Electronic Journal of Business and Management
ICDBSE Special Issue, 2025 pp. 14-28
e-ISSN:2550-1380-ISSN

From Lab to Market: A Computable General Equilibrium Analysis of Research Commercialization Policy in Thailand

Nattapon Siwareepan
Faculty of Economics, Thammasat University, Thailand

Ronnakron Kitipacharadechatron
Faculty of Economics, Thammasat University, Thailand
School of Economics, Sukhothai Thammathirat Open University, Thailand
ronnakron.kit@st.econ.tu.ac.th
ronnakron.kit@stou.ac.th

Abstract

As presently, the international market has become highly competitive, particularly for agricultural products and simple manufactured goods. This competitiveness affects newcomers and existing competitors, often weakening their market position. Therefore, improving production technology and innovation may be the solution to increasing market power by developing innovative products that are difficult for others to replicate, it could lead to sustainable market growth, especially for countries that rely heavily on exports. Thailand, one of the top four countries in ASEAN, has increasingly focused on research commercialization, particularly in deep science and technology, to enhance productivity and competitiveness in the global market. However, there is still insufficient evidence regarding the economic outcomes of these policy promotions in Thailand. Therefore, this paper aims to provide evidence of policy outcomes after adoption of technology by presenting a scenario and investigating it through a static computable general equilibrium approach. The findings of this paper indicate that technology adoption and improvement have the potential to expand the economy by increasing market competitiveness for both domestic and international markets, especially in the service sectors. Moreover, the optimal rate of technology adoption for transforming the economy could be approximately 1.5 percent points. This paper suggests that the government should play a key role in facilitating investment in new technologies, whether through policy or regulation to encourage industries to replace outdated technology with newer ones. Additionally, the government could act as a facilitator in connecting industries with university research outputs or supporting new start-up businesses with deep technology.

Keywords: *Research Commercialization Policy, Scenario Analysis, CGE Analysis, Technological Innovation, Economic Competitiveness*

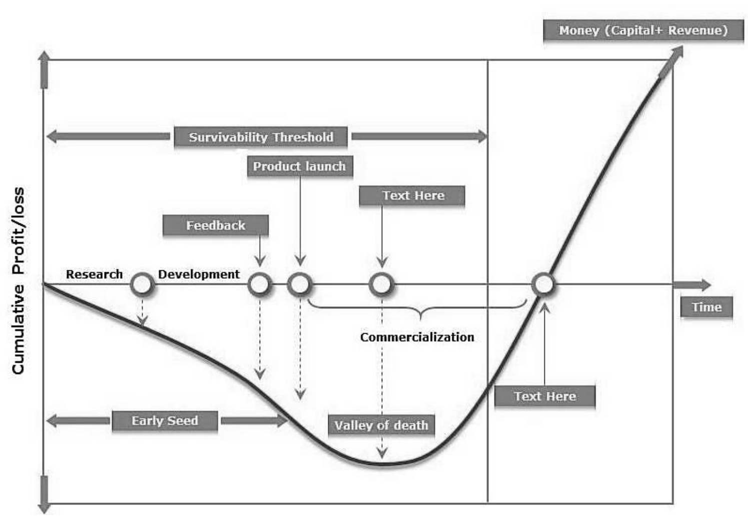
1.0 Introduction

For decades, Thailand's economic development has been strongly supported by investments in infrastructure, which serve as a key resource for urban expansion and wealth distribution. These investments have also improved the country's competitiveness in the global market, especially in exporting agricultural products and serving as a manufacturing base for foreign companies (National Economic and Social Development Council, 2023). However, global demand trends have changed with the rise of new competitors in the world market, such as Vietnam, Brazil, China, and Malaysia. This increased competition has affected Thailand's market share in terms of price, quantity, and quality, dominated by these countries. When looking at Thailand's exported products, it is clear that more than half are simple goods without any innovation (National Innovation Agency, 2022), making them easy to replace in the market. To overcome these challenges, Thailand needs to promote innovation in its products to improve competitiveness and ensure long-term economic growth (Program Management Unit for Competitiveness, 2022).

Fortunately, with the wealth of knowledge resources in the country, particularly from university research outcomes, the government has decided to implement a research commercialization policy. This policy focuses on providing research funding to universities to scale up their prototypes and match them with businesses or industries. The aim is to speed up commercialization processes and increase the country's technology adoption rate, contributing to sustainable growth and international competitiveness in the future.

However, in practice, research commercialization has not progressed smoothly. Approximately 80 to 90 percent of prototypes require significant further validation and standardization before they can reach the market (Siegmund et al., 2021), which consumes a large amount of funding without support from agencies (Markham et al., 2010). This situation, known as the "Valley of Death," represents the gap between research and successful commercialization. Many promising innovations get stuck in this phase because they lack the necessary resources or validation to be commercially viable, leading to lost revenue streams, stifled economic growth, and an innovation ecosystem that fails to reach its full potential (Hudson and Khazragui, 2013), as shown below.

Figure 1: Illustration of Research Commercialization Process.



Therefore, this paper aims to address this critical juncture by using a novel and powerful tool: a computable general equilibrium (CGE) model. Unlike traditional economic analyses, a CGE model allows for the analysis of the complex interactions within Thailand's entire economic system. By quantifying the long-term economic effects of the government's research commercialization policy across different sectors and industries, this study seeks to provide policymakers with key evidence for improving the policy's effectiveness and maximizing its impact. While the research question is straightforward, the findings will not only highlight the potential economic benefits of successfully bridging the commercialization gap but also serve as a guide for developing future strategies to unlock Thailand's full innovation potential. Ultimately, this paper aims to provide academic evidence for policymakers in other developing countries, demonstrating the results of a more innovative-driven economy.

2.0 Literature Review

The literature journey reveals that computational General Equilibrium (CGE) has been a powerful tool for economic impact assessment (Rajbhandari et al., 2019; Boonpanya et al., 2021). The CGE model can be applied to various contexts related to economic structure, such as the impact of greenhouse gas emissions (Rajbhandari et al., 2019), the effects of subsidies and taxation on the economy (Chanthawong et al., 2020; Puttanapong et al., 2015), environmental impact assessment (Boonpanya et al., 2021), trade liberalization (Karunaratne, 1998), and income distribution (Bhattarai and Benjasak, 2021). This approach enables users to track all adjustments in economic activities, especially price and volume changes in consumption under economic theories (Suttiwichienchot and Puttanapong, 2014). The development of the CGE model began around 1970 with Scarf (1982), who introduced programming techniques to general equilibrium modeling. Since then, many economic studies have employed CGE as a method to trace economic structure in response to external shocks (Borgess and Goulder, 1984; Berman, 1991; Manne and Richels, 1994; Bhattacharyya, 1996).

In specific studies related to technological policy promotion, there is worldwide evidence. For instance, Antoszewski (2019) assessed energy-related technology shocks in the Polish economy using different economic systems under CGE simulation. The results were positive for economic growth across all examined models, although the magnitude of changes varied depending on the model setup, especially aggregate price. Similarly, Doroodian and Boyd (2003) examined economic growth in the presence of technological advances in the US, indicating that technological advances strongly impacted US growth, with significant contributions to aggregate prices (CPI and PPP).

For the case of Asian countries, Hübler (2011) investigated technology diffusion in China, indicating that an increase in technological advancement initially reduced economic growth but significantly increased productivity. This was due to welfare compensation playing a role in emission reduction. However, China might be a special case in Asia where welfare compensation cannot fully support the country's growth. In Japan, evidence from Tiwari et al. (2003) also confirmed that technological progress caused an overall aggregate price decrease of 1.39 percent and positively contributed to economic growth. While the context of the Thai economy, there is limited evidence of technological advancement contributing to growth. Fortunately, a few studies have found relevant results. For example, Karunaratne (1998) showed that interventions in industry technology could benefit export-oriented industries while harming import-oriented industries. Nevertheless, the Thai economy still gained an international competitive advantage. Although the recent advanced research in this field, as documented in the work of Kitipacharadechatron (2024), which displayed that the advancement of technology improved the economic complexity and growth significantly, was limited in tracing the economic wide impact. Resulting in there not being clear evidence regarding this issue.

Given the limited evidence on the impact of technological advancement on growth in Thailand, and the introduction of research commercialization policy promotion, which directly affects the country's total factor productivity, this paper applies scenario analysis with a standard CGE model to investigate the potential impact of policy promotion on the Thai economy. The next section will elaborate on the research methodology and analysis procedures conducted in this paper.

3.0 Research Methodology

3.1 Database and Model Description

This paper employed the input-output table (IOT) of Thailand for 2021, which included six sectors of commodities and activities in the economy: Agriculture, Mining, Light Industry, Petrol Refinery, Heavy Industry, and Services. The IOT was provided by the Asian Development Bank (ADB). The IOT was then transformed into a social accounting matrix (SAM) by incorporating financial factors aggregated from the socio-economic survey (SES) of the same year, provided by the National Statistical Office of Thailand.

Computational general equilibrium (CGE) was considered as a tool in the impact assessment throughout the open economic system, with the following assumptions: i) Households aim to maximize their utilities under consumption choices with constant elasticity of substitution. ii) Producers aim to maximize their profit under production conditions with constant returns to scale. iii) The markets for goods and services are in equilibrium with optimal price determination. iv) Other economic determinations (e.g., exchange rate, government spending, tax rate, etc.) are given according to policy. and v) There is dynamic behavior in the substitution mechanism for domestic goods consumption, imported goods consumption, and exported goods consumption (the system of equation was shown in appendix) (Chanthawong et al., 2020; Puttanapong et al., 2015).

3.2 Scenario Description

This paper aimed to analyze the economic impact from the different levels of technology adoption under research commercialization policy promotion, which was resulting in productive efficiency of the country. The scenarios were designed to increase the initial total factor productivity by separated into 4 situations following 1%, 1.5%, 2%, and 2.5% technological shock in production of the country, as suggested by Comin and Hobijn (2010) and Comin and Mestieri (2018) for the developing countries. The outcome from simulations will be compared to the based case CGE and reported as table which presented in the next section.

3.3 Closure Rule Selection

In the static CGE simulation process, the closure rule was a crucial key to the economy. This process assumes certain conditions to make the model realistic, such as government balance, saving-investment balance, and rest of the world balance (Wianwiwat and Asafu-Adjaye, 2013). For this investigation, the saving-investment balance was employed in the simulation process, meaning that saving and investment were allowed to change in the capital market system. Additionally, the labor market was assumed to have full employment, and the exchange rate was fixed in the international market.

4.0 Result and Discussion

The outcomes obtained from the CGE simulation revealed that Thailand's GDP was 18,428.59 billion THB in the base case simulation. According to the results, the Thai economy circulates about 20,600.91 billion THB of total domestic output, with 65.10 percent for domestic supply and 34.89 percent for international supply.

Additionally, imposing idiosyncratic shocks such as research commercialization policy promotion, which resulted in changes in the total factor productivity, showed increased investment, especially in the agricultural sectors for all scenarios (with growth ranging from 1.560 to 3.830 percent compared to the base case). Interestingly, the results indicated that investment behavior changes with increasing technological advancement, particularly in the light industrial and service sectors. However, the simulation projected no investment in the mining and petrol refinery sectors for all scenarios in Thailand.

The most significant consequence of this policy appeared in the petrol refinery sector, with total supply growth ranging from 1.019 to 2.547 percent compared to the base case. The heavy industrial sector was notable for domestic supply. In terms of international market orientation, the Thai economy performed well in the heavy industrial sector for imported output and the service sectors for exported output. However, a shortage of supply might exist as domestic demand concentrated on heavy industrial sectors, implying that excess demand would need to be compensated for imports, as evidenced below.

Table 1: Economic-wide Impact After Imposing Shock Compared to Based Case

	SEC-1	SEC-2	SEC-3	SEC-4	SEC-5	SEC-6
Investment Demand						
TFP + 1.0%	1.560	0.000	1.517	0.000	1.507	1.507
TFP + 1.5%	2.270	0.000	2.252	0.000	2.260	2.260
TFP + 2.0%	3.121	0.000	3.033	0.000	3.013	3.013
TFP + 2.5%	3.830	0.000	3.768	0.000	3.767	3.767
Total Supply						
TFP + 1.0%	0.997	0.994	1.002	1.019	1.005	0.976
TFP + 1.5%	1.496	1.490	1.503	1.528	1.508	1.464
TFP + 2.0%	1.995	1.987	2.004	2.038	2.011	1.952
TFP + 2.5%	2.493	2.484	2.505	2.547	2.513	2.440
Domestic Supply						

Table 1: Economic-wide Impact After Imposing Shock Compared to Based Case

	SEC-1	SEC-2	SEC-3	SEC-4	SEC-5	SEC-6
TFP + 1.0%	1.010	1.029	1.014	1.035	1.084	0.972
TFP + 1.5%	1.514	1.543	1.521	1.553	1.626	1.458
TFP + 2.0%	2.019	2.058	2.027	2.070	2.167	1.944
TFP + 2.5%	2.524	2.572	2.534	2.588	2.709	2.430
Import						
TFP + 1.0%	1.016	1.032	1.020	1.040	1.099	0.968
TFP + 1.5%	1.524	1.548	1.531	1.560	1.648	1.452
TFP + 2.0%	2.033	2.064	2.041	2.079	2.198	1.935
TFP + 2.5%	2.541	2.579	2.551	2.599	2.747	2.419
Export						
TFP + 1.0%	0.980	0.985	0.982	0.985	0.970	0.988
TFP + 1.5%	1.470	1.478	1.473	1.477	1.454	1.482
TFP + 2.0%	1.961	1.970	1.964	1.968	1.939	1.976
TFP + 2.5%	2.451	2.463	2.456	2.460	2.424	2.470
Domestic Demand						
TFP + 1.0%	1.007	1.019	1.010	1.025	1.065	0.973
TFP + 1.5%	1.510	1.530	1.516	1.538	1.598	1.459
TFP + 2.0%	2.014	2.039	2.021	2.050	2.130	1.946
TFP + 2.5%	2.517	2.549	2.526	2.563	2.663	2.432

Remark:
SEC-1 denoted agricultural sector; SEC-2 denoted mining sector;
SEC-3 denoted light industrial sector; SEC-4 denoted petrol refinery sector;
SEC-5 denoted heavy industrial sector; SEC-6 denoted service sector.

In terms of other economic consequences, it was revealed that consumption, revenue, and economic growth increased gradually with the technological advancement of the country. Additionally, the explicit effect of total factor productivity on the overall economic structure was observed to range from 1.0 to 1.5, after which the scale returns decreased gradually. Interestingly, despite the overall economic impact, only high-income households received significantly greater benefits compared to other groups, as evidenced below.

Table 2: Consumption and Revenue After Imposing Shock Compared to Based Case

	TFP + 1.0%	TFP + 1.5%	TFP + 2.0%	TFP + 2.5%	Delta 1 - 1.5	Delta 1.5 - 2	Delta 2 - 2.5
GDP	0.988	1.482	1.976	2.470	50.001	33.334	25.000
HH1 - Revenue	0.979	1.469	1.958	2.448	50.016	33.319	25.008
HH2 - Revenue	0.981	1.472	1.963	2.454	50.008	33.337	25.002
HH3 - Revenue	0.984	1.476	1.968	2.459	50.000	33.333	24.995
HH4 - Revenue	0.984	1.477	1.969	2.461	50.003	33.339	25.003
HH5 - Revenue	1.254	1.880	2.507	3.134	50.000	33.333	25.000
Gov. Revenue	1.033	1.550	2.067	2.583	50.003	33.335	25.001
Consumption	1.118	1.678	2.237	2.796	50.004	33.334	25.001
Import	1.033	1.549	2.066	2.582	49.999	33.334	25.000
Export	0.978	1.468	1.957	2.446	50.001	33.334	25.000

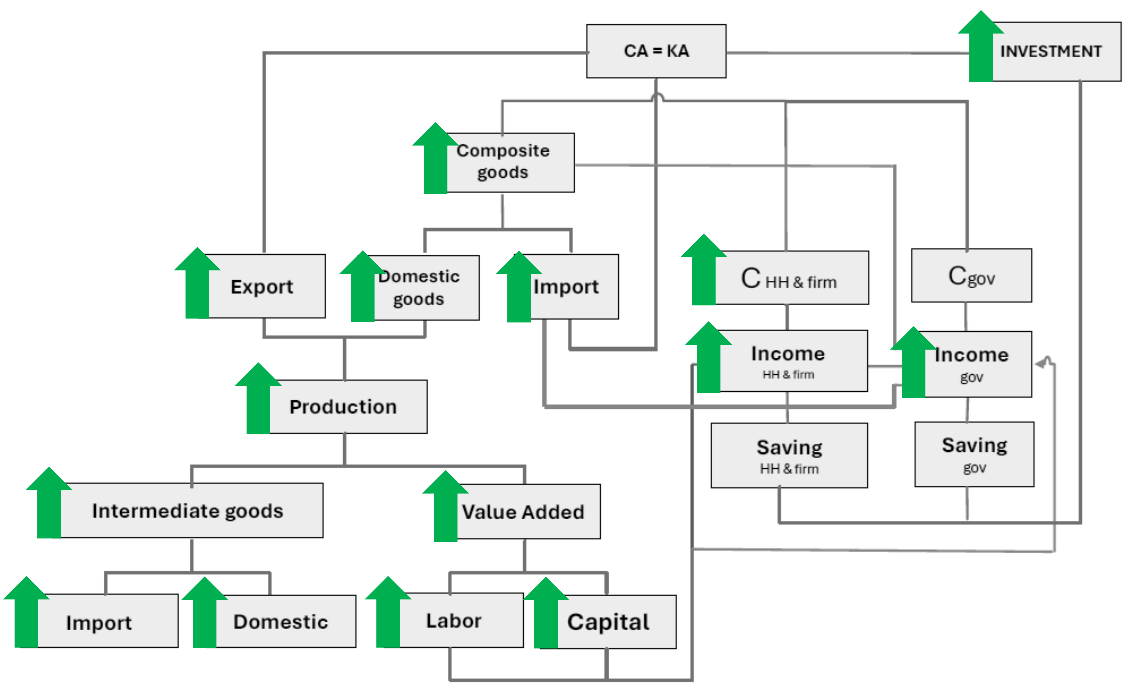
Table 2: Consumption and Revenue After Imposing Shock Compared to Based Case

	TFP + 1.0%	TFP + 1.5%	TFP + 2.0%	TFP + 2.5%	Delta 1 - 1.5	Delta 1.5 - 2	Delta 2 - 2.5

Remark: HH1 to HH5 denoted households' income from percentile 1st to 5th

Results from the computable general equilibrium simulation illustrate that a technological shock impacted the entire economy, even with only a one percent increase in technological advancements. Based on the saving-investment balance closure rule used in this study, investment increased despite a constant marginal propensity to save. This was due to improved production efficiency across industries, leading to economies of scale in output costs. All economic agents benefited from higher returns on their investments through labor and capital or other inputs' cost, resulting in increased income. Additionally, the government gained from higher income tax revenue. The introduction of technological advancements in production sectors provided households with more options to balance consumption and saving for investment, as illustrated in the diagram below.

Figure 2: Illustration of Economic-wide Impact.



5.0 Conclusion and Implications

This paper investigated the economy-wide impact of imposing a technical shock resulting from the promotion of a research commercialization policy. The CGE model was employed to quantify the impact and economic adjustment of all agents under the saving-driven investment closure rule. The results were divided into two parts: the first part highlighted the consequences for the country's output, while the second part emphasized the economy-wide impact and growth of the country.

The findings indicated that technological advancements directly affected investment in the light industrial sectors in the early stages of technology adoption, which then rotated to the service sectors during advanced stages of technology adoption. Additionally, it was found that there was significant potential growth in the heavy industrial sectors of the country. Ultimately, the policy support could enhance the country's income level and market competitiveness. However, inequality issues should be considered since only certain groups gained a significant advantage.

The outcomes of this paper were consistent with Tiwari et al. (2003) and Doroodian and Boyd (2003), which found that technological progress or advancements increased economic growth, particularly productivity and international market competitiveness, in the US and Japan. However, some documents argue against this finding, such as Hübler (2011), who stated that technological progress could increase productivity while maintaining constant growth, as in the case of China. Karunaratne (1998) found that technological progress brought advantages only to export-oriented industries in Thailand, whereas this paper found advantages for both export-oriented and other types of industries.

The main contribution of this paper was to provide evidence for policymakers as a guideline for promoting deep science and technology, particularly regarding the optimal rate necessary for the evolution of the economy. The outcomes suggested that the government should implement deep science and technology promotion until technology adoption in Thailand approaches the range of 1 to 1.5 percent point compared to the reference point to evolve the economy. This paper suggests that the government should play a key role in facilitating new technologies adoption for industries, whether through policy or regulation, such as tax and tariff reductions, to encourage industries to replace outdated technology with newer innovations. Additionally, the government could act as a facilitator by connecting industries with university research outputs or supporting new start-up businesses with deep technology. Moreover, the government should support sustainable growth in each industry sector, such as creating more opportunities in the international market.

The main limitation of this paper was related to the closure rule used in this simulation, specifically the labor market and the role of currency exchange. Hence, future work should consider these aspects to bridge the academic gaps when applying a similar approach in investigations. Besides, applying the CGE technique should be incorporated with other investigations, such as the forward-backward linkage index, to quantify the structural change of the economy regarding such issues of study as well as complete the picture of the total policy effect on the economy. Throughout the findings in this paper were just the preliminary results of the first part in evaluating research commercialization policy in Thailand; the rest finding, such as scenario analysis of structural decomposition of the economy, will be published further.

6.0 Acknowledgement

The authors extend their sincere gratitude to Thammasat University for supporting the Ph.D research scholarship during the year 2022 until now. In particular, the Faculty of Economics provides opportunities to participate in international research collaborations. Additionally, the authors express their gratitude to the reviewers for their insightful comments, which assisted in the revision of this article prior to presentation and publication.

7.0 Author Contributions

Nattapon Siwareepan: Conceptualization, Validation, Data Curation, Visualization, Project Administration; *Ronnakron Kitipacharadechatron:* Formal Analysis, Original Draft, Writing-review and Editing, Method.

8.0 Conflicts of Interest

The authors declare that there is no conflict of interest regarding this paper and all authors have read with agreed to publish this manuscript.

9.0 References

Antoszewski, M. (2019). Assessment of Energy-Related Technological Shocks Within a CGE Model for the Polish Economy. *Gospodarka Narodowa. The Polish Journal of Economics*, *297*(1), 9-45.

Bergman, L. (1991). General equilibrium effects of environmental policy: a CGE-modeling approach. *Environmental and Resource Economics*, *1*, 43-61.

Bhattacharyya, S. C. (1996). Applied general equilibrium models for energy studies: a survey. *Energy Economics*, *18*(3), 145-164.

Bhattarai, K., & Benjasak, C. (2021). Growth and redistribution impact of income taxes in the Thai Economy: A dynamic CGE analysis. *The Journal of Economic Asymmetries*, *23*, e00189.

Boonpanya, T., & Masui, T. (2021). Assessing the economic and environmental impact of freight transport sectors in Thailand using computable general equilibrium model. *Journal of cleaner production*, *280*, 124271.

Borges, A. M., & Goulder, L. H. (1984). *Decomposing the impact of higher energy prices on long-term growth*. *Applied General Equilibrium Analysis*, Cambridge university Press., Cambridge.

Chanthawong, A., Dhakal, S., Kuwornu, J. K., & Farooq, M. K. (2020). Impact of subsidy and taxation related to biofuels policies on the economy of Thailand: A dynamic CGE modelling approach. *Waste and Biomass Valorization*, *11*, 909-929

Comin, D., & Hobijn, B. (2010). An exploration of technology diffusion. *American economic review*, *100*(5), 2031-2059.

Comin, D., & Mestieri, M. (2018). If technology has arrived everywhere, why has income diverged? *American Economic Journal: Macroeconomics*, *10*(3), 137-178.

Doroodian, K., & Boyd, R. (2003). The linkage between oil price shocks and economic growth with inflation in the presence of technological advances: a CGE model. *Energy Policy*, *31*(10), 989-1006.

Hübler, M. (2011). Technology diffusion under contraction and convergence: A CGE analysis of China. *Energy Economics*, *33*(1), 131-142.

Hudson, J., & Khazragui, H. F. (2013). Into the valley of death: research to innovation. *Drug discovery today*, *18*(13-14), 610-613.

Karunaratne, N. D. (1998). Trade liberalization in Thailand: A computable general equilibrium (CGE) analysis. *The Journal of Developing Areas*, *32*(4), 515-540.

Kim, Y. E., & Loayza, N. (2019). Productivity growth: Patterns and determinants across the world. *World Bank Policy Research Working Paper*, (8852).

Kitipacharadechatron, R. (2024). Understanding Economic Complexity and Consequence on Growth of Thailand. *RMUTT Global Business and Economics Review. 19*(2).

Manne, A. S., & Richels, R. G. (1991). Global CO2 emission reductions-The impacts of rising energy costs. *The Energy Journal*, *12*(1), 87-108.

Markham, S. K., Ward, S. J., Aiman-Smith, L., & Kingon, A. I. (2010). The valley of death as context for role theory in product innovation. *Journal of Product Innovation Management*, *27*(3), 402-417.

National Economic and Social Development Council. (2023). National Economic and Social Development Plan 13. Retrieved from: https://www.nesdc.go.th/main.php?filename=develop_issue

National Innovation Agency. (2022). NIA Deep Tech Incubation Program. Retrieved from: https://moocs.nia.or.th/project/aritech

Program Management Unit for Competitiveness. (2022). PMUC accelerates research and innovation towards commercialization. Retrieved from: https://pmuc.or.th/en/pmuc-accelerates-research-and-innovation-towards-commercialization/

Puttanapong, N., Wachirarangsrikul, S., Phonpho, W., & Raksakulkarn, V. (2015). A monte-carlo dynamic CGE model for the impact analysis of Thailand's carbon tax policies. *Journal of Sustainable Energy & Environment*, *6*, 43-53.

Rajbhandari, S., Limmeechokchai, B., & Masui, T. (2019). The impact of different GHG reduction scenarios on the economy and social welfare of Thailand using a computable general equilibrium (CGE) model. *Energy, Sustainability and Society*, *9*, 1-21.

Scarf, H. E. (1982). The computation of equilibrium prices: an exposition. *Handbook of mathematical economics*, *2*, 1007-1061.

Siegmund, D., Metz, S., Peinecke, V., Warner, T. E., Cremers, C., Grevé, A.,& Apfel, U. P. (2021). Crossing the valley of death: from fundamental to applied research in electrolysis. *Jacs Au*, *1*(5), 527-535.

Suttiwichienchot, A., & Puttanapong, N. (2014). A Study on Internal Labor Movement and Policy Multiplier in Thailand. *Eurasian Journal of Economics and Finance*, *2*(3), 57-68.

Tiwari, P., Doi, M., & Itoh, H. (2003). A CGE analysis of the potential impact of information technology on the Japanese economy. *The Journal of Policy Reform*, *6*(1), 17-33.

Wianwiwat, S., & Asafu-Adjaye, J. (2013). Is there a role for biofuels in promoting energy self-sufficiency and security? A CGE analysis of biofuel policy in Thailand. Energy Policy, 55, 543-555.

10. Appendix

System Equation for CGE

Notation Sets:

$a \in A$	Activities of the industrial sectors
$c \in C$	Commodities of the industrial sectors
$c \in CM\ (\subset C)$	Imported commodities
$c \in CNM\ (\subset C)$	Non-imported commodities
$c \in CE\ (\subset C)$	Exported commodities
$c \in CNE\ (\subset C)$	Non-exported commodities
$f \in F$	Factors
$h \in H\ (\subset I)$	Households
$i \in I$	Institution e.g., households, government, and rest of the world

Parameters:

ad_a	Production function efficiency parameter
aq_c	Shift parameter for composite supply (Armington) function
at_c	Shift parameter for output transformation (CET) function
cpi	Consumer price index
$cwts_c$	Commodity weight in CPI
ica_{ca}	Quantity of c as intermediate input per unit of activity a
mps_h	Share of disposable household income to savings
pwe_c	Export price (foreign currency)

pwm_c	Import price (foreign currency)
qg_c	Government commodity demand
$\overline{qinv_c}$	Base-year investment demand
$shry_{hf}$	Share of the income from factor f in household h
te_c	Export tax rate
tm_c	Import tariff rate
tq_c	Sales tax rate
tr_{ij}	Transfer from institution i to institution j
ty_h	Rate of household income tax
a_{fa}	Value-added share for factor f in activity a
β_{ch}	Share of commodity c in the consumption of household h
δ_c^q	Share parameter for composite supply (Armington) function
δ_c^t	Share parameter for output transformation (CET) function
θ_{ac}	Yield of commodity c per unit of activity a
ρ_c^q	Exponent ($-1 < \rho_c^q < \infty$) for composite supply function
ρ_c^t	Exponent ($-1 < \rho_c^t < \infty$) for output transformation (CET)

Variables:

EG	Government expenditure
EXR	Foreign exchange rate
$FSAV$	Foreign savings
$IDAJ$	Investment adjustment factor
PA_a	Activity price
PD_c	Domestic price of domestic output
PE_c	Export price
PM_c	Import price
PQ_c	Composite commodity price
PVA_c	Value-added price
PX_c	Producer price
QA_a	Activity level
QD_c	Quantity of domestic output sold domestically
QE_c	Quantity of exports
QF_{fa}	Quantity demanded of factor f by activity a
QFS_f	Supply of factor f
QH_{ch}	Quantity of consumption of commodity c by household h
$QINT_c$	Quantity of intermediate use of commodity c by activity a
$QINV_c$	Quantity of investment demand
QM_c	Quantity of imports
QQ_c	Quantity supplied to domestic commodity demanders
QX_c	Quantity of domestic output
$WALRAS$	Dummy variable (zero at equilibrium)
WF_f	Average wage (rental rate) of factor f
$WFDIST_{fa}$	Wage distortion factor for factor f in activity a
YF_{hf}	Transfer of income to household h from factor f

YG	Government revenue
YH_h	Household income
$Total\ E$	Total export
$Total\ M$	Total import
$Total\ C$	Total consumption
$Total\ D$	Total quantity sold domestically of domestic output
$Total\ Q$	Total goods supplied domestically (composite supply)
$Total\ X$	Total output
GDP	The value of GDP

Equations in Price Block:

- Import Price

$$PM_c = (1 + tm_c) \cdot EXR \cdot pwn_c \qquad ; c \in CM \quad (1)$$

- Export Price

$$PE_c = (1 + te_c) \cdot EXR \cdot pwe_c \qquad ; c \in CE \quad (2)$$

- Absorption

$$PQ_c \cdot QQ_c = [PD_c \cdot QD_c + (PM_c \cdot QM_c) \mid c \in CM] \cdot (1 + tq_c) \qquad ; c \in C \quad (3)$$

- Domestic Output Value

$$PX_c \cdot QX_c = [PD_c \cdot QD_c + (PE_c \cdot QE_c) \mid c \in CE] \qquad ; c \in C \quad (4)$$

- Activity Price

$$PA_a = \sum_{c \in C} PX_c \cdot \theta_{ac} \qquad ; a \in A \quad (5)$$

- Value-added Price

$$PVA_a = PA_a - \sum_{c \in C} PQ_c \cdot ica_{ca} \qquad ; a \in A \quad (6)$$

Equations in Production and Commodity Block:

- Activity Production Function

$$QA_a = ad_a - \prod_{f \in F} QF_{fa}^{a} \cdot fa \qquad ; a \in A \quad (7)$$

- Factor Demand

$$WF_f \cdot WFDIST_{fa} = \frac{a_{fa} \cdot PVA_a \cdot QA_a}{QF_{fa}} \qquad ; a \in A \ ; f \in F \quad (8)$$

- Intermediate Demand

$$QINT_{ca} = ica_{ca} \cdot QA_a \qquad ; a \in A \ ; c \in C \quad (9)$$

- Output Function

$$QX_{ca} = \sum_{a \in A} \theta_{ac} \cdot QA_a \qquad ; c \in C \quad (10)$$

- Composite Supply (Armington) Function

$$QQ_c = aq_c \cdot (\delta_c^q \cdot QM_c^{-p_c^q} + (1-\delta_c^q) \cdot QD_c^{-p_c^q})^{\frac{-1}{p_c^q}} \quad ; c \in CM \quad (11)$$

- Import-Domestic Demand Ratio

$$\frac{QM_c}{QD_c} = (\frac{PD_c}{PM_c} \cdot \frac{\delta_c^q}{1-\delta_c^q})^{\frac{-1}{1+p_c^q}} \quad ; c \in CM \quad (12)$$

- Output Transformation (CET) Function

$$QX_c = at_c \cdot (\delta_c^t \cdot QE_c^{p_c^t} + (1-\delta_c^t) \cdot QD_c^{p_c^t})^{\frac{1}{p_c^t}} \quad ; c \in CE \quad (13)$$

- Export-Domestic Supply Ratio

$$\frac{QE_c}{QD_c} = (\frac{PE_c}{PD_c} \cdot \frac{1-\delta_c^q}{\delta_c^q})^{\frac{1}{p_c^q-1}} \quad ; c \in CE \quad (14)$$

Equations in Institution Block:

- Factor Income

$$YF_{hf} = shry_{hf} \cdot \sum_{a \in A} WF_f \cdot WFDIST_{fa} \cdot QF_{fa} \quad ; h \in H \; ; f \in F \quad (15)$$

- Household Income

$$YH_h = \sum_{f \in F} YF_{hf} + tr_{h,gov} + EXR \cdot tr_{h,row} \quad ; h \in H \quad (16)$$

- Household Consumption Demand

$$QH_{ch} = \frac{B_{ch} \cdot (1 - mps_h) \cdot (1 - ty_h) \cdot YH_h}{PQ_c} \quad ; c \in C \; ; h \in H \quad (17)$$

- Investment Demand

$$QINV_c = \overline{qinv}_c \cdot IADJ \quad ; c \in C \quad (18)$$

- Government Revenue

$$YG = \sum_{h \in H} ty_h \cdot YH_h + EXR \cdot tr_{h,row} + \sum_{c \in C} tq_c \cdot \left(PD_c \cdot QD_c + (PM_c \cdot QM_c)\right) | c \in CM$$
$$+ \sum_{c \in CM} tm_c \cdot EXR \cdot pwm_c \cdot QM_c + \sum_{c \in CE} te_c \cdot EXR \cdot pwe_c \cdot QE_c \quad ; \quad (19)$$

- Government Expenditure

$$GE = \sum_{h \in H} tr_{h,row} + \sum_{c \in C} PQ_c \cdot qg_c \quad ; \quad (20)$$

Equations in System Constraint Block:

- Factor Markets

$$\sum_{a \in A} QF_{fa} = QFS_f \quad ; f \in F \quad (21)$$

- Composite Commodity Markets

$$QQ_c = \sum_{a \in A} QINT_{ca} + \sum_{h \in H} QH_{ch} + qg_c + QINV_c \quad ; c \in C \quad (22)$$

- Current Account Balance for Rest of the World

$$\sum_{c\in CE} pwe_c \cdot QE_c + \sum_{i\in I} tr_{i,row} + FSAV = \sum_{c\in CM} pwm_c \cdot QM_c \qquad ; c \in C \quad (23)$$

- Saving-Investment Balance

$$\sum_{h\in H} mps_h \cdot (1 - tr_h) \cdot YH_h + (YG - EG) + EXR \cdot FSAV$$
$$= \sum_{c\in C} PQ_c \cdot QINV_c + WALRAS \qquad ; \quad (24)$$

- Price Normalization

$$\sum_{c\in C} PQ_c \cdot cwts_c = cpi \qquad ; c \in C \quad (25)$$

Industries Classification

SEC-1: *Agricultural Sectors* - Agricultural Products and Livestock, Forestry, Fisheries
SEC-2: *Mining Sectors* - Minerals
SEC-3: *Light Industrial Sectors* - Processed Food, Beverages, Tobacco, Textile Mill Products, Wearing Apparel and Accessories, Wood and Wooden Products, Paper Products Printing and Publishing, Chemical Materials, Man-Made Fibers, Plastics, Plastic Products, Miscellaneous Chemical Products, Non-Metallic Mineral Products, Metallic Products, Household Electrical Appliances, Electronic Products
SEC-4: *Petrol Refinery Sectors* - Petroleum Products
SEC-5: *Heavy Industrial Sectors* - Steel and Iron, Miscellaneous Metals, Machinery, Electrical Machinery and Apparatus, Transport Equipment, Miscellaneous Products