Growth and Redistribution Impacts of Income Taxes in the Thai Economy: A Dynamic CGE Analysis

Keshab Bhattarai[1] and Chonlakan Benjasak[2]

Business School, Hull University. HU6 7RX, UK[3]

Abstract

A reform in the personal income tax (PIT) is helpful in reducing inequality in the distribution of income and consumption in both short and long terms in Thailand. It boosts private consumption, investment, employment, capital stock, exports, imports and GDP. Output, employment and capital stock in every sector grow faster with the reforms in the personal income tax than without reforms. While the revenue from the PIT decreases with a cut in PIT rate, the total revenue of the government still remains at the same level before such cut as increase in revenue from other taxes can compensate for the decrease in revenue from the personal income tax. These conclusions are based on results of the dynamic CGE model of the Thai economy constructed for this paper which was calibrated to the micro-consistent data contained in the most recent Input-Output Table of Thailand obtained from the OECD and the household-quintile data collected from the National Statistical Office in Bangkok. This study makes a unique contribution to the literature on the dynamic CGE model of Thai economy assessing the magnitudes of the complicated and asymmetric economy-wide income and substitution effects from reduction in PIT rates over coming 25 years. This DCGE model could be further applied to study impacts of fiscal or financial, pension or health care policies in Thailand, with some modifications.

Keywords: Tax Policy, Personal income tax, Thailand, Dynamic CGE

JEL Classification: C68, D58, H20, H24, H30, O53

[1] Corresponding author: Keshab Bhattarai, PhD, University of Hull, FBLP, Business School, HU6 7RX, UK; K.R.Bhattarai@hull.ac.uk ; Phone: 441482463207

[2] Chonlakan Benjasak, PhD, School of Management, Walailak University, Thaiburi, Thasala, Nakhon Si Thammarat, Thailand 80160. Email: bchonlak@wu.ac.th

[3] We are grateful to two anonymous reviewers and the editor Professor Anastasios Malliaris for constructive comments in the earlier version of the paper. This is a paper from the CGE Workshop in the University of Hull on 14 June 2018.

Growth and Redistribution Impacts of Income Taxes in the Thai Economy: A Dynamic CGE Analysis

Abstract

A reform in the personal income tax (PIT) is helpful in reducing inequality in the distribution of income and consumption in both short and long terms in Thailand. It boosts private consumption, investment, employment, capital stock, exports, imports and GDP. Output, employment and capital stock in every sector grow faster with the reforms in the personal income tax than without reforms. While the revenue from the PIT decreases with a cut in PIT rate, the total revenue of the government still remains at the same level before such cut as increase in revenue from other taxes can compensate for the decrease in revenue from the personal income tax. These conclusions are based on results of the dynamic CGE model of the Thai economy constructed for this paper which was calibrated to the micro-consistent data contained in the most recent Input-Output Table of Thailand obtained from the OECD and the household-quintile data collected from the National Statistical Office in Bangkok. This study makes a unique contribution to the literature on the dynamic CGE model of Thai economy assessing the magnitudes of the complicated and asymmetric economy-wide income and substitution effects from reduction in PIT rates over coming 25 years. This DCGE model could be further applied to study impacts of fiscal or financial, pension or health care policies in Thailand, with some modifications.

Keywords: Tax Policy, Personal income tax, Thailand, Dynamic CGE

JEL Classification: C68, D58, H20, H24, H30, O53

1. Introduction

In the 1980s, Thailand had been one of the widely cited development success stories with sustained strong growth and impressive poverty reduction. In addition, it had made remarkable progress in social and economic development, moving from a lower-middle income country to an upper-middle income country in less than a generation. Income inequality, however, had not improved even slightly. In the late 1980s, the Thai economy took off on a rapid growth path with economic liberalisation and a shift of labour from agriculture to manufacturing and services. This raised income inequality even further. The Gini coefficient reached a highest value of 47.9 percent, particularly during the high growth period of 1988-1992. Following redistribution programmes, the Gini coefficient consequently had dropped toward the current level of 37.8 percent in 2013, as shown in Figure 1. Vanitcharearnthum (2017) opines that this is consistent with the Kuznets hypothesis, which claims that income inequality worsens in the early stages of economic development before it gradually improves in the later stage.

A wide gap between average income of households in top quintile and the bottom quintile in Thailand is not acceptable. In 2011, the average income of households in the top quintile was approximately 7.49 times than that of the households at the bottom quintile (National Statistical Office, 2012). In addition, Gini coefficients Figure 2 and Table 1 illustrate that the distribution of income of Thailand was more unequal than many countries in OECD and other neighbouring countries including Nepal and can get worse as in Latin American, African and Asian countries including China, India, Indonesia, Bangladesh and Vietnam in policies for equality are not in place.

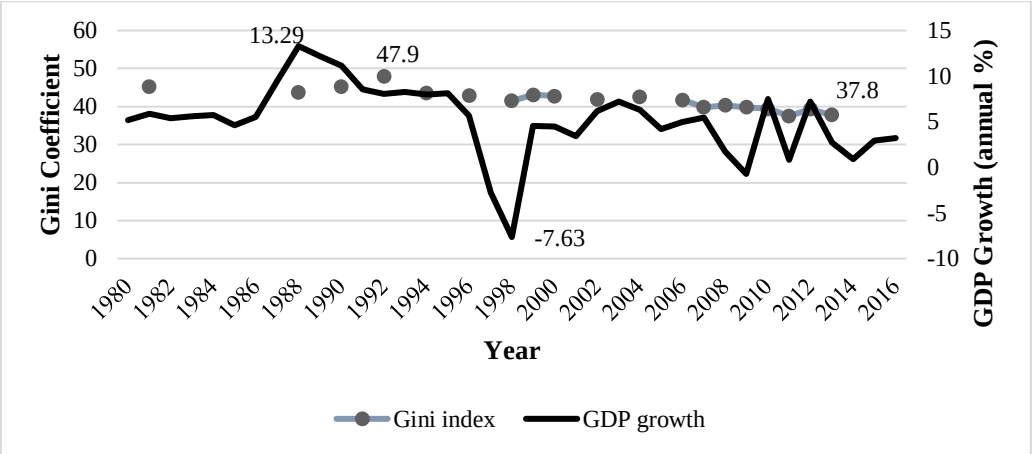

Figure 1: Gini Index and GDP Growth in Thailand
Source: World Development Indicator, World Bank (2017)

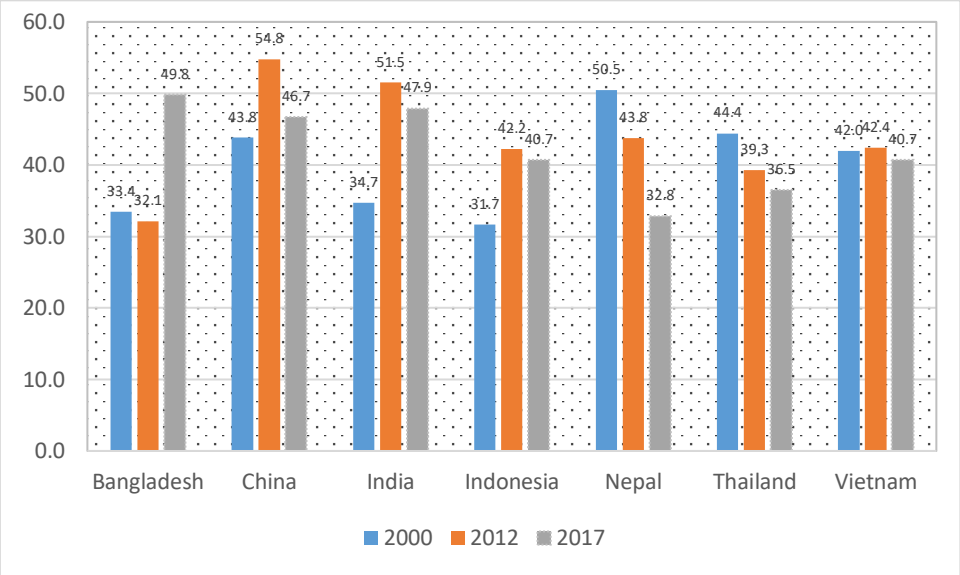

Figure 2: Income Inequality in Asian Economies between 2000 to 2017 (Gini coefficients)
Source: Authors compilation from the UNU-WIDER WIID 2020 database

Table 1
Income Inequality Across the Globe between 2000 to 2017
(Gini Coefficients based on UNU-WIDER, WIID database 2020)

	OECD				Latin America		
	2000	2012	2017		2000	2012	2017
Austria	28.9	30.48	27.2	Argentina	50.4	41.2	40.6
France	31.1	30.5	29.3	Bolivia	61.5	47.4	44.0
Greece	34.2	37.5	33.4	Brazil	58.3	52.5	53.3
Ireland	33.2	37.8	30.6	Columbia	58.7	52.8	51.1
Italy	34.7	32.4	32.7	Cota Rica	46.7	48.6	49.6
Netherlands	32.5	27.8	27.1	Haiti	59.5	60.8	41.1
Norway	30.8	25.3	26.2	Mexico	35.2	35.1	35.7
Spain	34.3	34.2	34.1	Nicaragua	52.9	50.3	56.8
Sweden	27.3	27.64	28.2	Panama	55.7	51.7	50.8
UK	35.2	35.1	35.7	Peru	49.1	44.5	44.8
	Asia				Africa		
	2000	2012	2017		2000	2012	2017
Bangladesh	33.4	32.1	49.8	Egypt	33.9	30.2	51.4
China	43.8	54.8	46.7	Nigeria	40.1	43.3	43.0
India	34.7	51.5	47.9	Senegal	41.2	37.8	40.3
Indonesia	31.7	42.2	40.7	Tanzania	35.0	37.3	37.8
Nepal	50.5	43.8	32.8	Tunisia	40.8	38.5	32.8
Thailand	44.4	39.3	36.5	Uganda	53.6	41.0	42.8
Vietnam	42.0	42.4	40.7	South Africa	67.0	69.3	61.6

Figures in Table 1 show that income inequality has remained lower with average Gini coefficient at 31.5% among EU economies compared to those in Asia (42%), Africa (43.7%) and Latin

America (49.9%). Patterns of these coefficients are stable in the EU but rising in some Asian countries including China, India and Indonesia and Bangladesh but falling slowly in Thailand and at a faster rate in Nepal. The differences in the tax-transfer and other means of redistribution cause such wide variations across countries. Carter and Matthews (2012) pointed out at the post-tax income distribution can be more equal through tax policy because tax policy is a vital tool for raising government revenues to finance public spending that benefit to low-income families through cash transfers, provision for education and health services. Aside from this, tax policy can improve social equity via the growth-facilitating infrastructure. Their view was also supported by the OECD's experts, who claimed that governments can use progressive income tax as one of the key approaches to redistribute incomes.

There are concerns in many countries about the potential trade-offs between meeting both economic growth and equity objectives. Effects of income tax on the distribution of income need to be considered in this context. This means the overall effects of any reform in taxation policies should be analysed as a whole for the economy, particularly with focus on the effects of tax on different categories of households and production sectors in the economy. According to Bhattarai (2017), the most appropriate technique for evaluating such impacts of taxes in an economy is the dynamic computable general equilibrium model (DCGE) of it. Compared to a static computable general equilibrium model a DCGE model provides deep intuitions on the intertemporal behaviour of households and firms and of their economic activities including consumption, investment, exports and imports. The explicit dynamic specification of demand and supply of commodities and factors of production allows the transition paths of output, employment and capital formation in various sectors to be assessed in response to a certain policy change that causes reallocation of resources through changes in factor and commodity prices (Bhattarai, 2008). The transitional effects of tax reform may differ significantly across sectors even when long-run impacts are similar. The sector-specific impacts of tax changes both in the short and in the long-run can be evaluated by a dynamic model through adjustment of price mechanism. Radulescu and Stimmelmayr (2010), also stated that the short-run and long-run impacts of policy proposals can be distinguished by a dynamic CGE model. Apart from aforementioned advantages of dynamic CGE method, this approach has some drawbacks on grounds of transparency as it is a big model with many assumptions. Hence, the modellers should have good knowledge of the modelled economy and great skill of software packages such as the GAMS/MPSGE to ensure that the constructed model is correct and suitable to evaluate policy under consideration.

Dynamic CGE models have been used extensively for measuring the impacts of tax policies in developed and developing countries (e.g., Wendner, 2001; Giesecke and Nhi, 2010; Radulescu and

Stimmelmayr, 2010; Bretschger et al., 2011; Xu et al., 2015; Bhattarai, 2017; Bhattarai et al., 2017; Tang et al., 2017). However, to our knowledge, there is no evidence of a dynamic CGE model that try to investigate the impacts of fiscal policy on the Thai economy. There were few studies in literature that tried to apply different versions of the static CGE models including Puttanapong et al. (2015), Winyuchakrit et al. (2011), and Wianwiwat and Asafu-Adjaye (2013), Wattanakuljarus and Coxhead (2008) and Field and Wongwatanasin (2007). Most of these researchers focus on evaluating impacts of energy and trade policies on Thai economy. Interestingly, Ponjan and Thirawat (2016) could be seen as the latest dynamic CGE model based study that provided empirical evidence of the impacts of cuts in tourism tax in Thailand in response to the floods in 2011.

The main objective as well as a contribution of this study, remains in developing a multi- household multi-sectoral dynamic CGE model of Thailand in order to address the question of whether the reduction of personal income tax (PIT) can lower the inequality in the distribution of income and consumption of Thai households.This is the first of this kind of model to study the dynamic process of re-allocation of resources across sectors and redistribution of income among households in Thailand. We also contribute to previous general equilibrium models of Thailand in constructing a standard micro-consistent dataset based on the OECD 33 sector input-output table of Thailand for 2011 and income distribution information from the household surveys of the National Statistical Office of Thailand. Calibrated to the benchmark with these datasets this DCGE model provides reliable results of model by simulations for policy analyses for Thailand by examining how changes in tax rates will affect key macro and micro economic variables through relative price mechanism of commodities and the reallocation of resources among sectors and households.

The rest of the paper is structured as follows: Section 2 discusses previous literature relating to applying a dynamic CGE model of Thailand. Section 3 gives some information on the change of personal income tax in Thailand. The dynamic CGE model of Thailand, together with model calibration and parameter specification, is presented in detail in section 4. The simulation results on the growth and reallocation from that policy are reported in section 5. Section 6 presents the conclusion of the Thai DCGE model and outlines the scope for future research.

2. Literature Review

There are some empirical studies that use a dynamic CGE model to analyse the impacts of tax policies on an economy. For instance, Wendner (2001) uses a dynamic computable general equilibrium model to examine usage of revenue from CO_2 taxation to partially finance the pension system in Austria. His findings reveal that such a pension policy is the most favourable only in

terms of growth, consumption, private investment and demand of labour compared to any other cash-transfer and labour cost subsidy policies. So, the CO_2 reduction and pension provision go in harmony otherwise some potential conflicts in tax-distortions or redistribution effects of environmental taxes in consumption and production. By including endogenous growth theory into the DCGE model, Bretschger et al. (2011) find that carbon tax moderately decreases welfare and consumption in Switzerland, but this policy has a positive effect on the growth rates of all non-energy sectors. For a regional perspective, Xu et al. (2015) develop the dynamic CGE model across multi-regions and multi-sectors to evaluate the impact of China's coal resource tax reform for correcting regional resource curse. Their finding shows that the change of coal resource tax rate affects resource curse differently among different regions of China. This policy increases revenues in resource-rich regions but hinders development of other regions. Similarly, Tang et al. (2017) construct a multi-sectoral dynamic CGE model to evaluate the impacts of coal resource tax reform on the environment and the Chinese economy. The results show negative effects of tax policy reforms on real GDP, consumption, investment, export, and income of rural and urban households, but this policy can effectively help China to achieve its emission-reduction target. Hayford (2017) had found fiscal policy induced temporary increases in disposable income (TIDI) to impact on personal consumption expenditure from 2000 to 2015 in the US.

In terms of a VAT policy, Giesecke and Nhi (2010) apply a dynamic CGE model to evaluate the macroeconomic, industrial and distributional effects of simplifying Vietnam's complex VAT system. In case of a single VAT rate, this policy could create an aggregate consumption gain of the order of 0.25 percent, but with adverse distributional effects to the rural poor. In addition, they simulate the alternative policy which excludes paddy and rice from an otherwise general policy of VAT simplification, concluding that this alternative policy increases real consumption, with little impact on Gini-measured inequality. Claus (2013) also uses a dynamic general equilibrium model to evaluate the usefulness of value added tax (VAT) as a macroeconomic stabilization instrument for New Zealand. He finds that a variable VAT rate is a less effective stabilization tool than an interest rate because a variable VAT rate generates greater welfare losses and larger fluctuations in the real economy and inflation. In addition, a variable VAT rate would affect saving and investment decisions over time, whereas a change in the interest rate influences only this period's saving and investment decisions.

Furthermore, the dynamic CGE has been applied to analyze the impact of capital and input tax reform, such as Radulescu and Stimmelmayr (2010), who conclude that the 2008 tax reforms in Germany reduced corporate firms' activities, while the non-corporate firms were almost unaffected by it. This reform led to a decrease in overall GDP as the increase in the non-corporate sector's

activity could not compensate for the fall in corporate firms' activity. In addition, this policy had a negative impact on overall households' welfare even though the consumption level increased in the long-run. This result contrasts with the finding by Bhattarai (2017), who reveals that reforms in capital and labour input taxes enhance real output, household's consumption and household's welfare in the Chinese economy.

There are non-CGE model-based analysis on impacts of taxes. Magazzino et al. (2019) assess the fiscal sustainability of G-7 countries over the period 1980-2015 by panel cointegration test showing a clear long-run relationship between primary deficit and government debt and contrasting implications of results for government expenditures and revenues among those countries. Panel pairwise causality tests indicate a feedback causation among government revenues and expenditures, and between government primary deficit and government gross debt. They recommend a joint-decision making among G-7 countries on tax and spending. Angyridis (2006) examines the optimal structure of capital income taxation in a stochastic small open economy. He states that the optimal tax rate on capital income should be zero in all periods, except the initial one, in the special case where the utility function of the representative household is separable in public and private goods and the production function is Cobb-Douglas. One major limitation of results of these non-CGE analysis is that these are based on partial equilibrium analysis and do not take account of economy wide income and substitution effects while explaining impacts of relative price systems in the economy as we do in our analysis here.

By incorporating multi-household and distribution effects, Bhattarai et al. (2015) find that tax reforms increase welfare in all household deciles in the short-run, and has a limited impact in reducing inequality in the distribution of income over the long-run. Additionally, Bhattarai et al. (2017) illustrate how reductions in the corporate income tax in the US economy can bring significant positive impacts on output, investment, capital formation, and employment. This policy, however, has an adverse effect on the poorest households because it reduces their wellbeing and consumption levels. Recent work by Bhattarai et al. (2018) use a DCGE model to estimate the macroeconomic impacts, particularly on efficiency and revenue, from the Trump and Clinton tax proposals of 2016 general election in the US. The reduction in tax and corporate tax, which was proposed and enacted by Trump, reduces the tax burden of all households but favours more those in the richest decile. This proposal increases income inequality. While it apparently appears to reduce total tax revenue but it may in fact increase due to dynamic scoring effects; the reduction in the corporate tax rate encourages investment and increases capital stock and consequently, increases real GDP and hence the tax revenue. On the other hand, the Clinton proposal on personal

income tax hikes, if implemented, would have increased US federal tax revenue, but lowered the real GDP.

Existing empirical studies mentioned above were developed with multisectoral and multi-household settings to study impacts of various policies on growth and redistribution but obviously not to consider the impact of fiscal policy, especially the reduction of personal income tax, on income distribution of the Thai economy. No evidence exists of any dynamic CGE model-based analysis on impacts of fiscal policy on the Thai economy, although only few studies are found applying static computable general equilibrium (CGE) models to investigate the impacts of energy and trade policies in Thailand such as include Puttanapong et al. (2015), Winyuchakrit et al. (2011), and Wianwiwat and Asafu-Adjaye (2013). Meanwhile, Field and Wongwatanasin (2007) employ a CGE model to assess the impacts on output, trade flows, income distribution and welfare from industrial policies. As stated earlier, Wattanakuljarus and Coxhead (2008) use applied general equilibrium models to evaluate the use of tax revenues to finance tourism promotion campaigns. They conclude that a 10 percent rise in inbound tourism creates growths in GDP, household consumption, total domestic absorption and prices index but worsens the real exchange rate, trade and income distribution among households as this policy has favourable effects on high-income non-agricultural households, whilst the low-income agricultural classes benefit less from it.

The recent work of Ponjan and Thirawat (2016) could be seen as the latest dynamic CGE study that provided empirical evidence on the impact of Thailand's tourism tax cut policy in response to the floods in 2011. This dynamic framework of TRAVELTHAI is not only based on the dynamic features of a Monash-style Applied General Equilibrium model for Malaysia (MyAGE) and MONASH but also incorporates three types of tourism sector including domestic, inbound, and outbound. The model is calibrated with the Thai Tourism Satellite Accounts for the year 2000 with 40 industries, 40 commodities, 40 investors, three primary factors of production, one representative household, one central government, and an international trade with net foreign liabilities. Their results show that the inbound tourism tax cut policy generates most benefits to direct-tourism industries, particularly in the short-run, whilst its long-term effects on the whole economy were found to be negligible. This study, however, does not consider the redistribution impacts on income and consumption of each household and neglects other long-term consequences such as tax refunds and/or transfers on investment and capital accumulation.

The main contribution of this paper is to develop and apply a multi-household dynamic CGE model of Thailand to evaluate the effects of tax policy on the Thai economy. To be more precise, this study aims to examine the impact of a reduction of PIT on key macroeconomic variables such as

GDP, employment, and investment, sectoral output, employment, investment and capital accumulation as well as on the distribution of household welfare and consumption in each quintile over 25 years from 2011 to 2036. There are two main reasons for why we focus our analysis on PIT. Firstly, this tax was the latest item of the recent tax reform process in Thailand. Secondly, PIT is the third biggest tax revenue of the Thai government after value added tax and corporate income tax. Although the analysis of the impacts of tax policy over 25 years seems appropriate to the current policy context in Thailand. Horizon of dynamic applied general equilibrium models applied varies among studies in the literature. For instance, Bretschger et al. (2011) assess the effects of carbon policies on consumption, welfare, and sectoral development from 2010 to 2050. Additionally, Bhattarai (2017) uses dynamic CGE model to analyse the impact of fiscal and financial policy of the Chinese economy for 34 years from 2006 to 2040. Bhattarai et al. (2017) evaluates the effects of changes in corporate income taxes on the US economy from 2017-2050.

3. Personal Income Tax in Thailand

The Revenue Department of Thailand defines personal income tax as a direct tax levied on income of a person who is of either resident or of non-resident status in Thailand. A resident is a person who lives in Thailand for a period or aggregate period of more than 180 days in any tax calendar year and receives income from sources in Thailand as well as on a portion of income from foreign sources brought into Thailand. Non-residents on the other hand only pay tax on income from sources in Thailand.

Table 2: Taxes revenues (Unit: Million Bahts)

Tax types	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY2016
Personal Income Tax	208,368	236,483	266,203	299,067	281,008	302,491	319,116
Corporate Income Tax	454,630	574,152	544,591	592,346	570,127	566,150	604,929
Petroleum Tax	67,599	81,444	94,097	113,291	102,165	83,522	46,297
Value Added Tax	502,260	577,725	659,804	698,033	711,523	708,905	716,384
Specific Business Tax	22,989	35,714	41,057	48,773	53,127	54,175	56,249
Stamp Duty	8,757	10,313	11,180	12,741	11,692	13,572	14,498
Other Income	243	279	362	290	339	388	469
Total	1,264,845	1,516,110	1,617,293	1,764,541	1,729,980	1,729,203	1,757,942

Source: The Revenue Department, Thailand (2018). Average exchange rate during 2010-2016 was 32.29 Baht per US dollars.

As stated above, the PIT is the third biggest tax revenue of the Thai government after VAT and CIT. Table 2 illustrates that government revenue from PIT increased gradually from 2010 to 2016, except in 2014, due to the slowdown of economic growth and a reduction in PIT rate which affected the tax years 2013 and 2014. The expansion of wages and employment along with the growth in bank deposits and interest rates, however, raised the PIT revenue in the following years.

In term of PIT rates, Figure 3 shows that the PIT rate in Thailand ranged from 0 to 35 percent, which is similar to Vietnam and other countries in the ASEAN, and not much different from other developed countries. Note that, there is a huge difference between the income of taxpayers in OECD countries and Thailand. The taxpayers in Thailand should have income at least 1.2 times of GDP per capita, whilst most of the taxpayers in OECD countries have to pay tax even when their income is less than the GDP per capita (Pitidol, 2017).

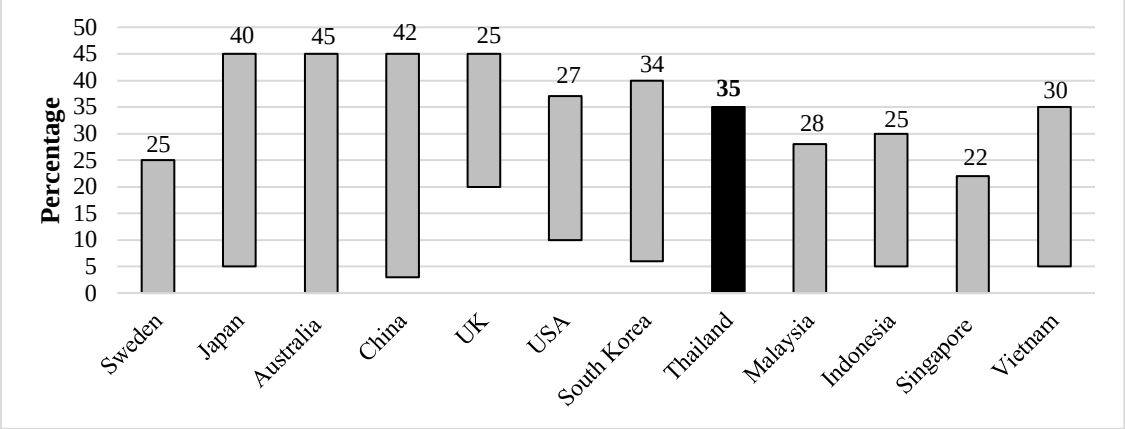

Figure 3: Highest and Lowest Personal Income Tax Rates in Selected Countries in 2018

Source: PWC (2018)

The latest tax reform in Thailand is the reduction of PIT. The Thai Cabinet agreed a proposal by the Ministry of Finance to revise the Personal Income Tax law on 19 April 2016. Then, the Department of Revenue announced this proposal to the public the next day and stated that this proposal would apply from the tax year 2017 onwards. The purpose of this tax change was not only to increase the efficiency of tax collection but also to reduce the burden on taxpayers by making it more consistent with the economic situation and living standards in the Thai society. The key reforms are concerned with (i) increasing the minimum income threshold for filing tax returns from THB 50,000 to THB 100,000 for single person and from THB 100,000 to THB 200,000 for married couples; (ii) increasing deductible expenses for some types of income such as income derived from employment and hire of service and income derived from copyrights, goodwill, patents or other IP rights from a maximum 40% or THB 60,000 to a maximum 50% or THB 100,000 (whatever is

lower); (iii) increasing the allowances for taxpayers and spouse from THB 30,000 to 60,000 and child allowance from THB 15,000 to THB 30,000 per child (Maximum child allowance is this plus THB 2,000 education support per child.); and (iv) increasing the minimum income for the last progression level (35 percent PIT rate) from THB 4,000,001 to 5,000,001 (Lorenz & Partners Co Ltd, 2016). The details of personal income tax reform are shown in Table 3.

Table 3: Progressive Personal Income Tax Rate in Thailand

Net Income (Baht)	Before Tax Year 2014	Tax Year 2014	Net Income (Baht)	Tax Year 2017
0-150,000	Exempt	Exempt	0-150,000	Exempt
150,001-300,000	10%	5%	150,001-300,000	5%
300,001-500,000	10%	10%	300,001-500,000	10%
500,001-750,000	20%	15%	500,001-750,000	15%
750,001-1,000,000	20%	20%	750,001-1,000,000	20%
1,000,001-2,000,000	30%	25%	1,000,001-2,000,000	25%
2,000,001-4,000,000	30%	30%	**2,000,001-5,000,000**	30%
Over 4,000,001	37%	35%	**Over 5,000,001**	35%

Source: Revenue Department News, Thailand (2016). Average exchange rate during 2014-2017 was 34 Baht per US dollars.

Since government revenue is the main source of government spending and tax revenue is the most significant source of government income, any changes in tax rates will affect tax revenue and spending simultaneously. Furthermore, the changes in the PIT rate also has impact on household income and welfare because this tax is a direct tax levied on a person's income. Hence, the change in PIT, especially the tax rate by income bracket, will affect households in each income threshold differently. These short and long-term impacts can be analysed using results of a dynamic CGE model with multi-households for the Thai economy constructed for this paper.

4. Dynamic CGE Model of Thailand

A general equilibrium model provides rich insight on interactions of demand and supply in the goods and factors markets in an economy. It helps to find out the optimal quantities and prices of goods and factors consistent to the general equilibrium of the economy. In addition, it includes governments that induce market outcomes by altering prices through transfers and taxes. The general equilibrium is reached when demand and supply are balanced, with zero excess demand in each market for each period. Fixed point theorems guarantee the existence of a general equilibrium. They are unique and stable when preferences and technologies are well defined.

The model in this paper is an advance from the comparative static general equilibrium analysis because it is able to capture the wide-ranging dynamic optimization aspects of income and

substitution effects of changes in relative prices regarding the changes in tax policies. To be more precise, the process of growth, investment and income redistribution can be assessed using this DCGE that is based on the constrained inter-temporal optimisation by households with standard constant elasticity of substitution (CES) preferences among commodities and intertemporal maximisation of profits by firms with CES technologies of production and constant elasticity of transformation (CET) functions for tradable commodities as applied in Bhattarai (2017) and Bhattarai et al. (2015, 2017). In addition, households in this model also make optimal choices consistent with the Ramsey problem, which states that economic agents use labour and capital to produce output and then distribute these products between consumption and capital accumulation (Heer and Maussner, 2009). Details of the model are described clearly in the next section, adopting from Bhattarai (2008) and Bhattarai et al. (2015, 2017). This model, however, differs from those previous studies in term of structure, model dimensionality and flexibility of model application to various policy issues of the Thai economy.

4.1 The Specification of the dynamic CGE Model Structure

4.1.1 Preferences of households

In this model, all Thai families are classified in one of the five quintiles and indexed by $h = 1, 2, 3, 4, and\ 5$, ranked from the lowest to the highest income levels. A composite consumption good for each household is produced from 33 domestic products and imports. Infinitely-lived households allocate lifetime income to maximise lifetime utility, which derives from the consumption of goods and services ($C_{i,t}^h$) and leisure $\left(L_t^h\right)$ as shown in equations (1) and (2), respectively.

$$LU^h = \sum_{t=0}^{\infty} \beta^t \frac{U_t^{h,1-\sigma_{lu}^h} - 1}{1-\sigma_{lu}^h} \quad \ldots. (1)$$

where LU^h is life-time utility of household h; β^t is the discount factor and shows the strength of time preference; U_t^h is its instantaneous utility function; and σ_{lu}^h is the elasticity of the intertemporal substitution for household h.

$$U\left(C_{i,t}^h, L_t^h\right) = \left[\alpha_c^h C_{i,t}^{h\ \frac{\sigma_u^h - 1}{\sigma_u^h}} + \left(1-\alpha_c^h\right) L_t^{h\ \frac{\sigma_u^h - 1}{\sigma_u^h}}\right]^{\frac{\sigma_u^h}{\sigma_u^h - 1}} \quad \ldots. (2)$$

where $C_{i,t}^h = \sum_{i=1}^{N} C_{i,t}^{h\ \frac{\sigma_i^h - 1}{\sigma_i^h}}$ is the composite consumption of good i by household h in period t; L_t^h is leisure of household h in period t; α_c^h denotes the consumption share of household h; and σ_u^h is the elasticity of substitution between consumption and leisure of household h.

The representative household in each quintile is subject to an intertemporal budget constraint where the present value of its consumption and leisure in all periods is less than or equal to the present value of infinite lifetime full income. Households pay consumption tax, value added tax, and labour income tax to the government. At the same time, they receive transfer money from the government. Therefore, it can be stated as

$$\left[\sum_{t=0}^{\infty}\mu(t)(P_{i,t}\left(1+tv_i^h\right)C_{i,t}^h+\ w_{i,t}^h(1-tw_i^h)L_t^h\right]\leq\left[\sum_{t=0}^{\infty}\left(1-tw_i^h\right)w_{i,t}^h\bar{L}_t^h+\left(1-tk_i^h\right)r_{i,t}K_{i,t}^h+TR_t^h\right] \qquad (3)$$

where $\mu(t)=\ \Pi_{s=0}^{t-1}\frac{1}{(1+r_s)}$ is a discount factor; r_s is the real interest rate on assets at time s; $P_{i,t}$ is the composite price of consumption in sector i at period t; tv_i^h is the value added tax on final consumption in sector i by household h; $w_{i,t}^h$ is the wage rate from sector i for household h; tw_i^h is the labour income tax rate paid by household h; $\bar{L}_t^h$ is labour endowment; tk_i is the tax rate on capital input; $r_{i,t}$ is the rental or return on capital in sector i; $K_{i,t}^h$ is the capital stock of sector i owned by household h; and TR_t^h is the transfer money from government to household h.

4.1.2 Production Function

The production function for each of the 33 industries in each period comprises a composite labour supply function from five quintiles of households and a sector-specific capital accumulation which generates to a value-added function for each sector. Then, the value added for each of these is summed up with intermediate inputs by a Leontief function. Gross output is distributed either to domestic supply or exported to the rest of the world for each tradeable sector by a constant elasticity of transformation (CET). Total supply of goods in an economy is defined by a constant elasticity of substitution (CES) function between domestic and imported commodities.

The production technology constraint of each firm can be expressed as

$$Y_{i,t}=\ \Omega_{i,t}\left[(1-\omega_i)K_{i,t}^{\frac{\sigma_{lk}-1}{\sigma_{lk}}}+\ \omega_i L_{i,t}^{\frac{\sigma_{lk}-1}{\sigma_{lk}}}\right]^{\frac{\sigma_{lk}}{\sigma_{lk}-1}} \qquad \ldots. (4)$$

where $Y_{i,t}$ is the gross value added of sector i; $\Omega_{i,t}$ is a shift parameter in the production function; ω_i is the share parameter of labour in production; $K_{i,t}$ is the amount of capital used in sector i; $L_{i,t}$ is the amount of labour used in sector i; and σ_{lk} is the elasticity of substitution between capital and labour.

Each firm in the model aims to maximise the present value of profits subject to production technology constraints, whereby a firm's profit is the difference between the revenue from sales and the cost of production. A profit function per unit of output can be written in dual form as:

$$\pi_{j,t}^{y} = \left[\left(\left(1-\varphi_j^{ex}\right)PD_{j,t}^{\frac{\sigma_y-1}{\sigma_y}} + \varphi_j^{ex}PE_{j,t}^{\frac{\sigma_y-1}{\sigma_y}}\right)\right]^{\frac{1}{\sigma_y}} - \theta_j^{va}PY_{j,t}^{va} - \theta_j^{do}\sum_i \alpha_{i,j}^{do}P_{i,t} \qquad \ldots. (5)$$

where $\pi_{j,t}^{y}$ is a unit profit of activity in sector j; $PD_{j,t}$ is the domestic price of good j; $PE_{j,t}$ is the export price of good j; $PY_{j,t}$ is the price of value added per unit of output in activity j; $P_{i,t}$ is the price of final goods used as intermediate goods; φ_j^{ex} is the share parameter for exports in total production; θ_j^{va} is the share of costs paid to labour and capital; θ_j^{do} is the share of cost for the domestic intermediate inputs; σ_y is an elasticity of transformation between domestic supplies and export products; and $\alpha_{i,j}^{do}$ are input-output coefficients for domestic supply of intermediate goods.

4.1.3 Labour Supply

The labour supply for each household is defined by the difference between the household labour endowment and the demand for leisure.

$$LS_t^h = \bar{L}_t^h - L_t^h \qquad \ldots. (6)$$

where LS_t^h is labour supply for each household h; $\bar{L}_t^h$ is the labour endowment; and L_t^h is leisure demand for each household.

4.1.4 Investment

The net investment for sector i in period t is given by the difference between the capital accumulation and the capital stock of period t net of depreciation, as follow:

$$I_{i,t} = K_{i,t} - (1-\delta_i)K_{i,t-1} \qquad \ldots. (7)$$

where $I_{i,t}$ is the net investment for sector i in period t; $K_{i,t}$ is the capital stock for sector i in period t; $K_{i,t-1}$ is the capital stock for sector i in period $t-1$; and δ_i is the rate of depreciation for sector i.

On the balanced growth path, where all prices are steady and all real economic variables grow at a constant rate, capital stocks must grow at a fast enough rate to sustain growth. This condition can be described as:

$$I_{i,T} = K_{i,T}(g_i + \delta_i) \qquad \ldots. (8)$$

Where T represents the terminal period of the model, and g_i is the growth rate for sector i in the steady state and is assumed constant across sectors for the benchmark economy.

4.1.5 Government Sector

The government collects revenues from value added tax (VAT), personal income tax (PIT), labour input tax and capital input tax.

$$RV_t = \sum_{h=1}^{H}\sum_{i=1}^{N} tv_i^h P_{i,t} C_{i,t}^h + \sum_{h=1}^{H}\sum_{i=1}^{N} tw_i^h w_{i,t}^h LS_t^h + \sum_{i=1}^{N} tk_i^h r_{i,t} K_{i,t}^h + \sum_{h=1}^{H} tp^h J_t^h \quad \ldots. (9)$$

where RV_t is total government revenue in period t; tv_i^h is the value added tax on final consumption by household h; tw_i^h is a tax rate on labour income of household h from sector i; tk_i^h is a composite tax rate on capital income of household h from sector i; tp^h is personal income tax rate of household h; and $J^h = \sum_{t=0}^{\infty}\left(1 - t_l^h\right) w_t^h \bar{L}_t^h + \left(1 - t_{i,k}\right) r_{i,t} K_{i,t}^h + TR_t^h$ is disposable income of household h in period t.

In this model, tax revenues can be used either to finance public consumption or to distribute to households as a real transfer, which can be stated as

$$RV_t = G_t + TR_t \quad \ldots. (10)$$

where G_t is composite consumption by the government?

4.1.6 Foreign Sector

In an open economy of applied general equilibrium models, consumers have a variety of goods to consume as total supply of goods consists of domestic and imported products. This is consistent with the Armington aggregation function, which explains that products are differentiated across countries of production. Therefore, intra-industry trade can happen because domestic and foreign produced products within a product category are qualitatively different and are not fully substitutes. This can be stated as follows:

$$A_{i,t} = \Phi_{i,t}\left(\gamma_i^d D_{i,t}^{\frac{\sigma_m - 1}{\sigma_m}} + \gamma_i^{im} M_{i,t}^{\frac{\sigma_m - 1}{\sigma_m}}\right)^{\frac{\sigma_m}{\sigma_m - 1}} \quad \ldots. (11)$$

where $A_{i,t}$ is the Armington CES aggregate of domestic supplies; $D_{i,t}$ is the supply of domestic goods for each sector; $M_{i,t}$ is import supplies for each sector; γ_i^d is the share of good i domestic production; γ_i^{im} is the share of good i in imports; σ_m is the elasticity of substitution between domestic products and imports from the rest of the world; and $\Phi_{i,t}$ is the shift parameter of the aggregate supply function.

Therefore, the total supply value in the economy must equal to the aggregate values of domestic products and imports.

$$PA_{i,t}A_{i,t} = PD_{i,t}D_{i,t} + PM_{i,t}M_{i,t} \quad \text{…. (12)}$$

where $PA_{i,t}$ is the gross price of composite commodity i; $PD_{i,t}$ is the gross price of domestic supplies and tariffs; and $PM_{i,t}$ is the gross price of imported products.

Apart from domestic sales, the remaining part of gross output is exported to the rest of the world, according to a CET function, as stated below.

$$GI_{i,t} = \phi_{i,t}\left((1-\varphi_i^{ex})D_{i,t}^{\frac{\sigma_y-1}{\sigma_y}} + \varphi_i^{ex}E_{i,t}^{\frac{\sigma_y-1}{\sigma_y}}\right)^{\frac{\sigma_y}{\sigma_y-1}} \quad \text{…. (13)}$$

where $GI_{i,t}$ is output in term of gross of intermediate inputs; $E_{i,t}$ is exports; φ_i^{ex} is the share of export goods; σ_y is the elasticity of transformation in total supply; and $\phi_{i,t}$ is the shift parameter in the transformation function.

Therefore, the total supply's value in the economy must be equal to the aggregate of the values of domestic products and exports.

$$P_{i,t}GI_{i,t} = PD_{i,t}D_{i,t} + PE_{i,t}E_{i,t} \quad \text{…. (14)}$$

where $PD_{i,t}$ is the gross price of domestic supplies; and $PE_{i,t}$ is the gross price of exported products and export taxes.

4.1.7 General Equilibrium in the Economy

General equilibrium in the economy occurs when the demand and supply sides balance each other in the goods, labour and capital markets, which can be stated as below.

Goods market clearing at time t:

$$A_{i,t} = C_{i,t} + G_{i,t} + I_{i,t} + \sum_j DI_{i,j,t} + \sum_j MI_{i,j,t} \quad \text{…. (15)}$$

where $C_{i,t}$ is composite consumption of domestic products and imports by households; $G_{i,t}$ is composite consumption by the government; $I_{i,t}$ is investment; $DI_{i,j,t}$ is demand for domestic intermediate input; and $MI_{i,j,t}$ is demand for imported intermediate inputs.

Labour market clearing at time t:

$$\bar{L}_t^h = LS_t^h + L_t^h;\ LS_t^h = \sum_{h=1}^{H} LS_{i,t}^h \quad \text{…. (16)}$$

where $\bar{L}_t^h$ is the labour endowment; LS_t^h is labour supply for each household h; and L_t^h is the leisure demand for each household.

Capital market clearing at time t:

$$K_t = \sum_{i=1}^{N} K_{i,t} = \sum_{i=1}^{N}\left[(1-\delta_i)K_{i,t-1} + I_{i,t}\right] \quad \text{…. (17)}$$

This is a perpetual inventory method of capital accumulation.

4.2 Construction of the Micro-Consistent Dataset for the Thai Dynamic CGE Model

This model uses the economic data from the Input-Output Table obtained from the Organisation for Economic Co-operation and Development (OECD, 2018) to construct micro-consistent data for Thailand. These are the latest available data consist of 33 production sectors, as shown in Table 4.

Table 4: Production Sectors in the Thai Dynamic CGE

Sector	Code	Sector	Code
1. agriculture, hunting, forestry and fishing	Agric	18. manufacturing nec; recycling	Manufac
2. mining and quarrying	Mining	19. electricity, gas and water supply	Electric
3. food products, beverages and tobacco	Food	20. construction	Const
4. textiles, textile products, leather and footwear	Textile	21. wholesale and retail trade; repairs	Wholsal
5. wood and products of wood and cork	Wood	22. hotels and restaurants	Hotel
6. pulp, paper, paper products, printing and publishing	Pulp	23. transport and storage	Transpt
7. coke, refined petroleum products and nuclear fuel	Coke	24. post and telecommunications	PostTel
8. chemicals and chemical products	Chemical	25. financial intermediation	Finance
9. rubber and plastics products	Rubber	26. real estate activities	RealEst
10. other non-metallic mineral products	OthNonme	27. renting of machinery and equipment	RentMac
11. basic metals	BasMetal	28. computer and related activities	ComRlAct
12. fabricated metal products	Fabric	29. R&D and other business activities	RnD
13. machinery and equipment, nec	Machine	30. public administration and defence; compulsory social security	PubAdmin
14. computer, electronic and optical equipment	Comput	31. education	Edu
15. electrical machinery and apparatus, nec	Elecal	32. health and social work	Health
16. motor vehicles, trailers and semi-trailers	Motor	33. other community, social and personal services	OthCommu
17. other transport equipment	OthTran		

Source: Organisation for Economic Co-operation and Development (2018)

In addition, this model utilised a share of household current income by five quintile groups from the National Statistical Office (2012) of Thailand to calculate the income share of each household. Then these data were used for calibration of the parameters of the model as shown in Appendix A, B, C and D. After that, the general algebraic modelling system with the MPSGE and Path algorithm (GAMS, 2017) were applied to compute the model in order to evaluate the impacts of tax policy on Thai economy over a horizon of 25 years from 2011 to 2036.

The values of elasticity used in this study are based on values widely accepted in the literature, whereas other values of parameters were obtained from the World Development Indicator (World Bank, 2017). Income tax rate and value added tax data were collected from the Revenue Department (2018), Thailand as shown in Table 5.

Table 5: Key Parameters of the DCGE Model of Thailand

Parameters	**Values**
Elasticity of substitution in consumption and leisure (σ_u^h)	2.95
Elasticity of substitution in intertemporal choices (σ_{lu}^h)	0.99
Elasticity of substitution between capital and labour (σ_{lk})	1.5
VAT rate (tv_i)	0.07
Personal Income Tax rate (tp^h)	0, 0.1.0.2, 0.3, 0.37
Growth rate of output $(g_{i,t})$	0.06
Rate of depreciation in section i $(\delta_{i,t})$	0.04
Interest rate (r)	0.10

Table 6: Progressive Personal Income Tax Rate in Thailand classified by each quintile

Quintile	Net Income (Baht)	Before Tax Year 2014	Average rate (Bench mark)	Net Income (Baht)	Tax Year 2017	Average rate (Counter factual)
H1	0-150,000	Exempt	**0%**	0-150,000	Exempt	**0%**
H2	150,001-300,000	10%	**10%**	150,001-300,000	5%	**7.5%**
	300,001-500,000	10%		300,001-500,000	10%	
H3	500,001-750,000	20%	**20%**	500,001-750,000	15%	**17.5%**
	750,001-1,000,000	20%		750,001-1,000,000	20%	
H4	1,000,001-2,000,000	30%	**30%**	1,000,001-2,000,000	25%	**27.5%**
	2,000,001-4,000,000	30%		2,000,001-5,000,000	30%	
H5	Over 4,000,001	37%	**37%**	Over 5,000,001	35%	**35%**

Source: The Revenue Department, Thailand (2018); Average exchange rate during 2014-2017 was 34 Baht per US dollars.

As aforementioned that the main objective of this study is to examine the impact of the reduction of PIT rate on the level and distribution of household welfare and consumption in each quintile over time, hence, we classified each net income threshold into five groups of households as shown in Table 6. Households in each quintile were represented by H1, H2, H3, H4 and H5. Then, we calculated the average PIT rate of each quintile. These average 2014 PIT rates in each quintile will

be used as benchmark PIT rates, while the average 2017 PIT rates in each quintile will used as counterfactual scenarios. We started our analysis by calibrating benchmark scenario by simulating the calibrated model by using new average PIT rates in the last column of Table 6 to evaluate the effects of PIT reduction on the Thai economy in the short and the long-term.

5. Results of the Thai DCGE with Personal Income Tax Reform

The results of the Thai DCGE model are used to assess the impacts of PIT reform, reductions of PIT rates by income quintiles as above, on distribution and time profiles of welfare of households from consumption in each quintile. They also show impacts on macroeconomic variables such as GDP, employment, investment and the microeconomic variables including sectoral production. A careful study of these impacts can provide an indication on likely effects of alternative PIT tax rates, and thus serve a as a guideline to policymakers who decide these rates.

5.1 Impacts of PIT Reform on Lifetime Utility and Consumption of Households

The result in Table 7 reveals that tax reform affects the wellbeing of each household's quintile differently, and such effects increase gradually when the economy evolves over time. In aggregate utility levels in 2036 will be about 4.29 times the current figure, with similar distribution patterns of utility in 2011 in the benchmark. After the reforms, the utility levels of households in 2036 will be 4.34 times greater than that in 2011. This indicates that the reform by slight cut in PIT rates as above has slightly improved the lifetime wellbeing of the families in Thailand. The finding also shows that this tax reform has the most favourable effect on the poorest households (H1) as their share of utility has increased from 14.66 percent in 2011 to 15.93 percent in 2036. In addition, this reform also enhances the utility levels of families in quintiles 2 and 3. Households in the fourth and fifth quintiles were worse off from in the short run but the reform improve utility levels households in the 4th quintile. Only the richest quintile seem to pay for the gains to other quintiles under the reformed scenario. This is very much in spirit of the motivations for such reform. In absolute terms the redistribution effects in the long-run will improve the utility level of households in quintiles 4 and 5 as well with the reforms.

The paths of utility level for the richest (H5) and the poorest (H1) households in Figure 4 show clearly that this tax reform benefits the poorest households throughout the study period. At the same time, the richest households are worse off but the magnitude of loss becomes smaller over time. This finding is consistent with the purpose of the tax reform proposal that aimed to reduce the burden of taxpayers particularly in the first three taxpayer brackets so that they had more disposable income for consumption and investment.

Table 7: Redistribution of Households' Lifetime utility before and after Tax Reforms, 2011 and 2036 (Unit: Million US Dollars)

Quintiles	Households utility in 2011			Households utility in 2036		
	Benchmark	Reformed system	Percentage change	Benchmark	Reformed system	Percentage change
H1	19,165.71	21,975.80	14.66	82,256.73	95,360.32	15.93
H2	29,961.32	33,085.94	10.43	128,590.12	143,611.87	11.68
H3	39,444.38	41,383.54	4.92	169,290.18	179,666.02	6.13
H4	53,264.75	52,741.85	-0.98	228,605.41	229,029.74	0.19
H5	126,457.33	119,353.72	-5.62	542,738.51	518,365.61	-4.49

Source: Author's calculations based on the Thai DCGE model

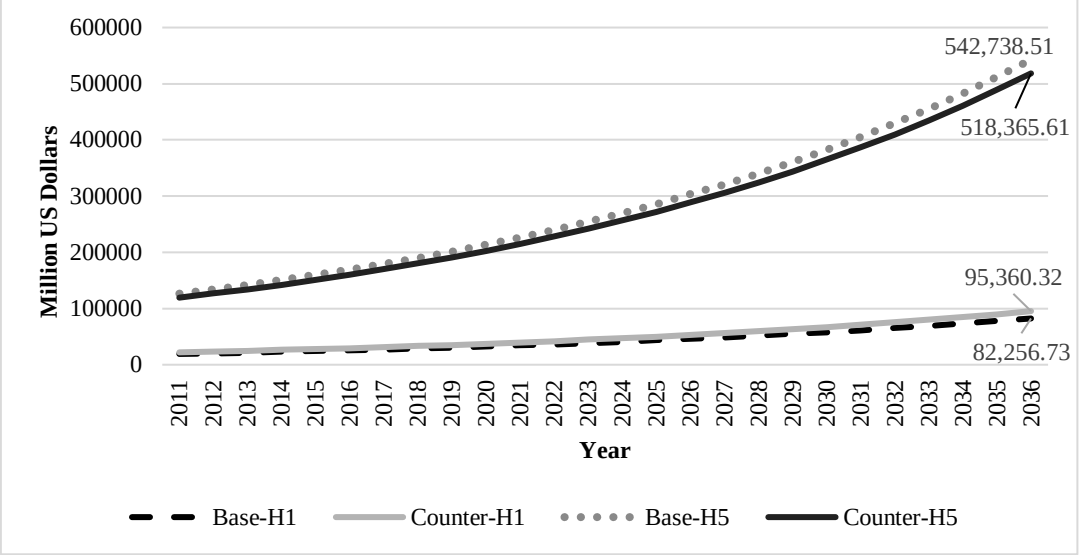

Figure 4: The path of money metric utility levels of the richest (H5) and the poorest (H1) households

Source: Author's calculations based on the Thai DCGE model

Table 8: Redistribution of Households Consumption before and after Tax Reforms, 2011 and 2036 (Unit: Million US Dollars)

Quintiles	Households consumption in 2011			Households consumption in 2036		
	Benchmark	Reformed system	Percentage change	Benchmark	Reformed system	Percentage change
H1	12,983.50	14,675.43	13.03	55,723.49	64,205.12	15.22
H2	20,973.34	23,415.91	11.65	90,014.87	102,386.96	13.74
H3	28,563.69	30,353.00	6.26	122,591.68	132,664.27	8.22
H4	39,949.22	40,141.54	0.48	171,456.89	175,368.67	2.28
H5	97,276.35	92,826.76	-4.57	417,497.53	405,419.90	-2.89

Source: Author's calculations based on the Thai DCGE model

The reduction of personal income tax rate not only raises the money metric utility of households, but also increases household consumption as shown in Table 8. The consumption level of each household category rises after tax reform except households in quintile 5. In the benchmark case, the benefits of reform go more to the poorest households as their consumption increases more than that of any others quintiles. That is followed by households in quintiles 2 and 3. This policy yields greater favourable effect to households in all quintiles in the long-run because the magnitude of changes in the long-run are higher than the percentage change of consumption in the short-run. Although the richest households (H5) seem to be worse off after the reform as evidenced by a reduction of consumption by 2.29 percent, that reduction in consumption is still less than the reduction of consumption in the short-run. This result is in line with the utility effect explained earlier from Table 7. In addition, this result accords with the findings by Bhattarai (2017), who reveals that tax reforms enhanced household consumption and household welfare in China. Radulescu and Stimmelmayr (2010) have also concluded that the 2008 tax reform in Germany raises the consumption level in the long-run.

5.2 Impacts of PIT Reform on Macroeconomic Variables

There are significant impacts on macroeconomic variables due to the reductions in personal income tax rates as shown in the last column of Table 6. This reform increases household real disposable income so that private consumption rises relative to the benchmark case, initially by 0.83 percent and ultimately to 2.65 percent in 2036. This increase in private consumption also boosts investment and imports. Consequently, it leads to an expansion in labour market, capital stock and export

products. Finally, GDP increases gradually, from 1.05 percent in 2011 to 2.94 percent in 2036, as shown in Table 9. These findings are consistent with the results of Bhattarai et al. (2017), who concluded that a reduction in the corporate income tax on the US economy has significant positive impacts on output, investment, capital formation, and employment.

Table 9: Percentage Changes in Key Macroeconomics Variables in Response to a Decrease in Personal Income Tax Rate

	2011	2016	2021	2026	2031	2036
GDP	1.0563	1.5533	1.9568	2.3129	2.6358	2.9411
Investment	1.4206	1.9482	2.3619	2.7475	3.1265	3.5263
Employment	2.4781	2.6633	2.7498	2.8304	2.9095	2.9929
Capital stock	0.0000	0.6578	1.2343	1.7416	2.1995	2.6291
Consumption	0.8343	1.3358	1.7542	2.1077	2.4054	2.6550
Export	0.9942	1.3787	1.7512	2.0810	2.3816	2.6680
Import	1.0393	1.4412	1.8307	2.1754	2.4896	2.7889

Source: Authors' calculations based on the Thai DCGE model

Kang (2007) applies a standard small open economy model with imperfect substitution between domestic goods and exports to study the impact of tariff-tax reform on welfare in the Asia-Pacific Economic Cooperation (APEC). He finds that the tariff reduction promotes domestic production efficiency by the same proportion and consumption tax replacement produces higher welfare gains than labour tax replacement. Welfare gains are more responsive to trade elasticities which means higher trade elasticities generate more welfare gains to consumers.

5.3 Impacts of PIT Reform on Output, Employment and Capital Stock by Sector

The above mention reduction of personal income tax rates affects economic activities unevenly across various industries. Table 9 shows that every sector grows faster with PIT reforms than without them, especially the output, employment and the capital stock. The most positive effects are observed in food products, textiles, hotel, finance and the wholesale sectors. Growth rates in these industries derive mainly from the expansion of capital stock, employment and investment in these sectors. In addition, there are significant increases in investment in numerous manufacturing industries including basic metals, electrical machinery, and motors sectors. This is consistent with the growth of the Thai economy and the expansion of household income. Despite the investment in public administration and education sectors increasing after the reforms, this could not compensate for the decline of capital stock, employment and output in these sectors in the long-run as more resources are diverted to production than service sectors by this reform. This might have been caused also by a decrease in real government consumption.

Table 10: Percentage Changes by Sector in Response to a Decrease in Personal Income Tax Rate

	Output		Employment		Investment		Capital Stock	
Year	**2011**	**2036**	**2011**	**2036**	**2011**	**2036**	**2011**	**2036**
Period	**1**	**25**	**1**	**25**	**1**	**25**	**1**	**25**
Agric	1.0921	4.0840	4.0444	4.9949	6.7820	4.6288	0.0000	3.5618
Mining	1.1398	2.9179	3.4746	3.8564	1.3431	3.2865	0.0000	2.4388
Food	1.1195	3.3272	2.8640	4.0473	0.0010	3.5287	0.0000	2.6271
Textile	1.2330	3.3509	3.3407	4.1946	1.5300	3.6612	0.0000	2.7723
Wood	0.9824	2.2722	2.6738	3.1778	-2.7878	2.4994	0.0000	1.7694
Pulp	0.9577	2.8959	3.4736	3.7537	1.7624	3.1366	0.0000	2.3375
Coke	1.0631	2.8709	2.6989	3.6923	-1.7615	3.1334	0.0000	2.2769
Chemical	1.1184	3.0609	3.3063	3.7829	0.8741	3.1957	0.0000	2.3663
Rubber	1.0841	2.9425	2.8407	3.6806	-0.5852	3.1056	0.0000	2.2654
OthNonme	0.7892	1.8478	2.9938	2.9237	-1.1887	2.1347	0.0000	1.5188
BasMetal	0.9749	2.2649	3.0111	3.3520	-1.1451	2.6841	0.0000	1.9413
Fabric	0.8665	2.2265	3.0381	3.3077	-0.5741	2.6071	0.0000	1.8976
Machine	0.7109	1.6764	2.8551	2.8781	-1.6806	2.0763	0.0000	1.4739
Comput	0.9945	2.5299	3.1065	3.5698	-0.1486	2.9391	0.0000	2.1561
Elecal	0.7816	2.0543	3.2166	3.2536	-0.0192	2.5217	0.0000	1.8442
Motor	0.7724	1.7111	2.4838	2.8660	-3.7555	2.1060	0.0000	1.4619
OthTran	0.8856	1.7903	2.9588	3.4714	-1.8285	2.8638	0.0000	2.0590
Manufac	1.1797	3.0047	2.9545	3.7699	-0.9915	3.1944	0.0000	2.3535
Electric	1.1729	3.1639	3.0281	4.0274	-0.2882	3.5486	0.0000	2.6074
Const	0.2426	0.4361	0.6605	1.3046	-11.0534	0.2639	0.0000	-0.0781
Wholsal	1.0709	3.4915	3.6737	4.3068	3.7349	3.8188	0.0000	2.8830
Hotel	1.1257	3.3122	3.2115	4.0928	1.0822	3.5489	0.0000	2.6720
Transpt	1.1420	2.8149	2.9060	3.6139	-1.6304	3.0186	0.0000	2.1996
PostTel	1.1319	3.7739	3.7862	4.7016	4.8014	4.3136	0.0000	3.2724
Finance	1.3778	3.8439	3.5915	4.7054	3.7368	4.3519	0.0000	3.2763
RealEst	0.6553	4.1479	3.7464	5.3038	6.3973	5.0194	0.0000	3.8664
RentMac	1.3403	2.6715	1.8298	2.9060	-13.9105	2.4934	0.0000	1.5014
ComRlAct	0.7733	1.7079	0.8407	1.7819	-23.6347	1.2954	0.0000	0.3926
RnD	1.1099	2.8284	2.5043	3.5709	-3.7105	3.0732	0.0000	2.1572
PubAdmin	1.1932	0.9748	1.2883	1.0766	-18.9718	0.1790	0.0000	-0.3030
Edu	0.3399	0.2395	0.3530	0.2897	-27.9075	-0.5732	0.0000	-1.0792
Health	0.3935	0.9207	0.7569	1.5221	-19.7875	0.8085	0.0000	0.1363
OthCommu	1.3021	3.1236	2.5261	3.7619	-3.9958	3.3088	0.0000	2.3456

Source: Author's calculations based on the Thai DCGE model

5.4 Impacts of PIT Reform on Government Revenue

The reform of the personal income tax rate of every quintile has a major impact on revenues as shown in Table 11. Government revenue from PIT decreases year by year in both the short and long-term around 5.5 percent. However, higher economic activities from consumption, production, investment and trade stimulate revenues from other taxes, particularly labour input tax and value

added tax. Revenue from capital input tax increases only slightly in the short-term. Conversely, in the long-term this revenue exceeds the revenue from value added tax as the Thai economy will become more capital intensive. Although, PIT reform changes revenues in each tax type, the total revenue of the government remains at the same level. This means growth in other tax revenues can compensate for the drop in personal income tax revenue, equal yield feature PIT reforms.

Table 11: Percentage Change of Government Revenue in Response to a Decrease in Personal Income Tax Rate

Revenue	**2011**	**2016**	**2021**	**2026**	**2031**	**2036**
Labour input tax	1.0407	1.2455	1.2623	1.2922	1.3414	1.4186
Capital input tax	0.0155	0.3173	0.4754	0.6270	0.7826	0.9550
Personal income tax	-5.4637	-5.4108	-5.4710	-5.5099	-5.5249	-5.5110
Value added tax	0.1290	0.3080	0.4008	0.4810	0.5513	0.6146
Total revenue	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Source: Author's calculations based on the Thai DCGE model

5.5 Impacts of Alternative Tax Policies on Macroeconomic Variable

In addition to the reduction of the PIT rate, we also simulated five alternative tax policies that the government can use to achieve target policy. These five scenarios include; (i) apply only 10 percent VAT rate, (ii) apply only 5 percent capital input tax, (iii) apply only 5 percent labour input tax, (iv) apply both PIT reform and 10 percent VAT rate, and (v) apply all taxes.

The effect of macroeconomic variables from alternative tax policies are presented in Figures 5 to 9. As we can see from Figures 5 to 7, the alternative tax policies that government can use to stimulate GDP, investment, and capital stock include labour input tax, which has the highest magnitude of percentage changes in both the short and long-term. On the other hand, the policymaker should avoid applying capital input tax because this tax leads to decreases in GDP, investment and capital stock.

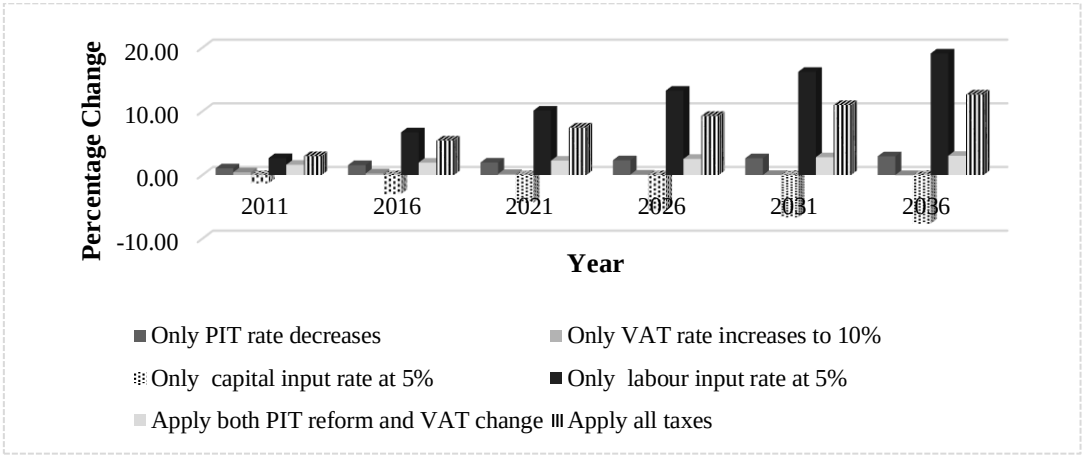

Figure 5: Percentage Change of GDP in Response to Alternative Tax Reform

Source: Author's calculations based on the Thai DCGE model

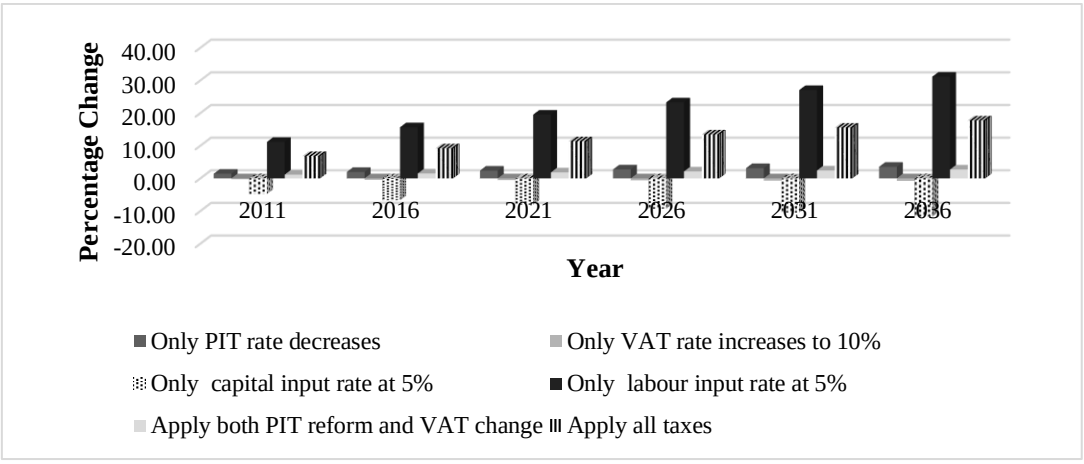

Figure 6: Percentage Change of Investment in Response to Alternative Tax Reform

Source: Author's calculations based on the Thai DCGE model

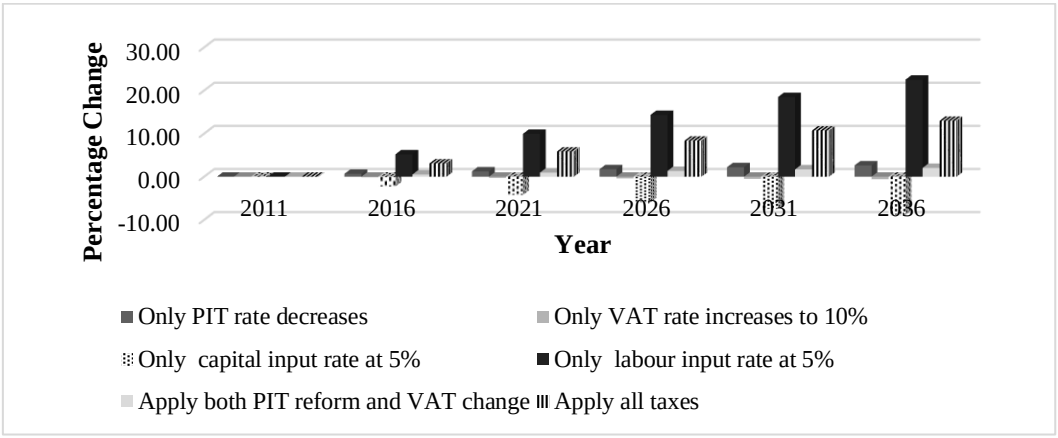

Figure 7: Percentage Change of Capital Stock in Response to Alternative Tax Reform

Source: Author's calculations based on the Thai DCGE model

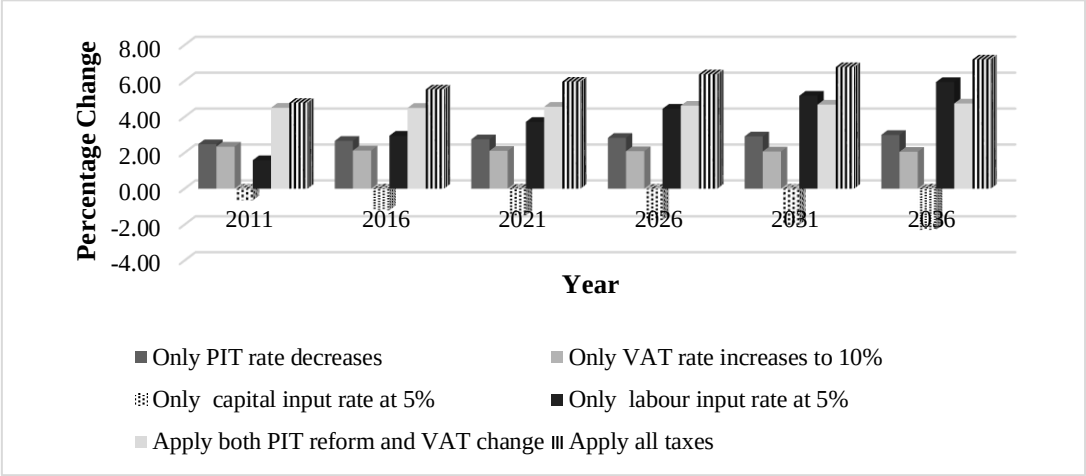

Figure 8: Percentage Change of Employment in Response to Alternative Tax Reform

Source: Author's calculations based on the Thai DCGE model

Another interesting conclusion can be made from the simulation results where all tax policies were applied. This policy would effectively increase employment both in the short and long-term in Thailand, as shown in Figure 8. In particular, employment increases from 4 percent in 2011 to 7.2 percent in 2036. Instead of applying all taxes, the policymaker would implement PIT reform and a VAT rate policy in the short-term while in the long-term applying labour input tax. As illustrated in Figure 8 that in short-term PIT reform and VAT rate policy stimulate higher employment than labour input tax, but conversely not in the long-term.

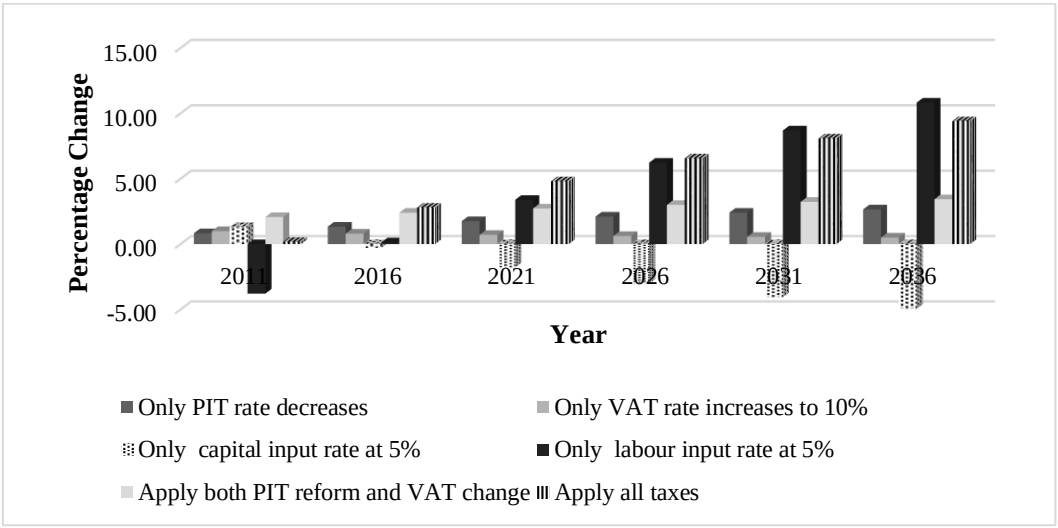

Figure 9: Percentage Change of Consumption in Response to Alternative Tax Reform

Source: Author's calculations based on the Thai DCGE model

It is noteworthy that labour input tax should be implemented with awareness to promote consumption because this policy decreases consumption at the beginning of the reform, before

becoming more effective afterwards, as it enhances consumption more than any other alternative tax policies. This is the reverse of the impact of applying capital input tax, as illustrated in Figure 9, this policy boosts consumption in 2011, before the positive effects gradually decline and eventually become negative in long-term.

Our focus so far has been in explaining consequence fiscal policy reforms in the long run growth and sectoral performance and household choices based on greater degree of micro-foundation in analysis than usual RBC models for emerging economies as presented in Ghate et al. (2016). We agree to Magazzino et al. (2019) that multinational coordination on tax and spending policies and domestic reforms considered here will be more effective in achieving stability in the short run and higher growth rate in the long run. Similarly, elasticity parameters need to be further investigated in the context of tax-tariff reforms as indicated in Kang (2007). While Hayford (2017 showed that tax cuts and increased spending are expansionary, we are able to illustrate which specific industries or individuals benefit or lose as economy-wide income and substitution effects settle down after changes in the tax system of the Thai economy.

6. Conclusion

This paper illustrates how a dynamic CGE model can be used to evaluate the impacts of recent reforms in the PIT in Thailand. The model was calibrated to the most recent micro-consistent dataset from the input-output table obtained from the OECD (2018) and the household level consumption and income data from National Statistical Office of Thailand for 2017.

The results of the Thai DCGE reveal that the PIT reform has been helpful in reducing the inequality in the distribution of income and consumption not only in the short-term but also will do so in the long-term. In addition, this reform boosts private consumption as households' disposable income increase. Consequently, investments, employment, capital stock, exports, imports and GDP rise. These results are comparable to Bhattarai (2017) for China and Bhattarai et al. (2017) for the US and Radulescu and Stimmelmayr (2010) for Germany. In terms of sectoral effects, the reduction of PIT rate affects economic activities unevenly across various industries. Findings show that every sector grows faster with the reforms in the personal income tax rates than without such reforms, except in public administration and education sectors where the output, employment and capital stock slightly decrease in the long-term implying more allocation of resources in production than service industries.

While the government revenue from PIT decreases year by year in both the short and long-term due to the reduction in PIT rates, expansion in economic activities from consumption, production, investment and trade stimulates revenues from other taxes, particularly labour input tax and value added tax. These additional increase in the amount of review from other taxes more than compensates for the drop in the revenue from personal income tax, so the cut in the PIT does not reduce the total revenue of the government. Thus, the PIT tax rate pays for itself. In the meanwhile, the government can increase their revenue even from the lower personal income tax rates by increasing the tax base and inducting people into the tax system because in the tax year 2014, only 15 percent of Thais filled in the PIT forms and only 6 percent paid the PIT from their income. This is possible as more than 28 million people were not included in the tax system (see Pawin (2016) cited in Pitidol (2017)). In addition, the government can provide incentives to discourage tax avoidance and informality to increase efficiency of tax collection and to strengthen enforcements against tax evasion. Thus there are opportunities to increase public revenue. Increase revenue can be used to reduce disparity in society because the government can use that to finance public spending that benefit low-income families through cash transfers, improved infrastructure, enhanced education and healthcare services.

Although findings of this study show a positive impact from the reduction in personal income tax rate, a reader or policymaker still has to consider some limitations of this study. Due to lack of the data, this study applied some parameter values on elasticities from the existing studies that might be better if they were estimated from the time series or cross section data from the Thai economy. On the other hand, this is the first paper that presents an analysis on the economic impacts of PIT reforms evaluating much complicated economy-wide income and substitution effects from the dynamic CGE model over 25 periods for the Thai economy. The model could be further applied to other tax policies or even to assess implications of changes in other fiscal or financial policies such as pensions or health care policy, with some modifications in it. Another possibility for further study is to assess how different abilities and productivities of skilled and unskilled labours could widen the income inequality and what should be done to solve such problems.

7. References

Angyridis, C., 2006. Optimal Capital Income Taxation in an Asymmetric Small Open Economy. *The Journal of Economic Asymmetries*, *3*(1), pp.87-101

Bhattarai, K. (2008) Part-II Dynamic General Equilibrium Tax Model of the UK Economy. *Static*

and Dynamic Applied General Equilibrium Tax and Trade Policy Models of the UK Economy. New Delhi: Serials Publications, 67-110.

Bhattarai, K., Haughton, J. & Tuerck, D. G. (2015) Fiscal policy, growth and income distribution in the UK. *Applied Economics and Finance*, 2(3), 20-36.

Bhattarai, K. (2017) Dynamic CGE Model of the Chinese Economy for Fiscal and Financial Policy Analysis. *China-USA Business Review*, 16(4), 141-164.

Bhattarai, K., Haughton, J., Head, M. & Tuerck, D. G. (2017) Simulating Corporate Income Tax Reform Proposals with a Dynamic CGE Model. *International Journal of Economics and Finance*, 9(5), 20.

Bhattarai, K., Bachman, P., Conte, F., Haughton, J., Head, M. & Tuerck, D. G. (2018) Tax plan debates in the US presidential election: A dynamic CGE analysis of growth and redistribution trade-offs. *Economic Modelling*, 68, 529-542.

Bretschger, L., Ramer, R. & Schwark, F. (2011) Growth effects of carbon policies: applying a fully dynamic CGE model with heterogeneous capital. *Resource and Energy Economics*, 33(4), 963-980.

Carvalho, E. and Lian, Z., 2010. The Impact of Goods and Services Tax on the Pattern of Canadian Consumer Spending and Saving. The Journal of Economic Asymmetries, 7(1), pp.123-136.

Carter, A. & Matthews, S. (2012) How tax can reduce inequality. OECD Observer, No290-291, Q1-Q2, Internet edition. Available online: http://oecdobserver.org/news/fullstory.php/aid/3782/How_tax_can_reduce_inequality.html [Accessed date 30/4/2018].

Claus, I. (2013) Is the value added tax a useful macroeconomic stabilization instrument?. *Economic Modelling*, 30, 366-374.

Field, A., J. & Wongwatanasin, U. (2007) Tax policies' impact on output, trade and income in Thailand. *Journal of Policy Modeling*, *29*(3), 361-380.

Ghate, C., Gopalakrishnan, P. and Tarafdar, S., 2016. Fiscal policy in an emerging market business cycle model. *The Journal of Economic Asymmetries*, *14*, pp.52-77.

GAMS Corporation (2017) *GAMS/MPSGE Manual*. www.gams.com.

Giesecke, J. A. & Nhi, T. H. (2010) Modelling value-added tax in the presence of multi-production and differentiated exemptions. *Journal of Asian Economics*, 21(2), 156-173.

Hayford, M.D., 2017. The impact of temporary tax changes on consumption: 2000–2015. *The Journal of Economic Asymmetries*, *15*, pp.32-38.

Heer, B. & Maussner, A. (2009) *Dynamic general equilibrium modeling: computational methods*

and applications. Springer Science & Business Media.

Kang, K., 2007. Asymmetries and Tariff-Tax Reforms in the Asia-Pacific Economic Cooperation: A Quantitative Assessment. *The Journal of Economic Asymmetries*, *4*(1), pp.89-97.

Lorenz & Partners Co Ltd. (2016) *Personal Income Tax in Thailand-An Update*. Available online: https://www.lexology.com/library/detail.aspx?g=ac09626f-9500-427b-8591-26e023baad77 [Accessed 19/1/2018].

Magazzino, C., Brady, G.L. and Forte, F., 2019. A panel data analysis of the fiscal sustainability of G-7 countries. *The Journal of Economic Asymmetries*, *20*, p.e00127.

National Statistical Office (2012) *The 2011 Household Socio-Economic Survey Whole Kingdom*. Available online: http://www.nso.go.th/sites/2014en/Survey/social/household/household/2011/whole%20kingdom/6.Full%20Report.pdf [Accessed 19/1/2018].

Organisation for Economic Co-operation and Development: OECD (2018) *Input-Output Tables 2011.* Available online: https://stats.oecd.org/Index.aspx?DataSetCode=IOTS [Accessed 1/4/2018].

Pitidol, T. (2017). *Changing Thailand's Future through Tax Reform: A Synthesis from Thailand's Policy Community on Taxation*

Ponjan, P. & Thirawat, N. (2016) Impacts of Thailand's tourism tax cut: A CGE analysis. *Annals of Tourism Research,* 61, 45-62.

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.

PWC (2018) *Worldwide Tax Summarises Online*. Available online: http://taxsummaries.pwc.com/ID/tax-summaries-home [Accessed 19/6/2018].

Radulescu, D. & Stimmelmayr, M. (2010) The impact of the 2008 German corporate tax reform: A dynamic CGE analysis. *Economic Modelling*, 27(1), 454-467.

Revenue Department News (2016) Personal Income Tax Reform. *Revenue Department News*. Available online: http://www.rd.go.th/publish/fileadmin/user_upload/news/news15_2559.pdf [Accessed 19/1/2018].

Tang, L., Shi, J., Yu, L. & Bao, Q. (2017) Economic and environmental influences of coal resource tax in China: A dynamic computable general equilibrium approach. *Resources, Conservation and Recycling*, 117, 34-44.

The Revenue Department (2018) *Annual Report, 2010-2016*. Available online: http://www.rd.go.th/publish/24602.0.html. [Accessed 1/4/2018].

Vanitcharearnthum, V. (2017) Top income shares and inequality: Evidences from Thailand. *Kasetsart Journal of Social Sciences*. Available online: http://dx.doi.org/10.1016/j.kjss.2017.07.010 [Accessed 18/1/2018].

Wattanakuljarus, A. & Coxhead, I. (2008) Is tourism-based development good for the poor?: A general equilibrium analysis for Thailand. *Journal of Policy Modeling*, 30(6), 929-955.

Wendner, R. (2001) An applied dynamic general equilibrium model of environmental tax reforms and pension policy. *Journal of Policy Modeling*, 23(1), 25-50.

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.

Winyuchakrit, P., Limmeechokchai, B., Matsuoka, Y., Gomi, K., Kainuma, M., Fujino, J. & Suda, M. (2011) Thailand's low-carbon scenario 2030: Analyses of demand side CO 2 mitigation options. *Energy for Sustainable Development*, *15*(4), 460-466.

World Bank. (2017) *World Development Indicators*. Available online: http://databank.worldbank.org/data/reports.aspx?source=2&country=THA. [Accessed 18/1/2018].

Xu, X., Xu, X., Chen, Q. & Che, Y. (2015) The impact on regional “resource curse” by coal resource tax reform in China-A dynamic CGE appraisal. *Resources policy*, 45, 277-289.

Appendix A: Thailand's Thirty-three Sectors Input-Output Table (Unit: Million US Dollars)

	1.Agric	2.Mining	3.Food	4.Textile	5.Wood	6.Pulp	7.Coke	8.Chemical	9.Rubber	10.OthNonme	11.BasMetal	12.Fabric	13.Machine
1.Agric	5933.4000	8.4000	23242.9000	1007.9000	1132.0000	224.0000	0.3000	610.7000	5040.7000	33.2000	2.0000	1.0000	0.5000
2.Mining	12.7000	805.1000	73.8000	8.6000	2.5000	62.5000	26625.9000	1206.9000	19.9000	2926.0000	1098.4000	29.1000	80.3000
3.Food	5564.7000	0.6000	11959.3000	347.4000	4.5000	90.1000	10.5000	458.6000	22.1000	36.4000	2.1000	1.5000	5.6000
4.Textile	152.4000	1.6000	59.8000	17429.2000	115.4000	28.5000	2.4000	604.5000	514.3000	49.9000	10.3000	8.5000	48.5000
5.Wood	138.2000	4.9000	18.2000	7.5000	2228.2000	5.3000	1.1000	51.4000	13.9000	28.7000	6.2000	70.2000	82.3000
6.Pulp	18.1000	3.3000	159.2000	89.2000	30.2000	2399.8000	3.4000	157.0000	25.8000	51.1000	18.2000	13.4000	57.4000
7.Coke	2923.7000	1593.1000	662.4000	295.8000	65.2000	130.2000	1170.2000	1047.8000	341.6000	558.9000	401.6000	131.9000	571.3000
8.Chemical	3657.6000	47.5000	546.0000	1260.8000	217.1000	734.7000	102.5000	7092.3000	3062.3000	646.1000	188.5000	188.7000	907.6000
9.Rubber	513.3000	12.2000	595.6000	603.5000	200.3000	149.5000	6.9000	374.6000	1676.8000	45.7000	21.1000	116.4000	871.8000
10.OthNonme	56.9000	1.1000	418.5000	4.8000	38.6000	2.5000	1.9000	123.8000	4.1000	1105.2000	19.1000	27.7000	304.4000
11.BasMetal	9.6000	7.2000	76.5000	6.8000	47.7000	18.6000	226.5000	29.9000	30.0000	384.3000	7517.9000	5460.7000	6025.0000
12.Fabric	813.9000	57.0000	1591.5000	144.4000	163.2000	81.0000	12.1000	173.4000	111.9000	41.9000	81.1000	377.7000	1219.8000
13.Machine	375.7000	210.6000	369.0000	179.8000	85.2000	171.6000	55.5000	259.4000	109.6000	141.2000	102.9000	51.7000	19570.0000
14.Comput	6.9000	9.4000	5.4000	6.9000	0.7000	2.3000	16.1000	11.8000	4.2000	3.0000	2.9000	1.9000	1121.9000
15.Elecal	16.9000	12.4000	7.0000	4.8000	2.0000	0.9000	2.1000	4.0000	2.3000	9.2000	8.5000	7.6000	1003.4000
16.Motor	5.7000	1.4000	9.6000	9.8000	1.1000	1.7000	4.0000	5.2000	3.4000	1.8000	2.1000	1.8000	127.0000
17.OthTran	112.6000	12.5000	1.2000	0.9000	0.2000	0.2000	0.6000	0.6000	0.4000	0.3000	1.0000	0.8000	8.8000
18.Manufac	28.1000	7.6000	29.6000	1165.6000	36.1000	22.5000	4.5000	84.0000	49.9000	22.9000	20.8000	10.1000	340.1000
19.Electric	153.6000	125.2000	1172.4000	1462.9000	225.3000	262.4000	58.1000	1527.9000	744.3000	752.6000	695.5000	130.8000	645.3000
20.Const	50.0000	13.9000	32.7000	28.9000	6.9000	18.8000	5.9000	44.7000	23.7000	29.2000	14.0000	5.3000	78.9000
21.Wholsal	2899.9000	618.4000	4876.7000	4912.0000	467.3000	574.6000	4630.7000	2204.9000	1521.1000	954.2000	1073.5000	717.2000	3232.1000
22.Hotel	73.7000	26.3000	65.9000	145.4000	17.0000	55.7000	4.9000	67.4000	36.6000	21.5000	16.3000	10.9000	70.9000
23.Transpt	1115.9000	828.8000	1906.0000	1467.7000	272.1000	379.6000	1120.4000	1153.1000	570.2000	456.8000	338.3000	279.7000	1314.9000
24.PostTel	106.7000	16.9000	109.4000	81.2000	18.3000	67.5000	17.9000	134.6000	60.2000	67.0000	26.6000	25.9000	185.0000
25.Finance	3123.0000	213.8000	1671.6000	1187.9000	434.0000	399.2000	79.5000	1300.1000	533.2000	678.9000	570.0000	276.6000	657.5000
26.RealEst	118.7000	56.9000	160.6000	145.6000	30.3000	30.1000	9.7000	162.2000	39.5000	23.3000	20.2000	45.9000	184.4000
27.RentMac	32.2000	3.3000	13.3000	1.2000	3.8000	23.5000	1.7000	16.2000	8.3000	4.9000	4.4000	8.5000	13.2000
28.ComRlAct	4.3000	1.5000	11.0000	5.8000	1.6000	55.7000	4.9000	30.0000	7.2000	4.2000	7.6000	17.7000	35.5000

Appendix A: Thailand's Thirty-three Sectors Input-Output Table (Unit: Million US Dollars), Continued

	1.Agric	2.Mining	3.Food	4.Textile	5.Wood	6.Pulp	7.Coke	8.Chemical	9.Rubber	10.OthNonme	11.BasMetal	12.Fabric	13.Machine
29.RnD	80.7000	1621.8000	779.0000	295.4000	80.4000	302.9000	25.6000	439.3000	167.9000	238.2000	41.2000	48.5000	258.3000
30.PubAdmin	4.1000	1.1000	5.7000	3.7000	0.7000	2.7000	1.4000	3.8000	2.2000	1.2000	0.8000	0.6000	2.8000
31.Edu	0.2000	0.1000	0.3000	0.2000	0.1000	0.5000	0.1000	0.3000	0.2000	0.1000	0.1000	0.1000	0.2000
32.Health	1.1000	0.1000	1.0000	0.9000	0.1000	0.5000	0.4000	1.6000	0.8000	0.3000	0.2000	0.1000	0.8000
33.OthCommu	142.6000	14.5000	275.2000	209.4000	16.5000	51.7000	13.2000	78.5000	39.2000	75.6000	36.3000	14.0000	131.0000

Appendix A: Thailand's Thirty-three Sectors Input-Output Table (Unit: Million US Dollars), Continued

	14.Comput	15.Elecal	16.Motor	17.OthTran	18.Manufac	19.Electric	20.Const	21.Wholsal	22.Hotel	23.Transpt	24.PostTel	25.Finance	26.RealEst
1.Agric	0.4000	0.3000	0.4000	3.2000	35.5000	6.6000	133.1000	1.4000	3644.9000	52.3000	0.1000	23.3000	25.6000
2.Mining	16.7000	15.3000	129.1000	12.2000	370.6000	7408.1000	3462.5000	1.8000	0.6000	2.6000	0.0000	0.1000	0.0000
3.Food	3.8000	4.0000	3.7000	0.8000	159.7000	1.4000	3.7000	134.3000	6938.9000	288.1000	0.1000	42.5000	2.5000
4.Textile	29.9000	102.5000	131.1000	97.4000	795.9000	5.3000	35.8000	740.5000	338.5000	250.9000	0.3000	243.5000	11.2000
5.Wood	86.4000	53.1000	84.1000	61.7000	131.3000	0.5000	1053.6000	110.2000	15.2000	45.1000	0.0000	16.5000	0.6000
6.Pulp	71.6000	47.1000	85.2000	2.0000	84.2000	8.5000	15.7000	125.5000	24.1000	56.3000	9.7000	389.9000	3.6000
7.Coke	186.2000	215.2000	234.7000	86.9000	91.9000	1055.9000	620.2000	522.2000	391.1000	12709.7000	56.3000	170.2000	56.8000
8.Chemical	478.5000	331.0000	652.0000	75.7000	385.4000	43.1000	360.2000	122.4000	116.2000	50.8000	1.8000	71.3000	2.9000
9.Rubber	1038.1000	533.5000	1150.4000	58.0000	250.8000	11.5000	364.0000	919.0000	62.9000	564.7000	2.7000	18.3000	7.1000
10.OthNonme	702.0000	944.7000	212.2000	35.9000	67.4000	1.5000	7605.4000	48.7000	71.5000	2.0000	0.0000	6.0000	10.1000
11.BasMetal	1736.3000	1814.3000	6054.7000	567.3000	4022.5000	62.0000	4040.5000	398.7000	1.1000	8.8000	0.1000	0.3000	0.6000
12.Fabric	418.1000	563.2000	855.4000	168.0000	100.3000	29.6000	1407.8000	116.8000	49.3000	64.6000	8.3000	8.9000	11.0000
13.Machine	312.3000	157.7000	3260.1000	287.0000	65.1000	103.9000	270.8000	465.0000	37.9000	153.7000	96.5000	123.6000	14.1000
14.Comput	14236.6000	82.5000	170.1000	4.2000	20.8000	8.4000	13.6000	70.2000	1.6000	7.6000	16.5000	0.9000	0.6000
15.Elecal	582.6000	6821.4000	1159.6000	78.1000	10.2000	279.8000	1796.3000	432.6000	129.8000	45.6000	26.3000	57.5000	17.1000
16.Motor	23.1000	13.6000	10574.3000	6.8000	22.2000	2.4000	8.3000	896.7000	2.0000	179.9000	0.3000	1.0000	2.4000
17.OthTran	8.3000	2.2000	3.7000	675.5000	1.8000	0.3000	2.2000	0.5000	0.3000	299.0000	0.0000	0.1000	0.0000
18.Manufac	133.1000	38.8000	53.2000	11.2000	4590.9000	13.3000	44.0000	86.5000	23.9000	70.5000	8.5000	114.3000	4.8000

Appendix A: Thailand's Thirty-three Sectors Input-Output Table (Unit: Million US Dollars), Continued

	14.Comput	15.Elecal	16.Motor	17.OthTran	18.Manufac	19.Electric	20.Const	21.Wholsal	22.Hotel	23.Transpt	24.PostTel	25.Finance	26.RealEst
19.Electric	541.6000	307.3000	548.7000	78.6000	170.5000	2057.3000	229.3000	1179.0000	1688.2000	486.9000	259.7000	369.2000	553.8000
20.Const	60.0000	12.7000	41.1000	3.5000	15.3000	22.7000	29.7000	39.3000	66.7000	21.7000	10.5000	79.6000	134.4000
21.Wholsal	3538.6000	1239.4000	2566.0000	216.4000	1981.0000	1420.7000	2626.1000	788.7000	1658.5000	5169.5000	87.3000	446.8000	50.3000
22.Hotel	85.9000	27.4000	38.9000	9.6000	40.1000	23.1000	195.1000	1357.3000	39.9000	426.4000	35.0000	230.1000	24.7000
23.Transpt	1681.5000	406.6000	958.8000	133.9000	747.7000	423.3000	5461.1000	2889.7000	491.1000	11596.1000	454.9000	756.7000	70.8000
24.PostTel	223.7000	20.1000	149.8000	14.0000	110.2000	29.5000	40.6000	560.6000	293.3000	296.6000	1154.5000	673.8000	15.1000
25.Finance	779.9000	259.2000	835.1000	185.4000	456.9000	1319.5000	935.3000	4921.4000	705.6000	2262.6000	881.1000	4018.3000	1950.7000
26.RealEst	102.2000	90.5000	72.6000	17.3000	66.7000	15.3000	195.6000	610.3000	298.0000	695.5000	68.7000	434.6000	110.4000
27.RentMac	20.6000	7.8000	17.0000	1.6000	3.3000	8.4000	50.2000	29.4000	4.2000	64.1000	5.8000	23.2000	1.9000
28.ComRlAct	66.4000	17.6000	36.1000	6.7000	5.7000	5.5000	6.9000	32.0000	3.0000	73.8000	49.0000	117.5000	14.1000
29.RnD	333.5000	115.4000	304.3000	55.0000	114.8000	59.9000	389.7000	336.6000	239.0000	1027.5000	252.1000	609.3000	266.1000
30.PubAdmin	3.0000	0.9000	1.9000	0.3000	4.2000	1.3000	6.3000	4.1000	1.5000	8.2000	0.6000	2.1000	0.6000
31.Edu	0.4000	0.1000	0.2000	0.0000	0.2000	0.1000	0.3000	0.2000	0.1000	0.4000	0.0000	0.1000	0.0000
32.Health	1.0000	0.3000	0.5000	0.1000	0.6000	0.2000	0.8000	0.3000	0.3000	0.8000	0.0000	9.5000	0.0000
33.OthCommu	166.1000	41.9000	276.7000	37.9000	28.7000	137.4000	70.4000	616.2000	144.4000	200.8000	183.3000	299.8000	129.9000

Appendix A: Thailand's Thirty-three Sectors Input-Output Table (Unit: Million US Dollars), Continued

	27.RentMac	28.ComRlAct	29.RnD	30.PubAdmin	31.Edu	32.Health	33.OthCommu
1.Agric	0.3000	0.2000	27.2000	0.0000	187.9000	446.4000	398.8000
2.Mining	0.6000	3.6000	0.1000	0.0000	0.5000	1.6000	99.2000
3.Food	0.0000	0.0000	2.7000	0.0000	323.2000	287.0000	816.3000
4.Textile	0.7000	1.3000	19.9000	0.0000	18.3000	173.0000	593.6000
5.Wood	0.5000	0.6000	48.6000	0.0000	27.4000	9.0000	63.4000
6.Pulp	3.8000	8.7000	991.2000	0.0000	499.5000	64.4000	121.1000
7.Coke	27.0000	23.5000	448.1000	0.0000	519.5000	149.7000	264.1000
8.Chemical	0.1000	1.2000	40.7000	0.0000	58.7000	2251.2000	290.3000
9.Rubber	0.0000	0.3000	72.2000	0.0000	11.3000	108.5000	258.1000

Appendix A: Thailand's Thirty-three Sectors Input-Output Table (Unit: Million US Dollars), Continued

	27.RentMac	28.ComRlAct	29.RnD	30.PubAdmin	31.Edu	32.Health	33.OthCommu
10.OthNonme	0.0000	0.0000	3.1000	0.0000	4.7000	5.8000	228.8000
11.BasMetal	0.0000	0.1000	12.8000	0.0000	0.6000	8.1000	235.7000
12.Fabric	0.9000	2.9000	11.3000	0.0000	19.3000	86.0000	262.9000
13.Machine	0.1000	0.5000	144.4000	0.0000	56.5000	9.4000	285.9000
14.Comput	1.2000	32.1000	40.2000	0.0000	19.0000	73.8000	105.3000
15.Elecal	0.2000	5.3000	5.1000	0.0000	6.4000	25.4000	213.8000
16.Motor	0.1000	0.0000	1.2000	0.0000	1.4000	1.5000	4.5000
17.OthTran	0.0000	0.0000	0.1000	0.0000	0.2000	0.2000	0.6000
18.Manufac	1.7000	1.4000	120.5000	0.0000	254.0000	34.4000	671.5000
19.Electric	10.9000	13.7000	165.6000	0.0000	581.3000	665.5000	440.4000
20.Const	20.1000	29.4000	60.6000	0.0000	34.7000	15.8000	69.7000
21.Wholsal	61.9000	15.8000	298.7000	0.0000	436.0000	706.6000	968.0000
22.Hotel	1.9000	7.3000	211.6000	0.0000	147.4000	66.6000	96.7000
23.Transpt	12.1000	65.5000	475.3000	0.0000	436.1000	383.4000	1256.1000
24.PostTel	8.7000	23.5000	402.2000	0.0000	100.2000	60.1000	665.3000
25.Finance	518.9000	135.1000	366.6000	0.0000	303.1000	122.7000	644.4000
26.RealEst	95.8000	103.7000	217.3000	0.0000	54.2000	13.5000	340.3000
27.RentMac	315.2000	22.7000	11.4000	0.0000	6.7000	27.0000	31.7000
28.ComRlAct	2.4000	630.2000	158.6000	0.0000	35.2000	75.0000	45.4000
29.RnD	335.1000	170.3000	257.6000	0.0000	122.1000	164.6000	283.7000
30.PubAdmin	6.9000	5.2000	1.5000	0.0000	1.0000	1.1000	2.0000
31.Edu	2.3000	93.7000	0.2000	0.0000	0.1000	0.1000	0.1000
32.Health	0.0000	0.0000	0.2000	0.0000	0.1000	1.2000	0.3000
33.OthCommu	8.6000	40.0000	4875.1000	0.0000	142.8000	78.2000	1924.4000

Appendix B: Benchmark data set by sectors (Unit: Million US Dollars)

	Consumption	Investment	Government	Export	Import	Labour wage	Capital return
1.Agric	16369.2000	1565.3000	142.6000	12344.0000	2698.1000	10562.8780	31104.5220
2.Mining	13.3000	1931.1000	0.3000	1538.4000	29598.7000	2848.8820	7707.7180
3.Food	26105.3000	867.0000	539.0000	22913.3000	5790.9000	4828.7380	12102.0620
4.Textile	19265.9000	1531.9000	67.3000	6304.5000	2766.7000	5007.3740	9075.4260
5.Wood	1625.4000	1873.6000	169.7000	1627.3000	478.7000	1229.1145	2062.7855
6.Pulp	606.9000	112.1000	626.4000	6066.4000	3836.0000	697.6730	2093.8270
7.Coke	6449.0000	521.7000	1415.0000	9361.3000	3760.3000	918.0515	3823.1485
8.Chemical	3912.4000	317.1000	205.4000	18359.7000	18077.0000	2846.2700	6262.4300
9.Rubber	1321.9000	332.4000	3.9000	10037.1000	3816.9000	1274.6810	2367.8190
10.OthNonme	781.8000	726.5000	130.7000	1944.9000	1377.1000	1273.1635	3533.2365
11.BasMetal	11.4000	1063.2000	0.7000	9371.3000	33459.2000	1138.7935	2266.5065
12.Fabric	674.1000	3133.1000	37.3000	4441.1000	6159.4000	910.2825	2158.3175
13.Machine	1173.6000	20361.2000	86.7000	16013.5000	14972.9000	2784.6145	7920.0855
14.Comput	834.1000	3695.2000	109.0000	34512.3000	22602.1000	1495.2590	3307.4410
15.Elecal	1162.7000	4724.8000	62.0000	8287.2000	8252.5000	1100.3105	3296.0895
16.Motor	4625.4000	14413.2000	17.4000	16076.8000	8434.9000	1800.6420	4702.8580
17.OthTran	5.2000	3097.0000	9.6000	4407.1000	4188.9000	597.7320	854.5680
18.Manufac	5949.7000	679.7000	268.4000	6903.8000	2489.3000	1617.8315	2629.9685
19.Electric	4585.4000	67.0000	1492.3000	410.5000	299.7000	3419.8110	5938.9890
20.Const	31.6000	38278.3000	643.5000	989.0000	343.2000	3341.4555	5521.8445
21.Wholsal	15618.3000	6293.1000	1656.2000	27434.8000	31938.6000	12080.7650	38998.3350
22.Hotel	15175.1000	5.2000	708.5000	9043.7000	20.6000	2832.6170	6991.2830
23.Transpt	24429.4000	1532.5000	2276.7000	21063.2000	33046.2000	7513.2575	11276.0425

Appendix B: Benchmark data set by sectors (Unit: Million US Dollars), Continued

	Consumption	Investment	Government	Export	Import	Labour wage	Capital return
24.PostTel	2122.0000	7.7000	630.0000	1146.3000	578.5000	1534.5365	3811.5635
25.Finance	5749.9000	90.5000	254.6000	949.9000	9391.0000	7015.3315	12571.7685
26.RealEst	15818.6000	13.1000	385.4000	754.0000	52.0000	1505.0210	14370.6790
27.RentMac	28.3000	1.9000	0.5000	1379.7000	29.1000	672.6155	5.4845
28.ComRlAct	46.5000	617.3000	7.2000	108.8000	180.0000	672.6155	5.4845
29.RnD	240.6000	41.6000	1660.4000	2719.3000	168.0000	1981.1340	2493.8660
30.PubAdmin	4397.2000	4.7000	18689.8000	0.0000	105.4000	21374.2355	1695.4645
31.Edu	1083.6000	1.4000	17519.0000	4.0000	7.1000	14038.8480	606.9520
32.Health	2690.9000	3.4000	7852.0000	1013.5000	19.4000	3374.4180	2000.5820
33.OthCommu	3773.9000	50.4000	747.8000	2787.3000	70.4000	2525.5935	2683.5065

Appendix C: Source of Income to the households (Unit: Million US Dollars)

	H1	H2	H3	H4	H5
intr	14055.6425	22705.2687	30922.4135	43248.1308	105309.1985
Wage	8242.9455	13315.5273	18134.4801	25362.9092	61758.6839
Conshh	12134.1090	19601.2530	26695.0398	37335.7200	90912.4782
Leisure	6182.2091	9986.6455	13600.8601	19022.1819	46319.0129

Appendix D: Source of Income to the households, by sector (Unit: Million US Dollars)

	1.Agric	2.Mining	3.Food	4.Textile	5.Wood	6.Pulp	7.Coke	8.Chemical	9.Rubber	10.OthNonme	11.BasMetal
H1	1063.9980	0.8645	1696.8445	1252.2835	105.6510	39.4485	419.1850	254.3060	85.9235	50.8170	0.7410
H2	1718.7660	1.3965	2741.0565	2022.9195	170.6670	63.7245	677.1450	410.8020	138.7995	82.0890	1.1970
H3	2340.7956	1.9019	3733.0579	2755.0237	232.4322	86.7867	922.2070	559.4732	189.0317	111.7974	1.6302
H4	3273.8400	2.6600	5221.0600	3853.1800	325.0800	121.3800	1289.8000	782.4800	264.3800	156.3600	2.2800
H5	7971.8004	6.4771	12713.2811	9382.4933	791.5698	295.5603	3140.6630	1905.3388	643.7653	380.7366	5.5518

Appendix D: Source of Income to the households, by sector (Unit: Million US Dollars), Continued

	12.Fabric	13.Machine	14.Comput	15.Elecal	16.Motor	17.OthTran	18.Manufac	19.Electric	20.Const	21.Wholsal	22.Hotel
H1	43.8165	76.2840	54.2165	75.5755	300.6510	0.3380	386.7305	298.0510	2.0540	1015.1895	986.3815
H2	70.7805	123.2280	87.5805	122.0835	485.6670	0.5460	624.7185	481.4670	3.3180	1639.9215	1593.3855
H3	96.3963	167.8248	119.2763	166.2661	661.4322	0.7436	850.8071	655.7122	4.5188	2233.4169	2170.0393
H4	134.8200	234.7200	166.8200	232.5400	925.0800	1.0400	1189.9400	917.0800	6.3200	3123.6600	3035.0200
H5	328.2867	571.5432	406.2067	566.2349	2252.5698	2.5324	2897.5039	2233.0898	15.3892	7606.1121	7390.2737

Appendix D: Source of Income to the households, by sector (Unit: Million US Dollars), Continued

	23.Transpt	24.PostTel	25.Finance	26.RealEst	27.RentMac	28.ComRlAct	29.RnD	30.PubAdmin	31.Edu	32.Health	33.OthCommu
H1	1587.9110	137.9300	373.7435	1028.2090	1.8395	3.0225	15.6390	285.8180	70.4340	174.9085	245.3035
H2	2565.0870	222.8100	603.7395	1660.9530	2.9715	4.8825	25.2630	461.7060	113.7780	282.5445	396.2595
H3	3493.4042	303.4460	822.2357	2262.0598	4.0469	6.6495	34.4058	628.7996	154.9548	384.7987	539.6677
H4	4885.8800	424.4000	1149.9800	3163.7200	5.6600	9.3000	48.1200	879.4400	216.7200	538.1800	754.7800
H5	11897.1178	1033.4140	2800.2013	7703.6582	13.7821	22.6455	117.1722	2141.4364	527.7132	1310.4683	1837.8893