ECONOMIC IMPLICATIONS OF CARBON EMISSION POLICIES: THE CASE OF THAILAND

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Main Contents

(1) Thailand's NDC

(2) Battle of Ideas: Carbon Tax vs. Carbon Market

(3) Economic Impact of Carbon Tax

- Results from Network Analysis, Forward Linkage Analysis and Structural Path Analysis

(4) Economic Impact of Carbon Market

- Results from game-theory-based model

(5) Conclusion

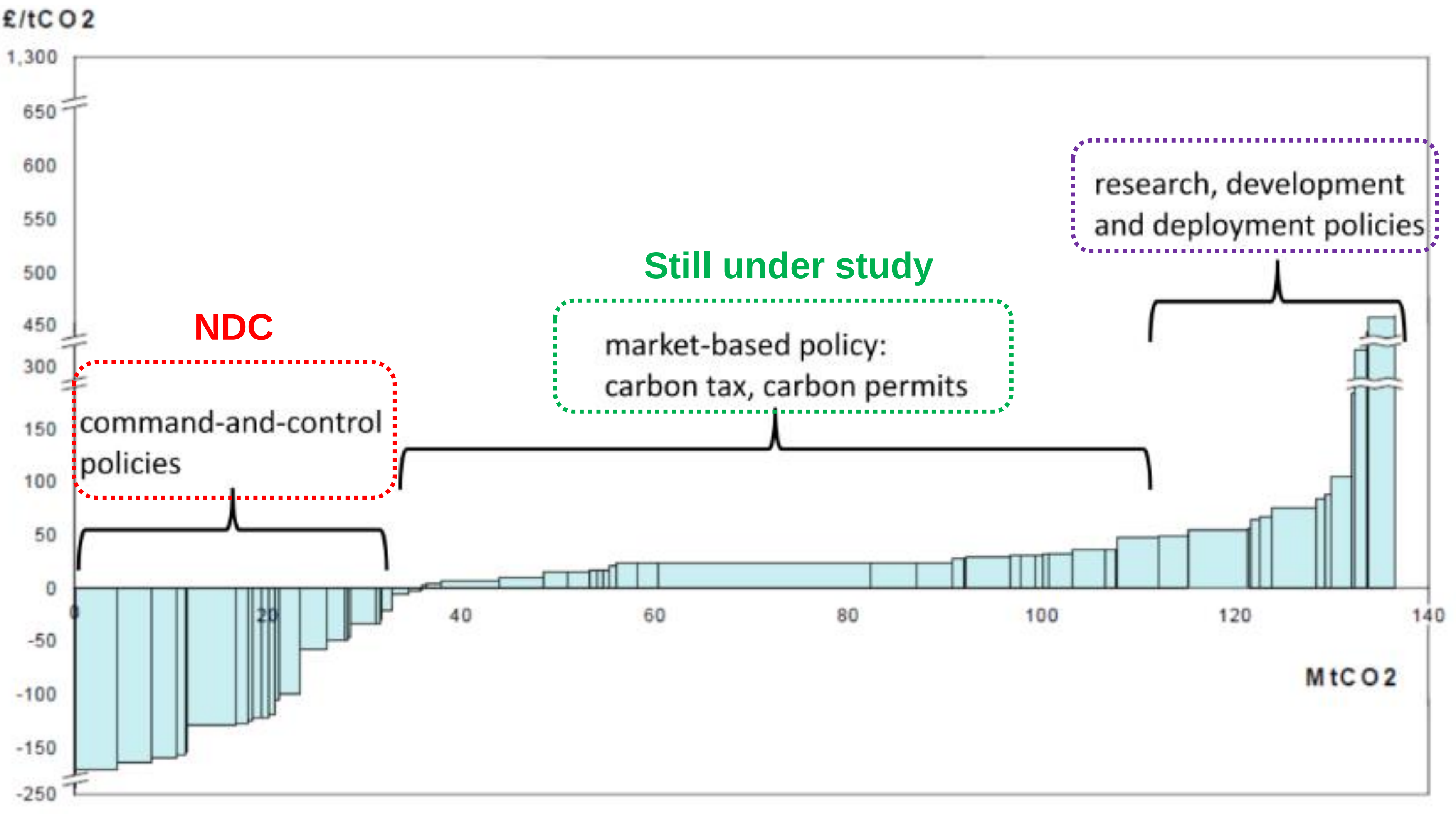
(1) Thailand's NDC

Thailand's Nationally Determined Contribution Roadmap on Mitigation 2021–2030

	2015	2020	2025	2030
Total GHG reduction (mil.ton)	**13.99**	**39.63**	**75.84**	**113**
1.Electricity generation	**9.13**	**14.62**	**20.71**	**24.00**
1.1 Energy efficiency enhancement programs	0.51	2.87	5.84	6.00
1.2 New renewable sources	8.62	11.75	14.87	18.00
2. Uses of energy in households	**0.69**	**1.63**	**2.82**	**4.00**
2.1. Energy efficiency enhancement programs	0.49	1.19	2.06	2.74
2.2 Uses of new renewable energy in households	0.2	0.44	0.76	1.21
3. Uses of energy in buildings (including government's ones)	**0.09**	**0.19**	**0.56**	**1.00**
4. Uses of energy in industrial process	**1.78**	**13.82**	**27.92**	**43.00**
4.1 Energy efficiency enhancement programs	0.04	2.38	8.27	11.00
4.2 Uses of new renewable energy in industrial processes	1.73	11.45	19.65	32.00
4. Uses of energy in transportation	**2.3**	**9.37**	**23.83**	**41.00**
4.1 Energy efficiency enhancement programs	1.74	7.08	18.02	31.00
4.2 Uses of new renewable energy in transportation	0.56	2.28	5.81	10.00

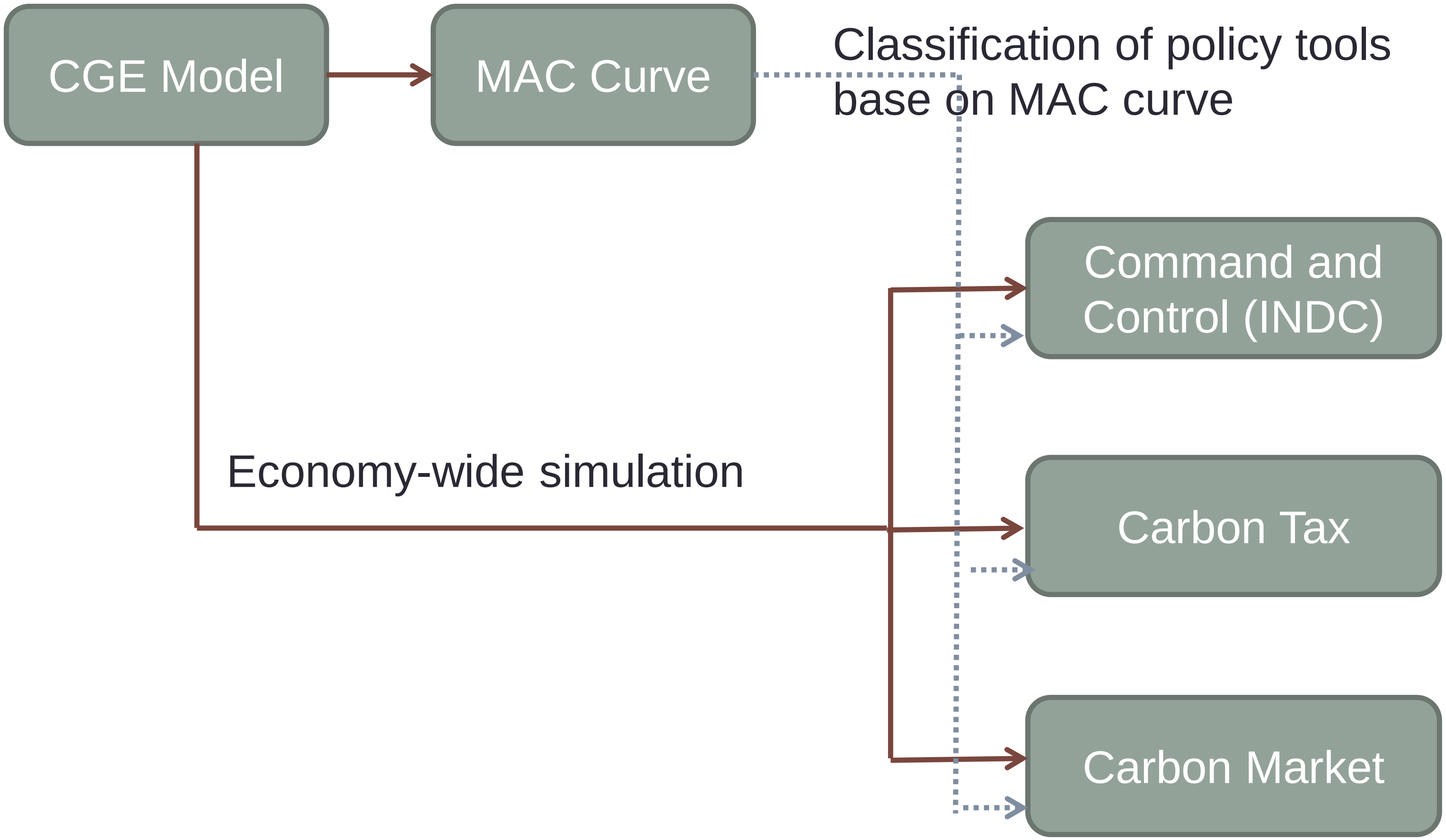
Source: Thailand's Ministry of Natural Resources and Environment

Classification of Policy Instruments based on MAC Curve



Source: www.homepages.ucl.ac.uk/~ucft347/Kesicki_MACC.pdf

Overview



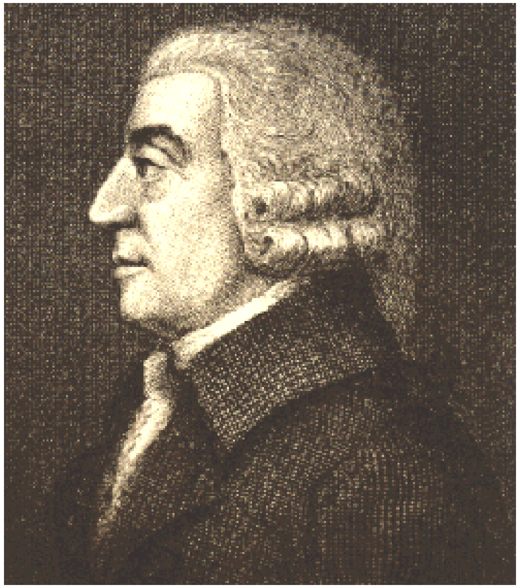
CGE Model
MAC Curve
Classification of policy tools base on MAC curve
Command and Control (INDC)
Economy-wide simulation
Carbon Tax
Carbon Market

(2) Battle of Ideas: Carbon Tax vs. Carbon Market

2.1 Market Failure and Externality

- Under certain conditions, markets allocate resources efficiently, as the magic of **Adam Smith's invisible hand**.

- The efficiency of market outcomes is derived with extraordinary rigor, and it is called the **"first fundamental theorem of welfare economics"**.



Adam Smith

(1723-1790)

Source: Eastern Economic Journal (2009) 35, 14 – 23. doi:10.1057/eej.2008.43

2.1 Market Failure and Externality

- All theorems are based on axioms, so when applying any theorem to the world, one has to evaluate whether the axioms assumed by the theorem are valid.
- In the case of the fundamental welfare theorem, one key axiom is **the absence of externalities**.
- Adam Smith's invisible hand will **fail** to lead to **an efficient outcome**

Source: Eastern Economic Journal (2009) 35, 14 – 23. doi:10.1057/eej.2008.43

2.1 Market Failure and Externality

Example: a private car creates these externalities :

- Global pollution : carbon emission
- Local pollution : smog
- Traffic congestion
- Accidents (and the higher insurance rates)

Summarized Impacts

Benefit : Personally earn

Cost : Publicly receive

Source: Eastern Economic Journal (2009) 35, 14 – 23. doi:10.1057/eej.2008.43

2.1 Market Failure and Externality

The Solution to Externality

- Simple way to remedy the market failure and restore the optimality properties from the fundamental welfare theorem, implying that :

  all individuals can be **charged for the external costs** they impose on others and also **subsidized for the external benefits** they give to others.
- The solution goes back to **Arthur Pigou**, the British economist from the early 20th century.
- In his honor, these corrective measures are called **Pigovian taxes.**

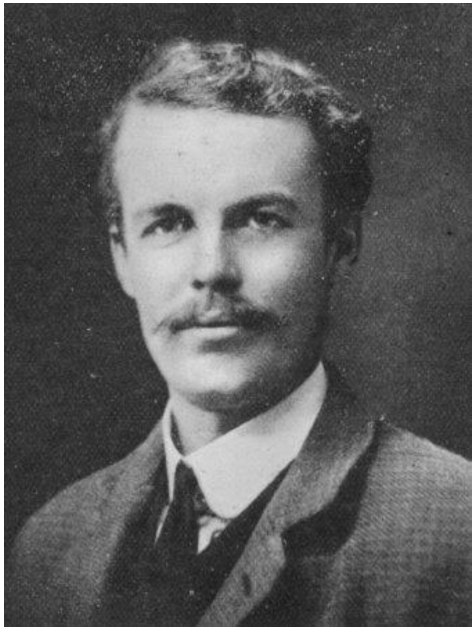
Source: Eastern Economic Journal (2009) 35, 14 – 23. doi:10.1057/eej.2008.43

2.2 Carbon Tax (Pigovian Tax)

Arthur C. Pigou

University of Cambridge

(1877 –1959)



Pigouvian taxes, named after Arthur C. Pigou, a renowned English economist, are designed to correct what economists call "market failures" or "negative externalities" that impose spillover costs on society, such as pollution.

Source: https://en.wikipedia.org/wiki/Pigovian_tax

2.2 Carbon Tax (Pigovian Tax)

Pigovian taxes are popular among economists.

1. They are often **the least invasive way** to remedy a market failure. They can restore an efficient allocation of resources without requiring a heavy-handed government intervention into the specific decisions made by households and firms.

2. They raise revenue that the government can **use to reduce other taxes**, such as income taxes, which distort incentives and cause deadweight losses

Source: Eastern Economic Journal (2009) 35, 14 – 23. doi:10.1057/eej.2008.43

2.2 Carbon Tax (Pigovian Tax)

Estimating the rate of carbon tax

- The right tax would equal the size of the external cost of carbon emission — that much is clear.
- Unfortunately, there is little consensus about how large that external cost is. One of the most prominent economists studying this topic is Yale's **William Nordhaus**.
- **Nordhaus [2007]** has suggested a tax of **$30 per ton of carbon**, increasing to about **$85 in 2050**. A $30 carbon tax is fairly modest in size: it would increase the price of gasoline by only about 8 cents per gallon.

Source: Eastern Economic Journal (2009) 35, 14 – 23. doi:10.1057/eej.2008.43

2.2 Carbon Tax (Pigovian Tax)

Estimating the rate of carbon tax (cont'd)

- By contrast, the economist **Nicholas Stern [2006]** reached a very different conclusion in a study prominently released by the British government.
- Stern estimates the external cost of carbon emission at over **$300 per ton** — more than **10 times** the Nordhaus number.
- Part of the **disagreement** arises from the question of **how one should discount the distant future**.

Source: Eastern Economic Journal (2009) 35, 14 – 23. doi:10.1057/eej.2008.43

2.2 Carbon Tax (Pigovian Tax)

The Pigou Club

- The Pigou Club is described by its creator, economist and blogger N. Gregory Mankiw, as "an elite group of economists and pundits with the good sense to have publicly advocated higher Pigovian taxes, such as gasoline taxes or carbon taxes.
- These pundits and economists often advocate lowering other taxes to keep the total amount of taxes collected the same, though many have also proposed dedicating the revenue to other worthwhile projects.

Source: Eastern Economic Journal (2009) 35, 14 – 23. doi:10.1057/eej.2008.43

2.2 Carbon Tax (Pigovian Tax)

Smart Taxes: An Open Invitation to Join the Pigou Club

N. Gregory Mankiw
Department of Economics, 223 Littauer Center, Harvard University, Cambridge, MA 2138, USA.
E-mail: ngmankiw@fas.harvard.edu

Many economists favor higher taxes on energy-related products such as gasoline, while the general public is more skeptical. This essay, based on a talk given at the March 2008 meeting of the Eastern Economic Association, discusses various aspects of this policy debate. It focuses, in particular, on the use of these taxes to correct for various externalities — an idea advocated long ago by British economist Arthur Pigou.
Eastern Economic Journal (2009) **35,** 14–23. doi:10.1057/eej.2008.43

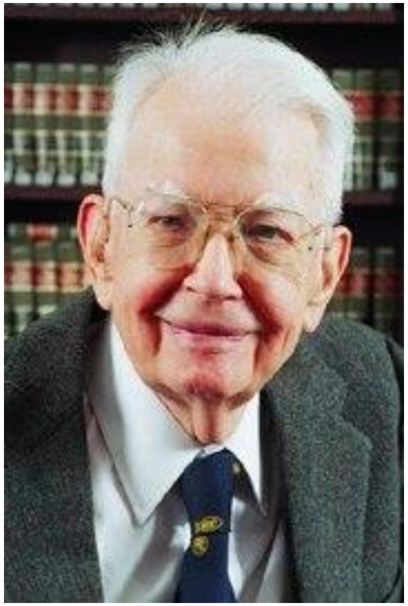
2.2 Carbon Tax (Pigovian Tax)

Members of The Pigou Club	Date of Induction
Gary Becker (Nobel prize winner)	17-Jun-06
Michael Bloomberg (Former New York City governor)	2-Nov-07
Robert H. Frank (Economist)	17-Jun-06
Thomas Friedman (Economist)	17-Jun-06
Al Gore (Former Vice President and Nobel prize winner)	24-Jun-06
Alan Greenspan (Former Chairman of the Federal Reserve)	2-Oct-06
Paul Krugman (Nobel prize winner)	24-Jun-06
N. Gregory Mankiw (Founder)	17-Jun-06
William Nordhaus (Climate Change Economist)	17-Jun-06
Kenneth Rogoff (Economist)	16-Sep-06
Nouriel Roubini (Economist)	9-Nov-06
Jeffrey Sachs (Economist)	9-Apr-08
Robert J. Shapiro (Economist)	20-Feb-07
Lawrence Summers (Former Secretary of the Treasury)	31-Oct-06
Hal Varian (Economist)	1-Oct-06
Paul Volcker (Former Chairman of the Federal Reserve)	14-Feb-07

Source: Eastern Economic Journal (2009) 35, 14 – 23. doi:10.1057/eej.2008.43

2.3 Carbon Market (Cap-and-Trade)

Nobel Memorial Prize in Economic Sciences : 1991



Ronald H. Coase

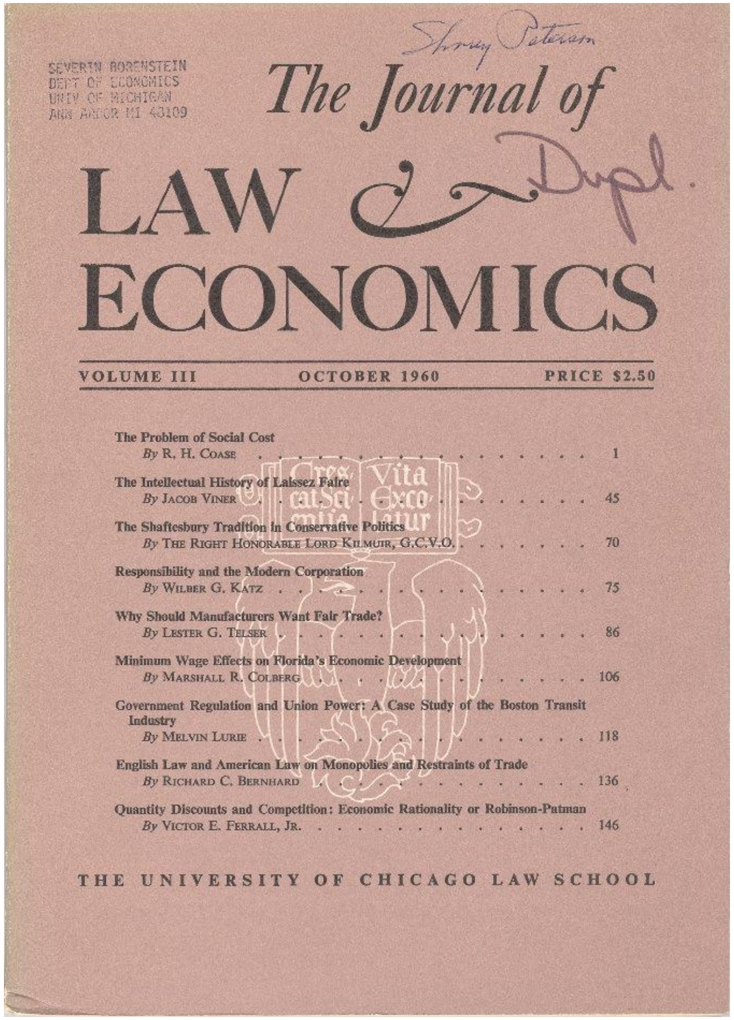
The University of Chicago

(1910 – 2013)

"for his discovery and clarification of the significance of transaction costs and property rights for the institutional structure and functioning of the economy".

Source: http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/1991/press.html
http://www.wikiwand.com/lt/Ronald_H._Coase

2.3 Carbon Market (Cap-and-Trade)



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- Coase's Theorem was introduced 40 years after Pigou had published his paper titled, *The Economics of Welfare,* explaining his idea of using tax as the policy tool in correcting the externality problem. Particularly the amount of tax has be equal to the magnitude of negative impact.
- The **"Coase Theorem**" has introduced the new perspective on resolving the negative externality problem, stating that it is not necessary for the producer of negative externality (e.g. polluters) to pay the tax or the fee. Rather the market or bargaining mechanism between the polluter and the pollutee can resolve the problem.

Source: energyathaas.wordpress.com/2013/09/09/learning-and-forgetting-the-wisdom-of-coase/

2.3 Carbon Market (Cap-and-Trade)

The Problem of Social Cost (1960)

Prof. Robert Stavins has concluded the main idea of Coase's theorem as follows.

- Coase showed that two factors are critical:

  (1) ownership of the property right must be clear – how much, if any, of the negative externality does the emitter have the *right* to create?

  (2) the willing and power to bargain over those rights.

- Coase recognized that these are not trivial assumptions. He spent a chunk of the paper explaining how transaction costs – finding all affected parties, negotiating a contract acceptable to all, monitoring and enforcing that contract, etc. – may be prohibitively costly.

Source: www.robertstavinsblog.org/2013/09/12/remembering-ronald-coases-contributions/

2.3 Carbon Market (Cap-and-Trade)

The Problem of Social Cost (1960) - continued

- Still, to the extent these criteria are met, Coase demonstrated, the parties can trade the right so that whichever entity values it most ends up owning it.
- **Efficient trading** of the right to pollute **moves society towards the optimal amount** and allocation of the pollution.
- The idea is **central to the cap and trade approach** to reducing greenhouse gases and other pollutants.

Source: www.robertstavinsblog.org/2013/09/12/remembering-ronald-coases-contributions/

2.3 Carbon Market (Cap-and-Trade)

Robert W. Hahn
University of Oxford

Robert N. Stavins
Harvard University

*"… Hahn and I [Stavins] carried out an empirical assessment of the independence property in past and current cap-and-trade systems a quick summary of our assessment is that **we found modest support for the independence property** in the **seven cases** we examined …"*

Source: www.robertstavinsblog.org/2013/09/12/remembering-ronald-coases-contributions/

2.3 Carbon Market (Cap-and-Trade)

The Effect of Allowance Allocations on Cap-and-Trade System Performance
Author(s): Robert W. Hahn and Robert N. Stavins
Reviewed work(s):
Source: *Journal of Law and Economics*, Vol. 54, No. 4, Markets, Firms, and Property Rights: A Celebration of the Research of Ronald Coase (November 2011), pp. S267-S294
Published by: The University of Chicago Press for The Booth School of Business of the University of Chicago and The University of Chicago Law School
Stable URL: http://www.jstor.org/stable/10.1086/661942
Accessed: 20/07/2012 14:30

- The **independence property** is important because it means that the government can establish the overall pollution reduction goal for a cap-and-trade system by setting the cap and leaving it up to the legislature to construct a constituency in support of the program by **allocating the allowances** to various interests **without affecting** either **the environmental performance** of the system or **its aggregate social costs**.

Source: www.robertstavinsblog.org/2013/09/12/remembering-ronald-coases-contributions/

2.3 Carbon Market (Cap-and-Trade)

Seven cases of Cap-and-Trade examined

(1) Lead trading

(2) Chlorofluorocarbons (CFCs) under the Montreal Protocol

(3) Sulfur Dioxide (SO2) allowance trading program

(4) Regional Clean Air Incentives Market (RECLAIM) in Southern California

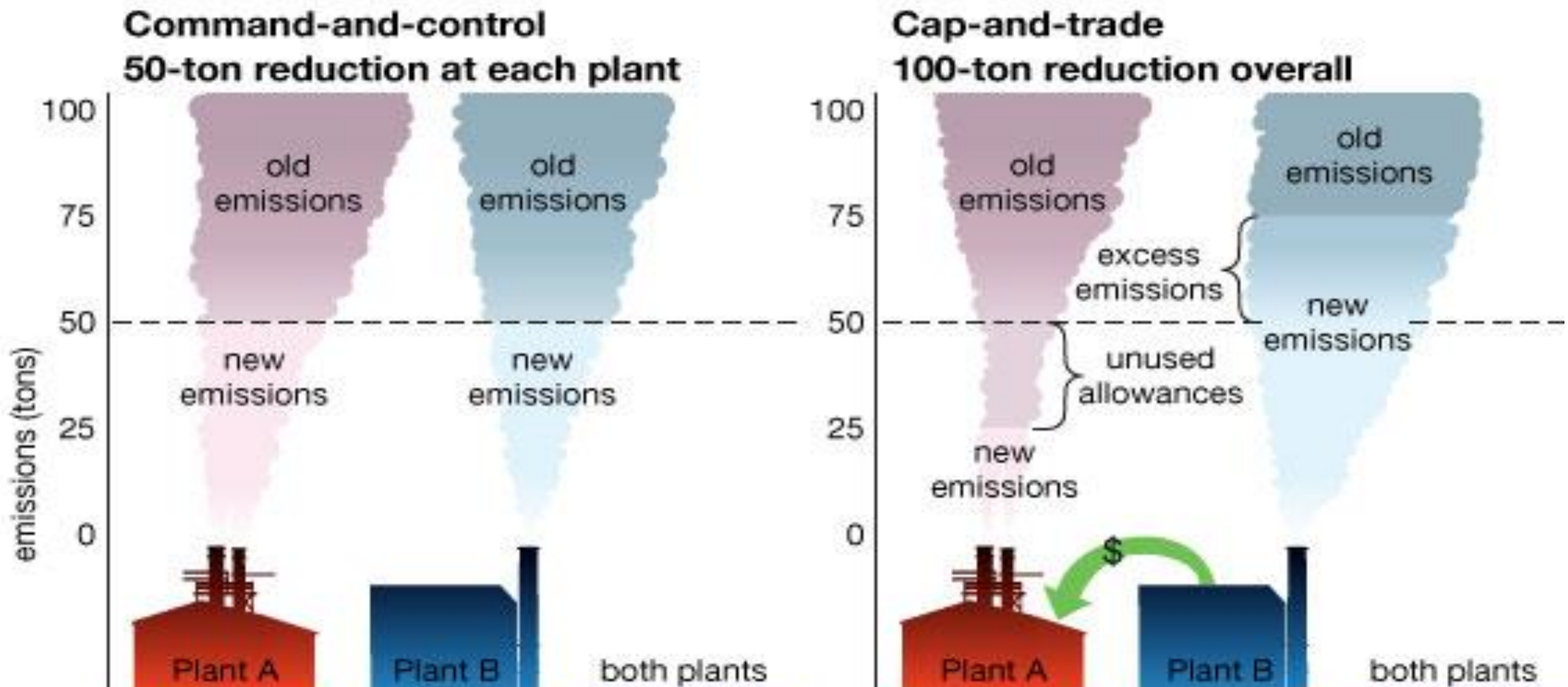
(5) Eastern Nitrogen Oxides (NOX) markets

(6) European Union Emission Trading Scheme (EU ETS)

(7) Article 17 of the Kyoto Protocol

Source: www.robertstavinsblog.org/2013/09/12/remembering-ronald-coases-contributions/

2.3 Cap and Trade Mechanism



	Command-and-control: Plant A	Command-and-control: Plant B	Command-and-control: both plants	Cap-and-trade: Plant A	Cap-and-trade: Plant B	Cap-and-trade: both plants
tons reduced	50	50	100	75	25	100
cost per ton reduced	$100	$200	—	$100	$200	—
cost of reduction	$5,000	$10,000	$15,000	$7,500 – payments from Plant B	$5,000 + payments to Plant A	$12,500

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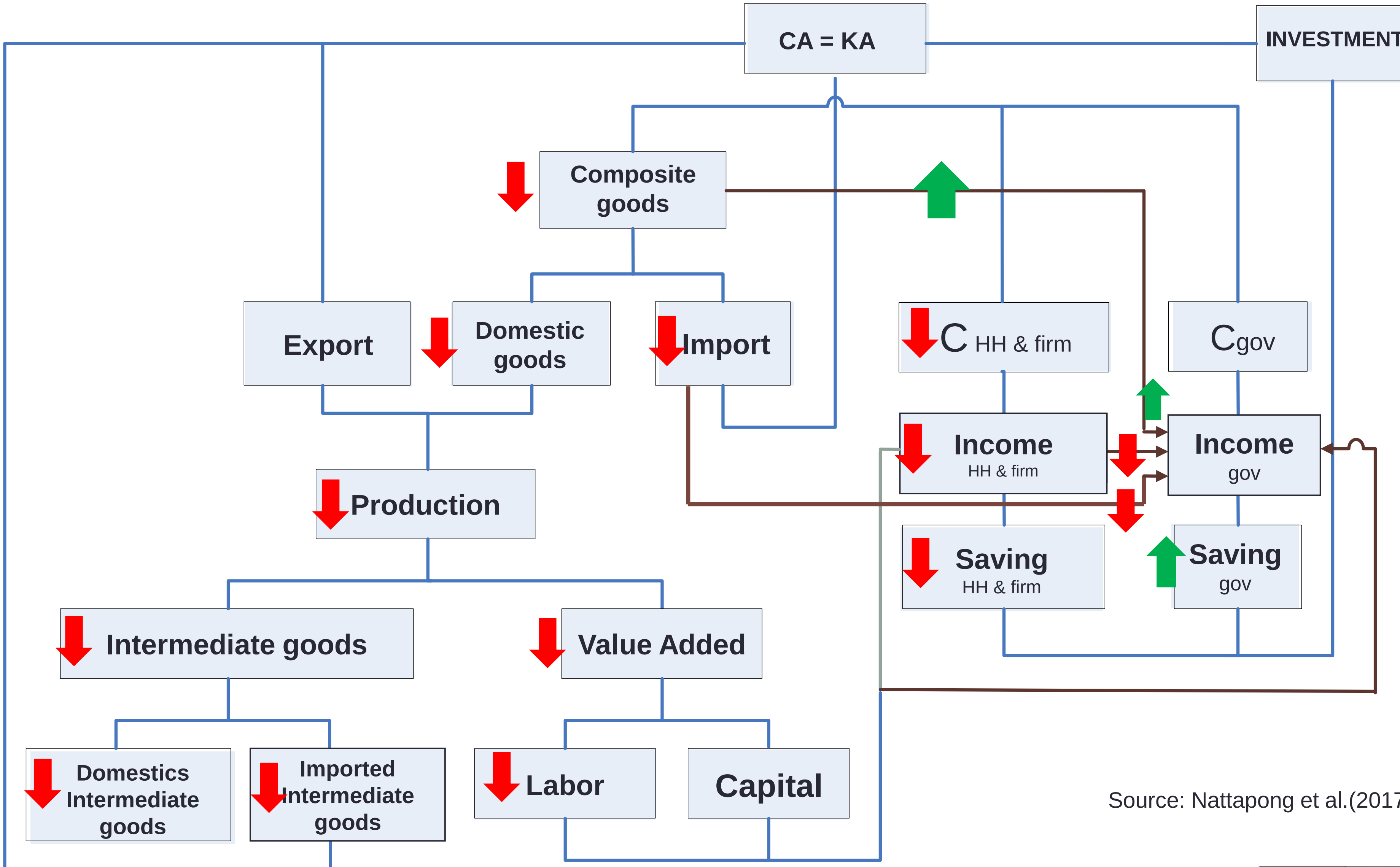
(3) Economic Impact of Carbon Tax

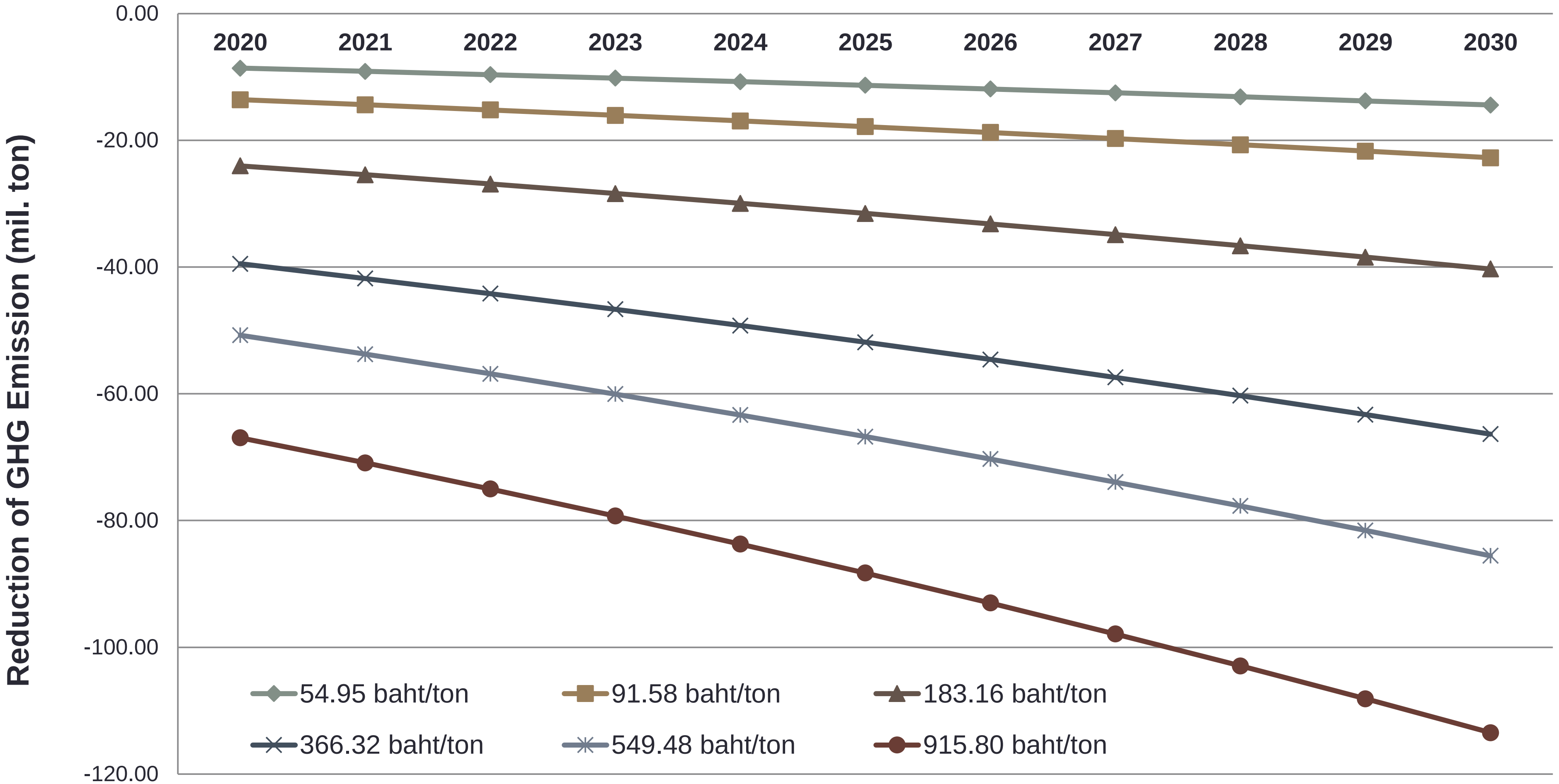
Economy-wide impact of carbon tax



Source: Nattapong et al.(2017)

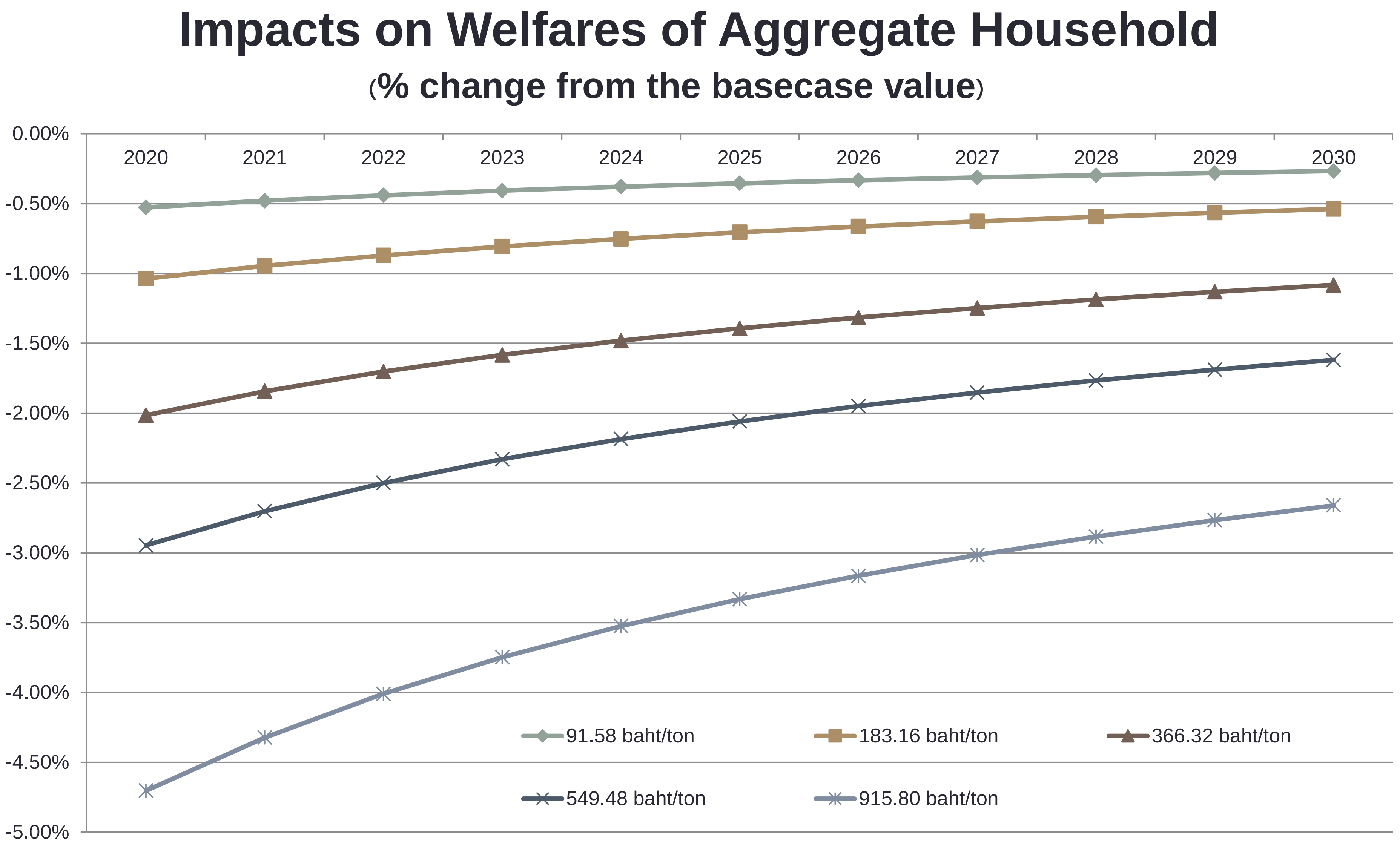
Economy-wide impact of carbon tax

Reduction of GHG emission caused by different rates of carbon tax



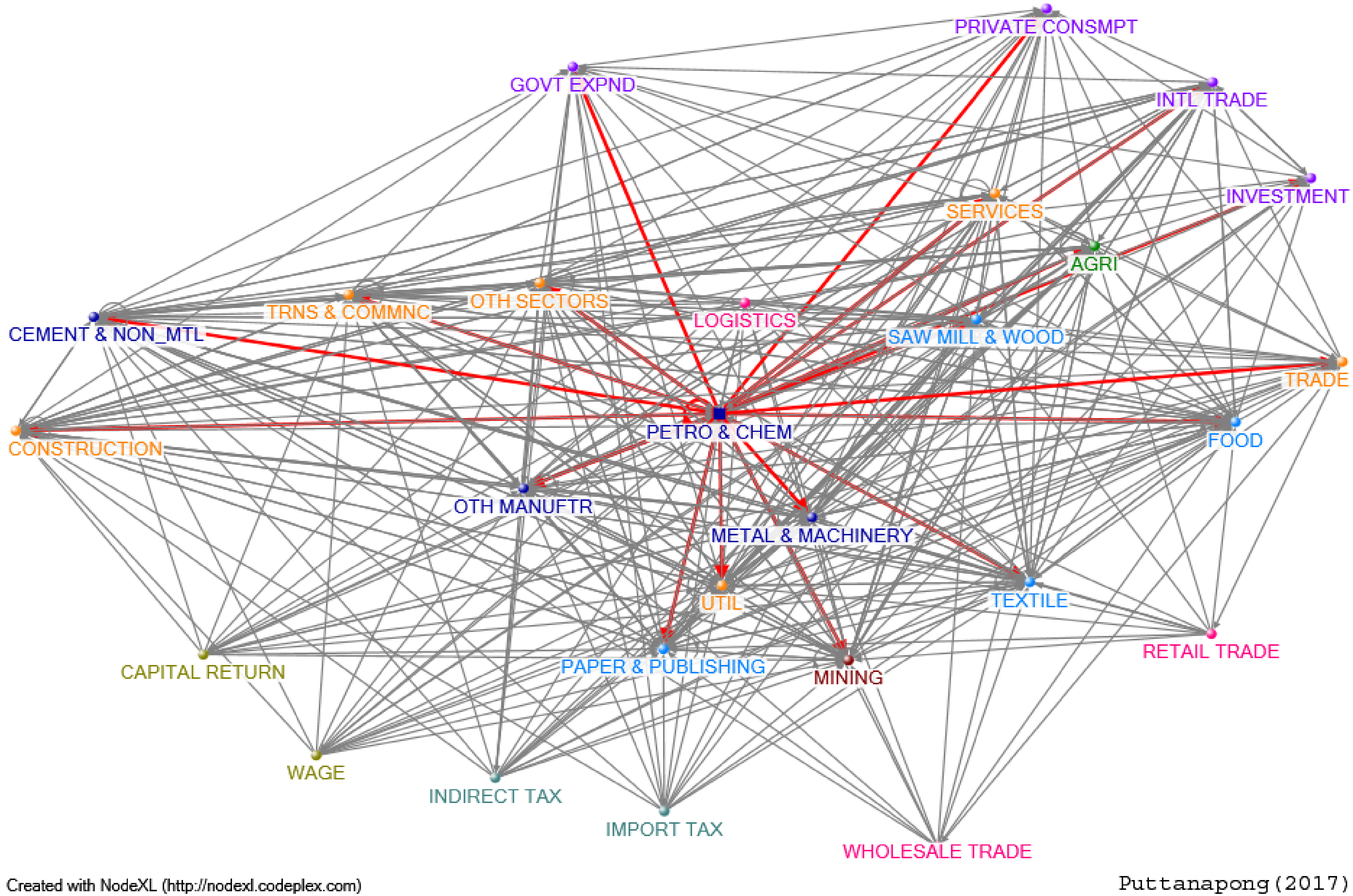
Source: Nattapong et al.(2017)

Economy-wide impact of carbon tax



Source: Nattapong et al.(2017)

- Results obtained from many quantitative methods, which are **Centrality Index, Forward Linkage Index, Structural Path Analysis**, indicate that the **refinery and petro-chem** industries have **the highest numbers of linkages to other sectors** in Thai economy.
- The **refinery and petro-chem, steel, cement and transportation** are the **highest GHG-emitting sectors**.
- Hence, in the case of Thailand, **the highest GHG-emitting sector are also the highly-connected industries**. The implementation of **carbon tax** can substantially generate **the negative impacts** to the economy.



From the network analysis, the refinery and petro-chem industries have the **highest centrality index**.

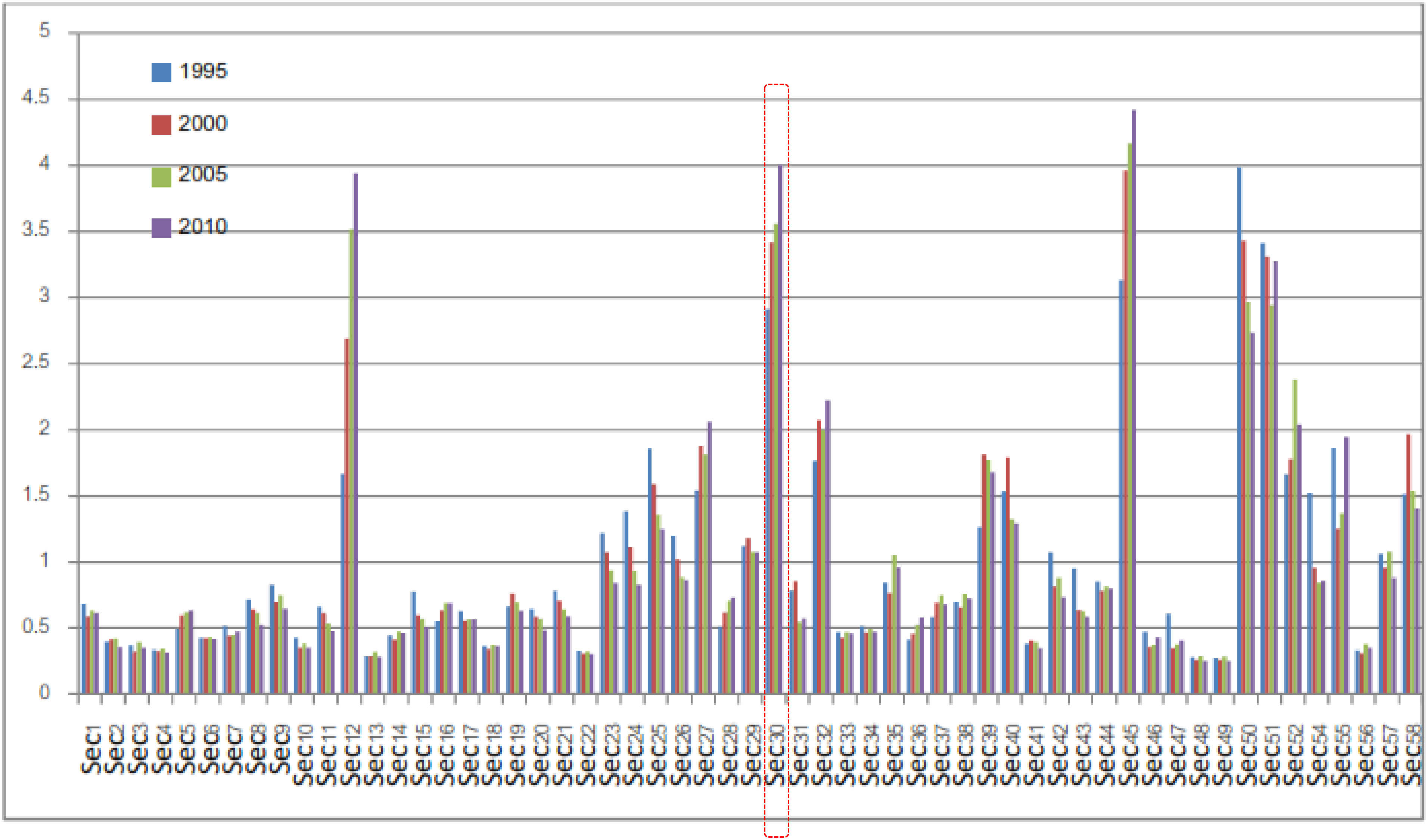
Ranking of Forward Linkage Index

- Results from the computation of forward linkage index based on the official Input-Output tables indicate that Refinery and Coal sector is among the 5 highest ones.
- This implies that Refinery and Coal sector is among the major upstream sectors in Thai economy.

1995		
Sector		**Multiplier**
Sec50	Restaurants and Hotels	3.053
Sec51	Transportation	2.616
Sec45	Electricity and Gas	2.400
Sec30	Petroleum Refineries and Coal	2.230
Sec55	Business Services	1.428
2000		
Sector		**Multiplier**
Sec53	Banking and Insurance	4.713
Sec45	Electricity and Gas	3.707
Sec50	Restaurants and Hotels	3.210
Sec30	Petroleum Refineries and Coal	3.195
Sec51	Transportation	3.092
2005		
Sector		**Multiplier**
Sec53	Banking and Insurance	5.673
Sec45	Electricity and Gas	3.826
Sec30	Petroleum Refineries and Coal	3.266
Sec12	Paddy	3.227
Sec50	Restaurants and Hotels	2.725
2010		
Sector		**Multiplier**
Sec45	Electricity and Gas	6.751
Sec30	Petroleum Refineries and Coal	3.974
Sec12	Paddy	3.599
Sec51	Transportation	3.546
Sec50	Restaurants and Hotels	2.945

Source: Puttanapong (2016)

Forward Linkage Index



Source: Puttanapong (2016)

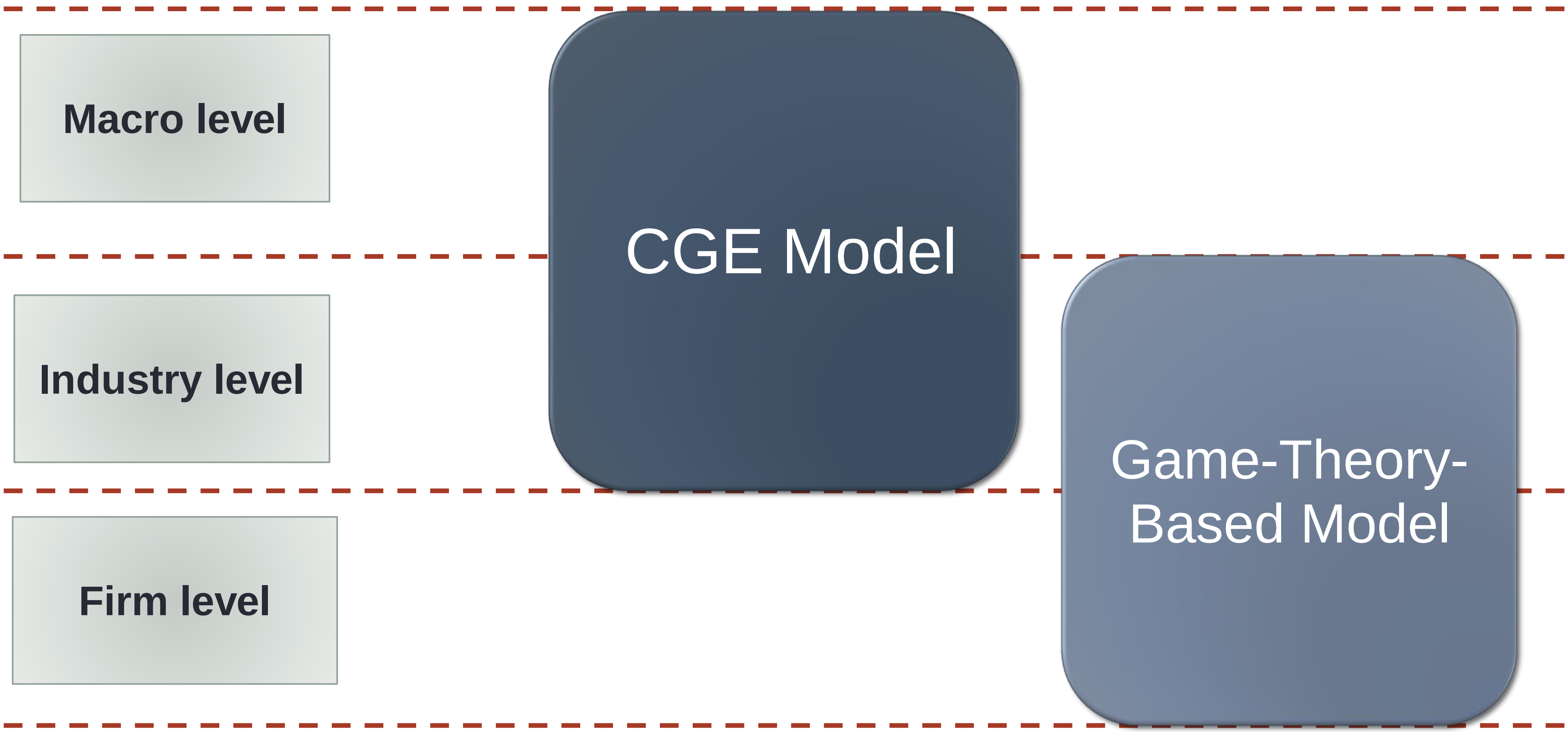
Structural Path Analysis showing major paths of fossil fuel (Thailand's IO table of 2010)

	Transmission Paths				Global Influence (GI)	Total Influence (TI)	TI/GI	Cumulative
1	Petroleum Refineries-->	Transportation			0.527	0.514	97.598	97.598
2	Petroleum Refineries-->	Fishery			0.152	0.146	95.727	95.727
3	Petroleum Refineries-->	Public Works and Other Construction			0.108	0.046	42.141	42.141
	Petroleum Refineries-->	Transportation -->	Public Works and Other Construction			0.027	24.631	66.772
	Petroleum Refineries-->	Cement -->	Public Works and Other Construction			0.011	9.697	76.469
	Petroleum Refineries-->	Non-Metal Ore -->	Public Works and Other Construction			0.007	6.652	83.121
	Petroleum Refineries-->	Non-Metal Ore -->	Cement -->	Public Works and Other Construction		0.002	2.168	85.289
	Petroleum Refineries-->	Iron and Steel -->	Public Works and Other Construction			0.002	2.052	87.341
	Petroleum Refineries-->	Transportation -->	Non-Metal Ore -->	Public Works and Other Construction		0.001	1.272	88.613
	Petroleum Refineries-->	Electricity and Gas -->	Cement -->	Public Works and Other Construction		0.001	1.128	89.741
	Petroleum Refineries-->	Business Services -->	Public Works and Other Construction			0.001	0.763	90.504
4	Petroleum Refineries-->	Electricity and Gas			0.100	0.078	78.449	78.449
	Petroleum Refineries-->	Crude Oil and Coal -->	Electricity and Gas			0.016	15.775	94.225
5	Petroleum Refineries-->	Cement			0.091	0.056	61.805	61.805
	Petroleum Refineries-->	Non-Metal Ore -->	Cement			0.013	13.817	75.622
	Petroleum Refineries-->	Electricity and Gas -->	Cement			0.007	7.188	82.810
	Petroleum Refineries-->	Transportation -->	Cement			0.003	3.435	86.245
	Petroleum Refineries-->	Transportation -->	Non-Metal Ore -->	Cement		0.002	2.643	88.888
	Petroleum Refineries-->	Crude Oil and Coal -->	Cement			0.002	1.923	90.811

Source: Puttanapong (2016)

(4) Economic Impact of Carbon Market

Combination of CGE and Game-Theory-Based Models



Source: Puttanapong et al.(2017)

Main Characteristics of Game-Theory-Based Model

- This study follows the approach introduced by Bernard et al.(2002), which is the dynamic game replicating the interaction among firms.
- Based on microeconomic theory, each firm maximizes the long-run profits. It simultaneously determine its production and trading the emission permits.
- The first group of firms consists of industries that have (1) the banked permits, (2) free allowance (i.e. hot air) and they also trade their permits in the carbon market.
- The second group of firms consists of industries similar to the first one except the absence of free allowance.

Source: Puttanapong et al.(2017)

- Market equilibrium is based on the concept of Nash equilibrium, representing the long-run optimality of all firms.
- **Player group 1:** having the permits of h(t) and maximizing their profits between t=0 and T-1

$$max \sum \beta_1^t \, [\rho(t)u_1(t) - c_1(q_1(t))] + \beta_1^T \pi_1 x_1(T) \qquad (1)$$

$$x_1(t+1) = x_1(t) - u_1(t) + h(t) + q_1(t) \qquad (2)$$

$$x_1(0) = 0 \qquad (3)$$

$$u_1(t) \geq 0 \qquad (4)$$

$$x_1(t) \geq 0 \qquad (5)$$

β_1 = discount factor of player 1
$x_1(t)$ = GHG emission governed by permit in period *t* of player 1
$u_1(t)$ = amount of permits sold in the market in period *t* of player 1
$h(t)$ = hot air in period *t*
$q(t)$ = Emission abatement in period *t*
$c_1(q_1)$ = cost function of GHG reduction by q_1 tons in period *t*
π_1 = Total value of emission permits in period T

Source: Puttanapong et al.(2017)

Player group 2: maximizing their profits between t=0 and T-1 (with no free allowance)

$$\max \sum \beta_2^t [p(t)u_2(t) - c_2(q_2(t))] + \beta_2^T \pi_2 x_2(T) \quad (6)$$

$$\text{s.t. } x_2(t+1) = x_2(t) - u_2(t) + q_2(t) \quad (7)$$

$$x_2(0) = 0 \quad (8)$$

$$u_2(t) \geq 0 \quad (9)$$

$$u_2(t) \equiv 0 \quad (10)$$

$$x_2(t) \geq 0 \quad (11)$$

Price of permits: The price determination is governed by exchange of permits under the inverse demand function ($D(u_1,u_2)$), leading to the market clearing price *P(t)*.

$$P(t) = D(u_1(t) + u_2(t)) \quad (12)$$

Source: Puttanapong et al.(2017)

Player1: Emission intensive group

- Paper and printing, Ethanol, Chemical and Chemical product, Refinery of Oil and Gas, Non-metallic product, Iron and Steel

Player 2: Less emission intensive group

- Food and Tobacco, Palm oil, Rice, Starch, Maize, Sugar , Rubber and Plastic, Fabricated Metal product, Motor and transport equipment, Machinery

T planning period: 4 periods 2015, 2020, 2025, 2030

- T0(T) = initial period, 0 ;
- T1(T) = time period subset 1,2,3,4 ;
- TT(T) = terminal period T

Source: Puttanapong et al.(2017)

Simulation results

Total banking (ton of CO_{2}-e)

Time period			
1	2	3	4
15.558	19.350	9.344	0

Total supply of permits (ton of CO_{2}-e)

Time period			
1	2	3	4
11.227	14.758	18.068	25.378

Total abatement of emission (ton of CO_{2}-e)

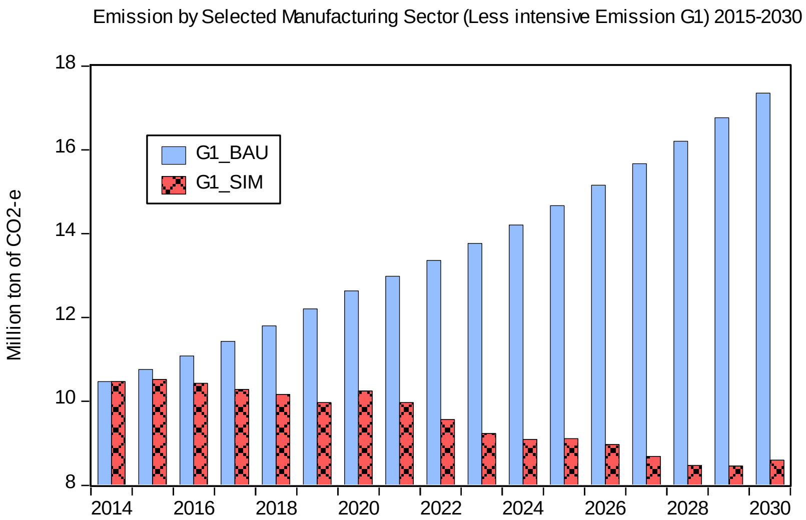
	Time period			
	1	2	3	4
Group 1	0.681	0.717	0.755	0.795
Group 2	15.504	16.333	17.207	45.939

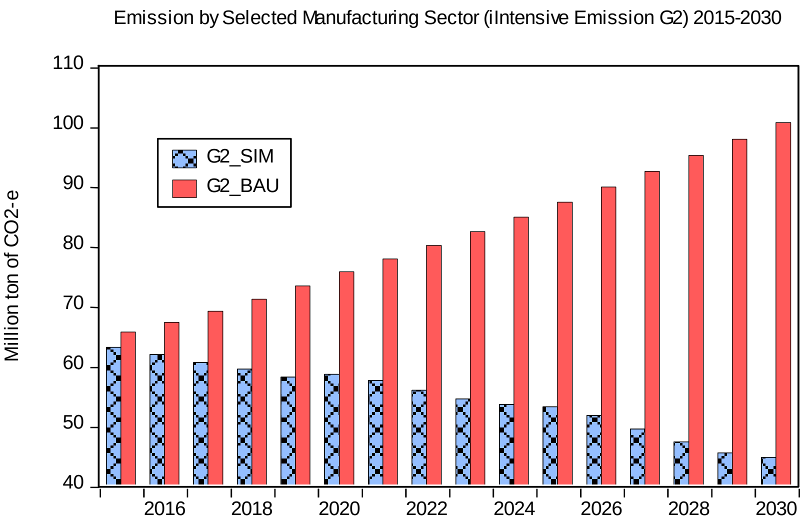
Source: Puttanapong et al.(2017)

Simulation results

Price of permit (baht per ton of CO_{2}-e)

Time period			
1	2	3	4
13.418	15.640	17.293	19.057



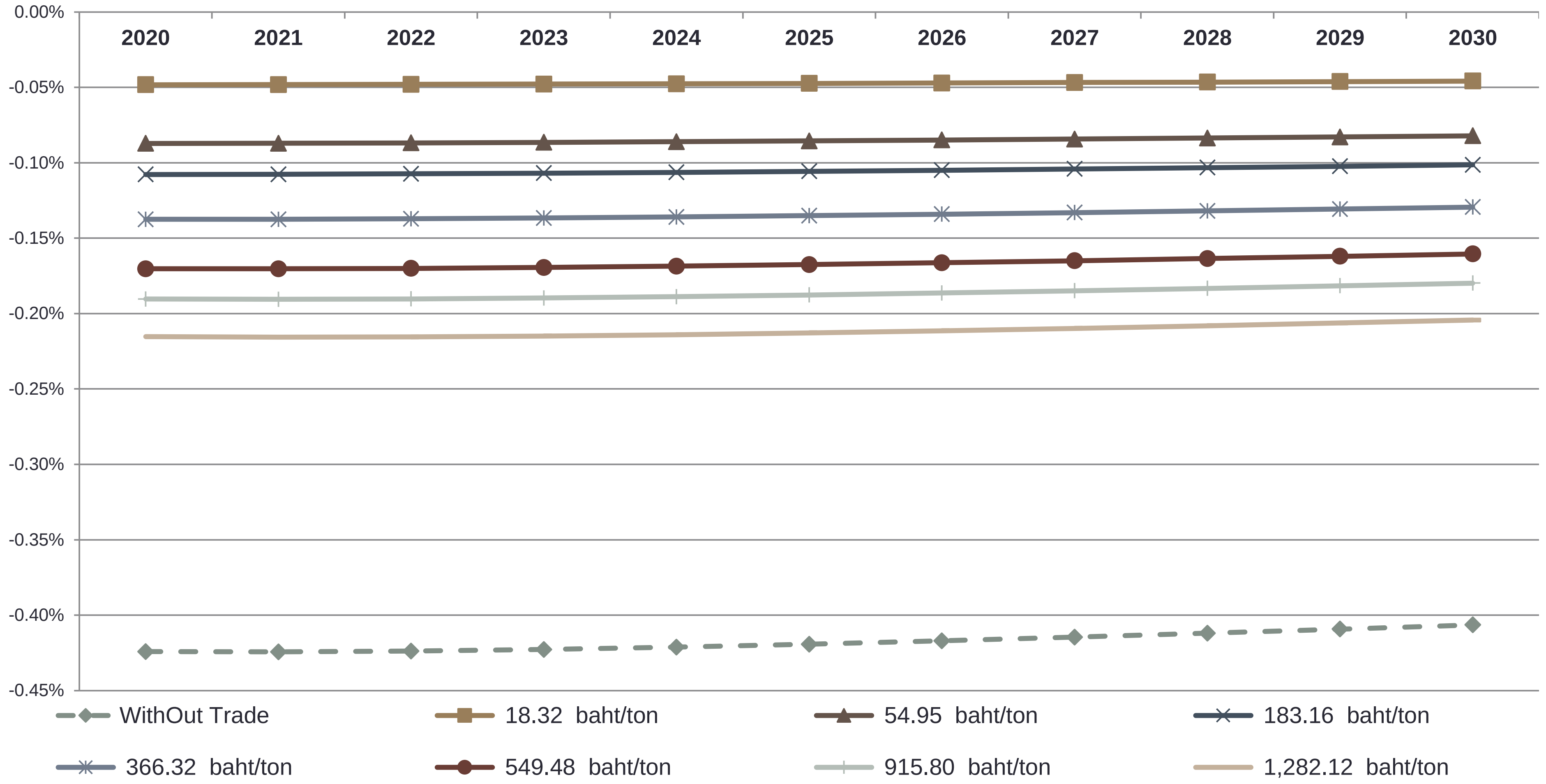


Source: Puttanapong et al.(2017)

Economic Impact of Carbon Market

Impacts on Real GDP

(% change from the basecase value)

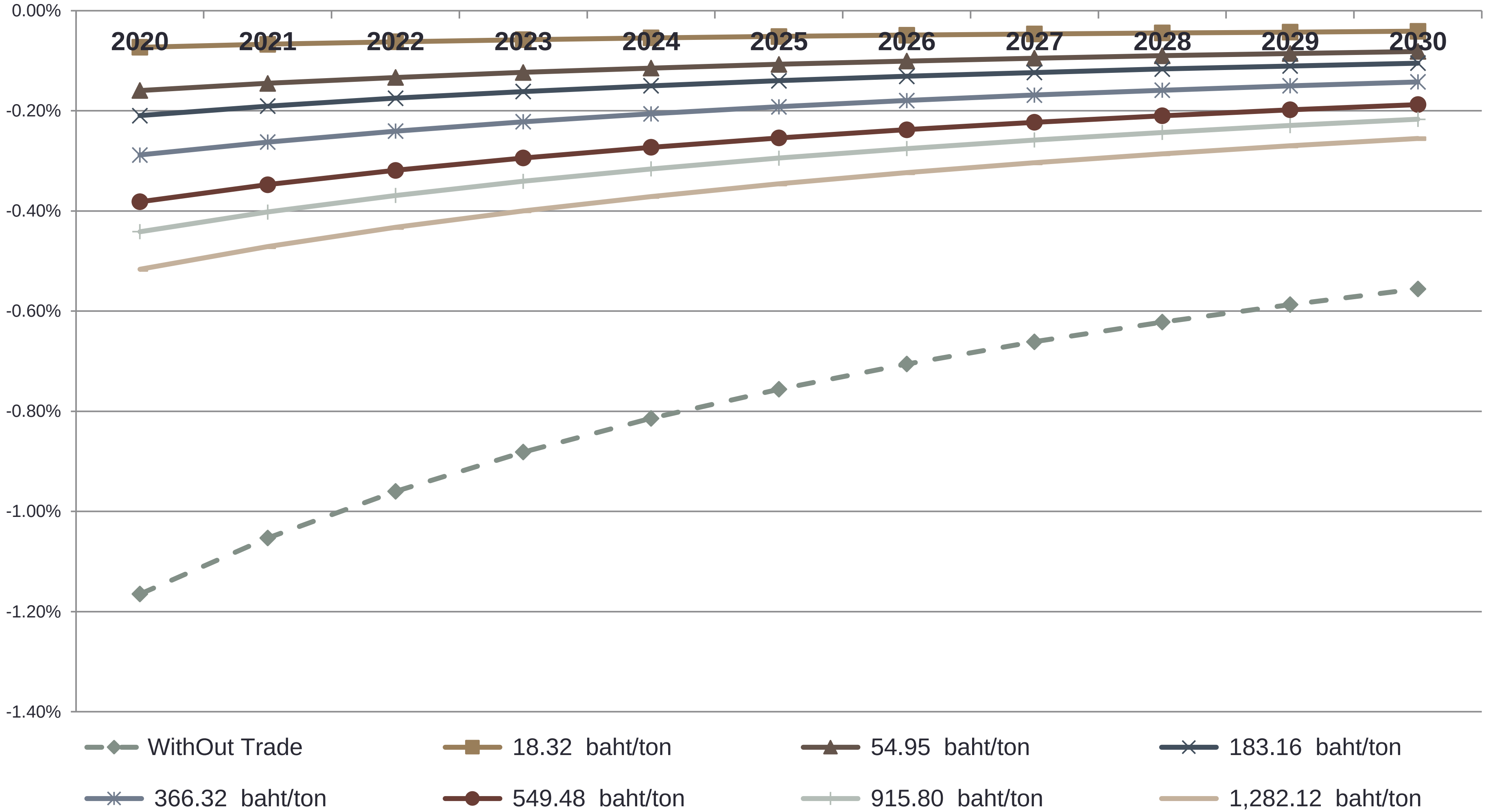


Source: Nattapong et al.(2017)

Economic Impact of Carbon Market

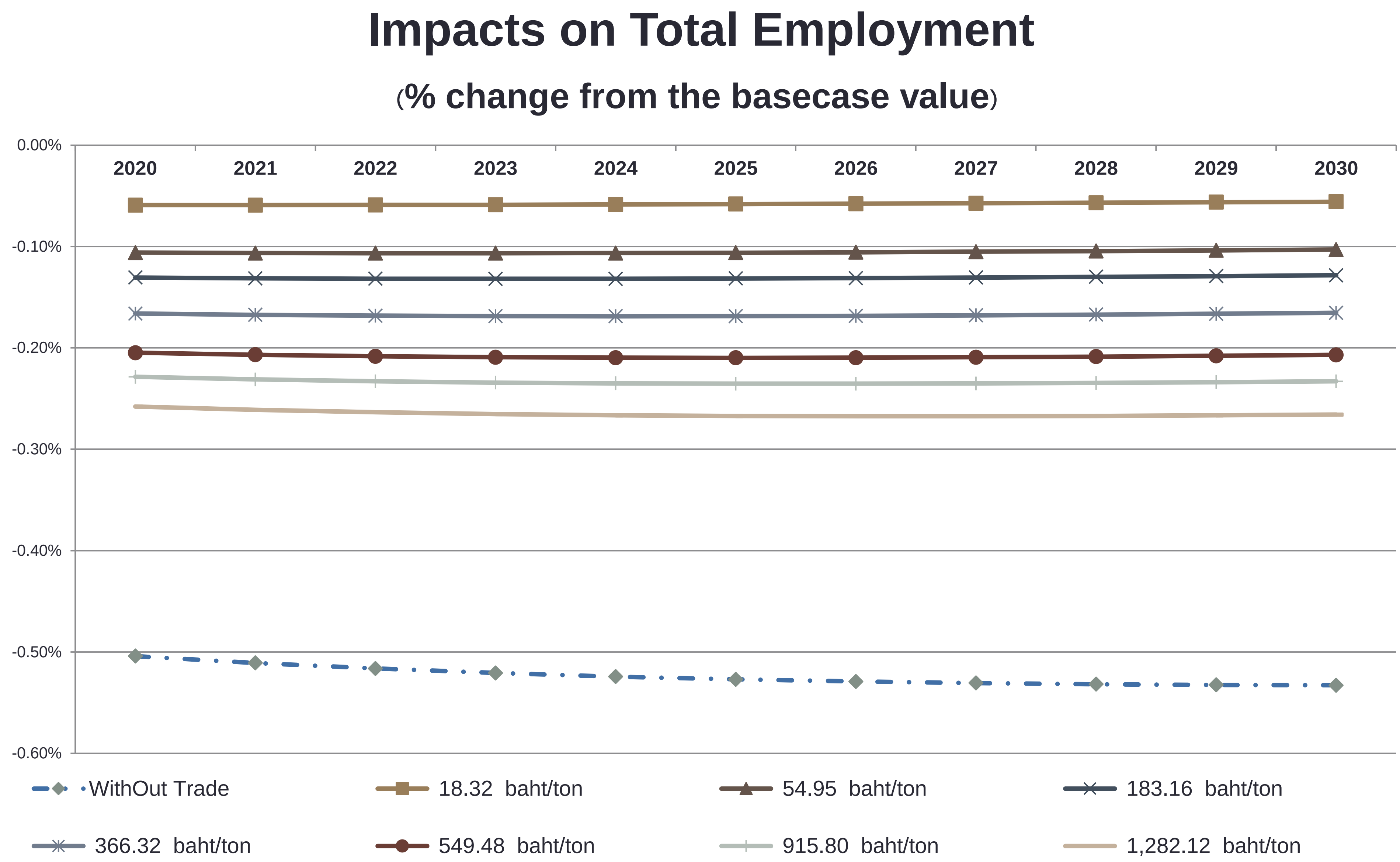
Impacts on Welfares of Aggregate Household

(% change from the basecase value)



Source: Nattapong et al.(2017)

Economic Impact of Carbon Market



Source: Nattapong et al.(2017)

(5) Conclusion

Key takeaways

(1) In addition to CGE model, the economy-wide impacts can be examined by alternative techniques such as network analysis, forward linkage analysis and structural path analysis. These techniques reveal the economy-wide propagation mechanism of adjustment of GHG intensive sectors. Hence the transmission of carbon tax can be quantitatively investigated.

(2) The GHG intensive industries are also the major upstream suppliers of Thai economy. Therefore the imposed carbon tax can generate the substantial negative impacts.

(3) In addition to CGE model, the simulation model based on game theory can be used for examining the interaction within carbon market.

(4) The game-theory-based model can show details of firm-level adjustment, generating more useful information of policy formulation.

(5) Free allowance and banking of permits are important to the responses of firms to the cap-and-trade scheme.

Key takeaways (cont'd)

The simulation result obtained from the case of implementing regulation and energy planning indicates the following findings.

(1) The continuous investment in technology, especially in the power generation, could accelerate the emission reduction. Particularly, the simulation result shows that **Thailand can reach the reduction target of 114-115 million tons by 2025**, **earlier than the goal officially specified in INDC**.

(2) In the case of continuous investment in technology improvement in **power generation**, the **carbon intensity can be progressively decreased during 2015-2030**. Specifically, during that period, **the carbon intensity of electricity generation will be lowered from 123.5 to 109.5 ton of CO2** equivalent per million baht of gross output. Concurrently the output of **electricity generation will increase over times** and **reach 1 trillion baht in 2030**.

Key takeaways (cont'd)

The second simulation undertaken is the case of **imposing carbon tax** as the policy instrument for carbon reduction. Main findings obtained from this simulation are discussed as follows.

(1) **The government can mainly utilize the carbon tax as the policy tool for achieving the reduction target of 113 million tons of CO2 in 2030**. However the government has to use the increased revenue gained from carbon tax as the main source for public expenditure and/or public investment. The simulation result indicates that **this recycle can lessen the negative economy-wide impact**. Particularly, the value of **GDP will be lowered by 0.2 percent and 1.2 percent in 2015 and 2030, respectively**.

(2) Based on the results obtained from various methods (e.g. the network analysis, forward linkage index and Structural Path Analysis), it is found that the **refinery, and coal industries have the largest network of nationwide linkages to other sectors**. Therefore, these sectors function as the **main upstream industries in Thai economy**.

(3) In addition, the results obtained from those analyses indicate that **petro chemical, cement, iron and transportation sectors** have the **large coverage of linkage networks in Thai economy**. These sectors are the top CO2 emission as well. With this fact, the implementation of **carbon tax imposed on these sectors can lead to the economy-wide negative impacts**. In order to mitigate the economic downturn, the government has to apply the **Counter cyclical scheme**, which is the use of **revenue received through carbon tax as the main source of public expenditure and/or public investment**.

Key takeaways (cont'd)

The last simulation is the integration of using both CGE model and **the ETS Market** one.

(1) There exists the **possibility of emission trading among 5-8 industries**.

(2) The **carbon tax can generate the nationwide negative outcomes**. However, the **combination of implementing both carbon tax and ETS mechanism can lessen the negative impacts**.

(3) The simulation results show that the trading mechanism leads to the carbon price of 11.2, 14.758, 18.068, and 25.378 baht per ton in 2015, 2020, 2025, 2030, respectively. However, it is noted that the conditions imposed on each player in the ETS market can substantially influence the outcome of market, particularly on the allocation of emission and the price of permit. Hence the further study on the effects of these conditions should be conducted

(4) The simulation result identifies that the **carbon market can lead to the emission reduction of 17.962 and 46.734 million tons of CO2 in 2025 and 2030, respectively**.

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Thank you

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