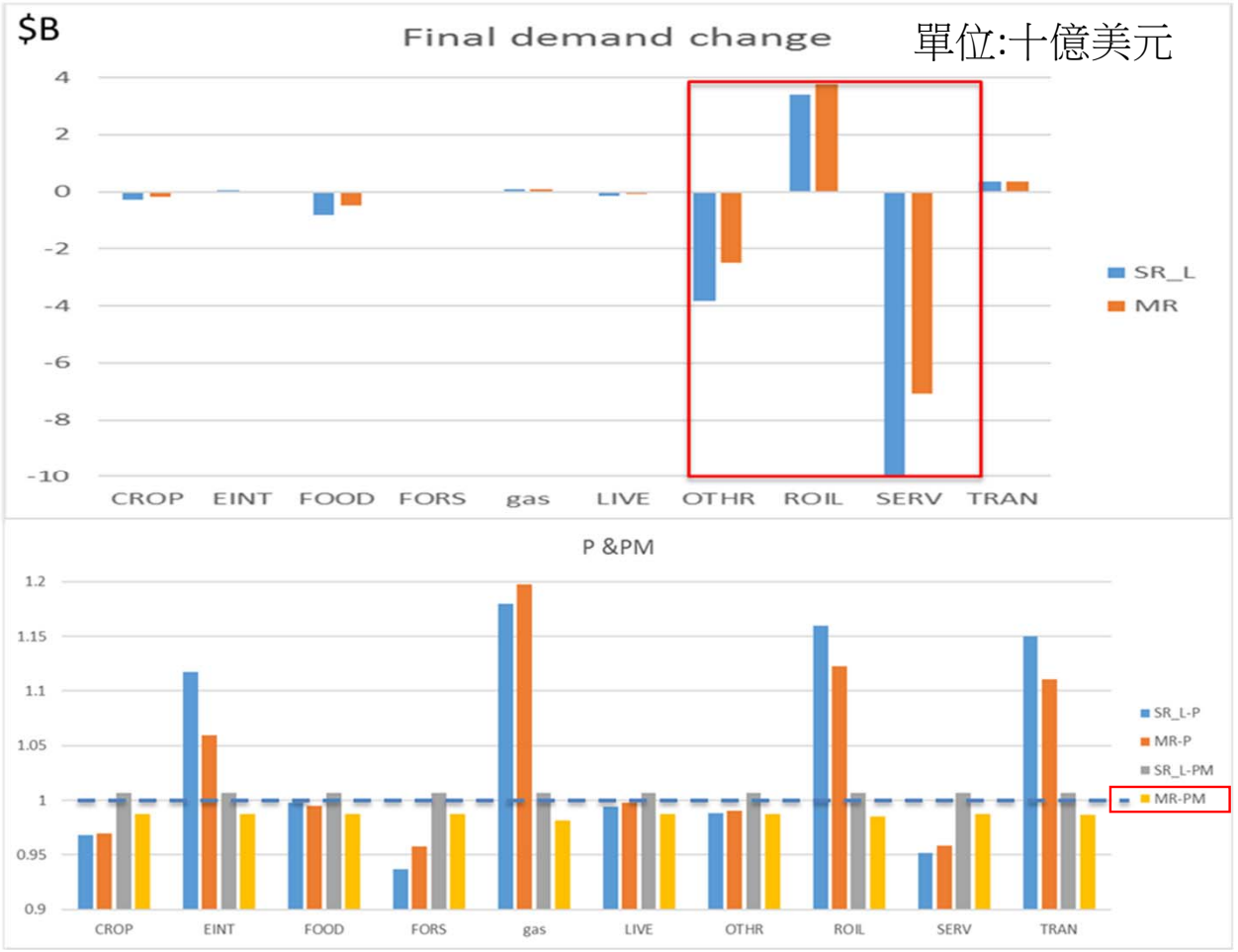
非核家園下，SOE(SR)與MRT(MR)設定模擬台灣單獨減量之結果比較

- 低度減碳情境下，兩者設定對經濟衝擊的差異不大，隨著減碳越嚴苛，貿易效果對台灣的正面影響越大。
- GDP=Final demand (C+G+I)+ net exports (X-M)

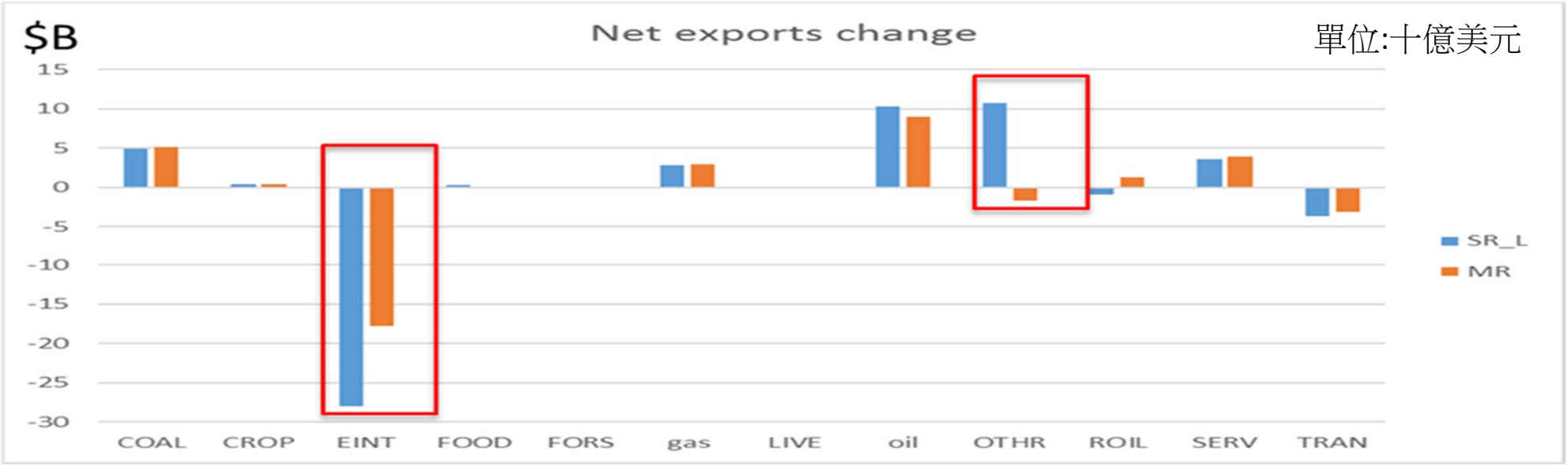


在非核政策及減碳50%下，各部門最終需求、國產品相對價格及進口相對價格的變化

- 在MRT設定中，台灣單獨減量，能源進口大幅減少，且全球化石能源價格微幅下降，歐美淨出口不變，減少化石能源進口額，但多進口能源密集產品，而使得台灣能源密集產業出口受損減小，綜合效果反而使台灣的實質匯率上升(例如50%減碳下，上升1.3%)，因此進口品價格相對大幅下降，減緩了台灣GDP的損失。



在非核政策及減碳50%下，各部門淨出口的變化



- 在SOE設定下，因為要負擔碳稅，能源密集產業出口大幅度受挫，勞動力轉移至低能源密集又以出口為主的電子電機業，而大量又低廉的勞動力促進了電子電機業的競爭力，並透過匯率貶值，促使出口增加以抵銷能源密集產業出口受挫的影響。
- 執政者若僅以SOE設定評估衝擊以進行各產業輔導轉型或補貼，可能會導致資源錯置。

Conclusion, limit and future research

Conclusions:

- 台灣雖為小國，但貿易比重大，若僅採小型開放經濟體(SOE) 的假設，礙於假設限制，無法考慮貿易效果，在高度減碳情境下，將高估經濟衝擊
- 基於貿易效果，台灣單獨減碳及非核政策，對不同模型設定下的各產業的內需或是外貿衝擊皆略有不同，尤其以能源密集產業、服務業及電子電機業差異最大

Limits:

- 不同政策衝擊，貿易效果應該也不同，本研究的發現不一定適用於其他政策研究
- 本研究採用靜態模型，無投資累積效果，採用完全就業假設，對經濟的負面影響評估結果可能過於樂觀

Future research

- Dynamic calibrations

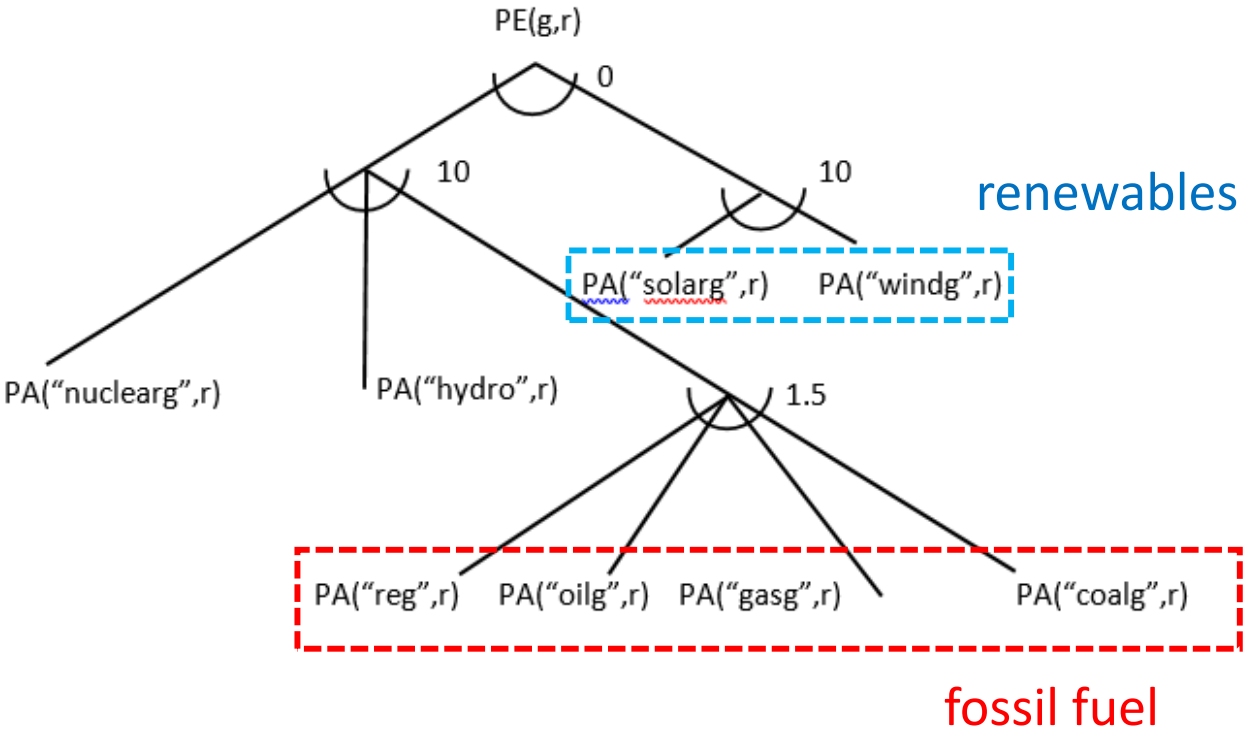
感謝聆聽，敬請指教

Related Link：

能源資訊平台：http://eip.iner.gov.tw/

臉書粉絲專頁-能源資訊與國際動態：https://goo.gl/V8ZxVv

Nesting structures: electricity sector



- the nesting structure for the cost function of the electricity sector in EPPA-Taiwan, which consists of four nests.
- the elasticity of substitution for each nest is the value beside the arc.
- the PA, PE, are price indices for Armington goods and electricity, respectively.