Thailand's Environmental Policy with CGE Models

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Abstract

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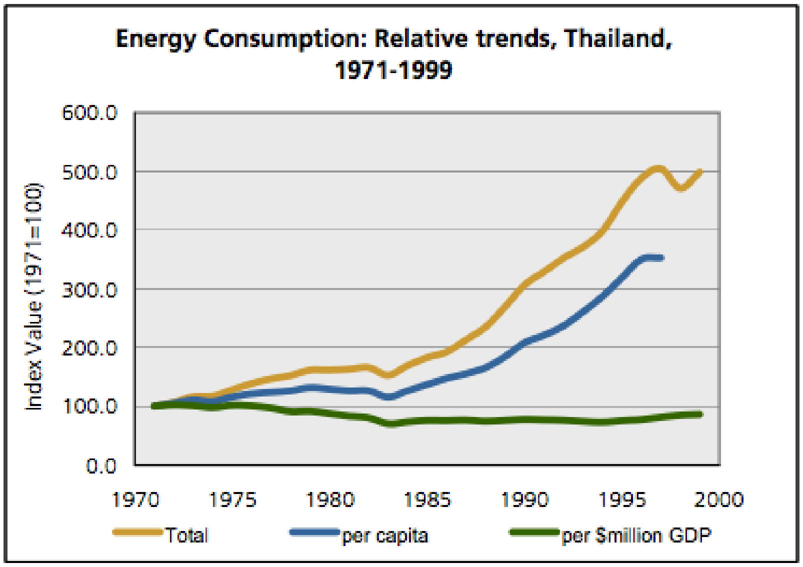
1 Introduction

1.1 Motivation

Thailand's economy has been experiencing continuous growth since 1985. During the economic boom years, the economic growth averaged at around 7 percent annually, considerably higher than those of neighbor countries in South East Asia. As the economy expanded, the final energy usage in Thailand has been increasing along with the growth. Below is a chart showing the trend of energy consumption.[**?**]



1.2 Goal

Different economic sectors consume varied amount of energy. This paper intends to study the effects of taxes and tariffs on the energy consumption across different economic sectors. Imposing higher taxes often leads to a decline in output for the respective sectors which translates to lower household consumption. However, by imposing high tax on sectors that are relatively energy intensive, we can considerably reduce the energy consumption. Even though the Gross Domestic Product is sure to suffer, the Green GDP, the environmentally adjusted output can potentially increase.

More specifically, given a decrease in the level of consumption that households can tolerate, we are interested in the configuration of tax rates of different economic sectors such that we achieve lowest energy consumption.

To do so, we employ the computable general equilibrium(CGE) model that balances the supply and demand for all markets in the economy providing the counterfactual tax rates. The CGE model gives us the the equilibrium levels of production for each sector from which we can calculate the total energy consumed. We give a brief overview Computable General Equilibrium Model and GAMS programming platforms that we use in this research.

1.3 Computable General Equilibrium

The concept of a CGE model is an exchange of inputs and outputs within the economy. Households or consumers receive income from factors, which in our case are capital and labor services. Households then consume commodities produced by firms, who on the other hand rent capital and labor factors from households. In the real world, government collect taxes and offer products and services to households. In the perspective of this general equilibrium model, the government bypass all taxes directly to households, which technically gives consumers the income to consume the private government goods. The equilibrium in the economy occurs when demands match supply for all interconnected sectors. More specifically, three conditions hold.

1. *Market clearance* For a given commodity, the supply by firms equal the demand by other production sectors and households.

2. *Zero profit* In the competitive markets for commodities, production sectors make zero profit. The income or value of each unit of good produced equal the sum of the values of all inputs, which include intermediate materials and factor employments.

3. *Income balance* The factor endowments to households are fully employed by firms

and the factor income to households equals the expenditure on goods consumed.

The CGE model solves the set of prices and quantities that satisfy all three conditions. The general equilibrium model can be thought of as a barter trade in commodities and factors as there is no explicit financial transfer. The price levels in CGE models are relatively prices.[1].

1.4 Computation Platforms

GAMS & MPSGE

The General Algebraic Modeling System (GAMS) is a high-level programming environment designed specifically for solving a large mathematical optimization problem. MPSGE (Mathematical Programming System of General Equilibrium) is a subsystem embedded in GAMS as a tool for solving the Computable General Equilibrium. The MPSGE system allows users to choose the non-algebraic representation of non-linear CGE models. Readers may refer to [?] and [?] for more detailed descriptions of GAMS and MPSGE systems.

GDXMRW & MATLAB

In addition to GAMS and MPSGE, I also use the GDXMRW interface, which allows me to import/export data between GAMS and MATLAB for further computations or visualization. Readers may refer to [?] further details.

[1] Given above is the abridged explanation of CGE model from [?]

2 Data

2.1 Thailand Social Accounting Matrix

We obtain a 1998 Social Accounting Matrix for Thailand from International Food Policy Research Institute (IFPRI).[**?**] The full Social Accounting Matrix has 61 sectors, 3 household types and 3 factors. Since the data for energy consumption are available only for aggregate economic sectors (Agricultural, Industry, Transportation, Commercial and Services, Residential and Non-energy Uses), for convenience we group micro activities into 10 macro activities(agriculture, energy intensive industries, energy non-intensive industries, primary energy sectors, transportation, service sectors).

We also combine three types of households (agricultural, non-agricultural, and , investment, household, government production sector, and the rest of the world) and 11 commodities (agriculture, energy intensive industries, energy non-intensive industries, primary energy, transportation, services, investment, government commodities, the rest of the world, labor factor, and capital factor). The macro SAM is presented in Appendix A.

The seven **agricultural** sectors consist of: (7) paddy rice, other crops, vegetables and fruits, livestock, other agricultural products, fishing and forestry.

Energy intensive industries consist of: (15) rice and flour, other agricultural products, other mining, beverages, textile, apparel, paper, basic chemical, plastic and rubber, non-metal, basic metal, machinery, electric equipments, other industry, and construction.

Energy non-intensive industries consist of :(11) meat, canned foods, other food, tobacco, leather & footwear, wood products, furniture, printing & publishing, fabric metal, transport equipment, and water supply.

Primary energy sectors are : (8) coal and lignite, crude petroleum and natural gas, gasoline, diesel, aviation fuel, fuel oil, electricity, and liquefied petroleum gas (LPG).

Transportation data are available by (5) five disaggregate categories: land transportation, ocean transportation, inland water transportation, air transportation, and other transportation.

Service sectors (15) : trade, restaurant, hotel, communications, insurance, real estate, banking, business services, public administration, education, health & medical services, non-profit, recreation, repairs, and personal services.

2.2 Energy Consumption by Economic Sectors

Each economic sector differ in their energy consumption. Below, we show the data for the total energy consumption by sector the energy consumption per unit quantity by sector.

Energy Consumption by Sector, 1999 (in thousand metric tons of oil equivalent)	
Industry	18,471
Transportation	18,242
Agriculture	2,181
Commercial & public services	2,270
Residential	8,005
Non-energy uses and "other" consumption	736
Total final energy consumption {d}	49,904

We assume that all the energy consumption for economic sector "industry" is due to energy intensive industries sector. Below, we convert the data from Earthtrends [**?**]

to unit energy consumption which we will use in policy analysis.

Table 1: Energy Consumption

SAM Notation	Earthtrends Notation	Energy Consumption
Agriculture	Agriculture	2,181
Energy Intensive	Industry	18,471
Energy Non-Intensive	Non-energy uses	368
Primary	Non-energy uses	368
Transportation	Transportation	18,242
Services	Commercial	2,270
Investment	Non-energy uses	0
Households	Residential	8,005
	Total	49,905

[2]

3 Model Specification

3.1 Production Functions

In addition to activities (agriculture, energy intensive industries, energy non-intensive industries, primary energy, transportation, and services), we treat government and investment as *domestic* production sectors with Constant Elasticity of Substitution (CES) production function. We use the elasticity of substitution 0.5. The rationale is that intermediary commodities as input to each production function are quite complimentary. We plan to do a sensitivity analysis for different elasticities of substitution later.

We note that the labor and capital factors are combined as a factor input to each production sector by a Cobb-Douglass production function; that is, the elasticity of substitution for capital and labor as input to produce factor output is 1.

3.2 Taxes

There are two kinds of taxes in this model, namely, output taxes on the total output excluding imports and income tax on household income. Taxes are accrued directly to the domestic consumer. In addition, there are tariffs on activities.

3.3 Armington Trade Model

For each domestic production sector, there is a corresponding import sector that uses foreign exchange to purchase import commodity. In addition, there is a corresponding aggregate production sector that serves to combine import commodity and domestic commodity to produce *aggregate commodity*. The aggregate commodity is what is consumed in the economy. We use the CES production function with the elasticity of substitution 4.0. This parameter will be adjusted during the phase of sensitivity analysis.

3.4 Consumers and Utility Functions

There are two consumers, namely, domestic consumer (household) and foreign consumer. The utility functions of both consumers are Cobb-Douglas. The domestic utility function takes the *aggregated* commodities as input. The foreign consumer takes domestic commodities (amounts to exports) as input to the utility function.

The domestic consumer is endowed with labor and capital factors, receive additional income from taxes and consumes all household welfare. The foreign consumer agent is endowed with foreign exchange (amounts to total exports) and consumes all foreign welfare.

In addition, we employ the classical price-floor unemployment model. The labor endowment, which is tied to the unemployment rate, is adjusted so that the price index of labor is above a certain price floor.

4 Preliminary Policy Experiments & Results

4.1 Policy Experiments 1: Effects of Output and Income Taxes on Energy Consumption, Welfare, and Unemployment.

The first policy experiments is to study the effect of taxes on unemployment, welfare, and output of each production sector. In this model, we adjust the tax multiplier for a given sector to be 2.0 with tax multipliers for all other sectors equal to 1. The tariff rates are unchanged.

For each experiment, we intend to investigate the unemployment rate, output for each sector including welfare, and the total energy consumption. Since we are interested in the total energy consumption, we use the effective output level, defined to be

$$\text{Effective Output Level} = \frac{\text{Output Level} \cdot \text{Domestic Output} + \text{Import Level} \cdot \text{Import}}{\text{Domestic Output} + \text{Import}}, \tag{1}$$

which captures the output from importing as well as domestic output. If we only looked at the domestic output level, the energy consumption would consequently be restricted to domestic consumption. Our policy suggestion would be biased towards higher import and lower internal production.

4.2 Policy Experiments 1: Results and Discussion

Table 2 shows the results for this set of policy experiments. The effective output levels reflect the consumption of each commodity, some of which are consumed by the foreign consumer. The energy consumption for a given scenario is the sum over all energy-consuming sectors the effective output level times the energy cost per unit level.

Table 2: Results for Policy Experiments 1

Energy per unit	Variable \ Policy	Benchmark	AGR	ENI	ENN	PRI	TRA	SER	W
N/A	Unemployment	0.04	0.04	0.084	0.057	0.083	0.04	0.07	0.101
8005	Welfare	1	1	0.99	0.997	**0.969**	1	0.991	0.982
2181	Eff AGR	1	0.999	0.988	0.984	0.995	1	0.998	0.982
18471	Eff ENI	1	1	0.945	0.994	0.988	1	0.995	0.982
368	Eff ENN	1	1	0.989	0.948	0.99	1	0.996	0.984
368	Eff PRI	1	1	0.983	0.997	0.776	0.999	0.999	0.978
18242	Eff TRA	1	1	0.987	0.998	0.96	0.998	0.999	0.984
2270	Eff SER	1	1	0.989	0.997	0.991	1	0.975	0.981
0	Eff INV	1	1	0.98	0.996	0.976	1	0.996	0.986
	Energy Consumption	49,905	49,903	48,510	49,662	48,584	49,873	**49,651**	49,053

Table 3: Tax Rates for Policy Experiments 1

	Tariff Rates						
Tax Rates	Benchmark	Pol AGR	Pol ENI	Pol ENN	Pol PRI	Pol TRA	Pol SER
W	**0.090**	0.045	0.045	0.045	0.045	0.045	0.045
AGR	0.000793	**0.001586**	0.000793	0.000793	0.000793	0.000793	0.000793
ENI	0.032	0.032	**0.064**	0.032	0.032	0.032	0.032
ENN	0.053	0.053	0.053	**0.106**	0.053	0.053	0.053
PRI	0.145	0.145	0.145	0.145	**0.29**	0.145	0.145
TRA	0.002	0.002	0.002	0.002	0.002	**0.004**	0.002
SER	0.032	0.032	0.032	0.032	0.032	0.032	**0.064**

From Table 2, we can see that the all policies except for the ones on agricultural and transportation tax rates result in higher unemployment. We can see from Table 3 that the original tax rates on both agricultural and transportation sectors are outstandingly low. Therefore, it is not surprising that doubling the tax rates of these sectors barely effect the output and unemployment.

The energy consumptions for different hypothetical scenarios including the benchmark model are given in Table 2. We can see that all energy consumption decrease. However, low welfare does not necessarily correspond to low energy consumption. In the column "PRI", we observe the lowest welfare level 0.969 with energy consumption $48,584$ thousands of tons of oil equivalent, lower than the benchmark energy consumption by roughly 2.6%. However, in column "SER", we observe a slight decrease of welfare to 0.991 but with energy consumption $49,651$ thousands of tons of oil equivalent, the lowest among all the tested scenarios. The unemployment for the experiment where income tax rate is doubled increases from 4% to 10.1%. Unsurprisingly, the welfare level is highly sensitive to income taxes. However, the energy consumption only decreases by 1.7% as the household sector is not highly energy intensive.

This gives motivation to the final policy analysis in which we attempt to minimize the energy consumption for a given level of welfare. The next set of policy experiments investigate the effect of tariffs increase instead of domestic taxes.

4.3 Policy Experiments 2: Effects of Tariffs on Energy Consumption, Welfare, and Unemployment.

The second set of policy experiments study the effects of imposing higher tariffs. In each policy sub-experiment, we double the tariff rate on a given sector while leaving the tariff rates for other sectors unchanged. Considering Table 4, the size of imports are small compared to the total output. We predict that the effect on unemployment, welfare, output and energy consumption will be much smaller as well.

Table 4: Benchmark Tariffs and Output

	AGR	ENI	ENN	PRI	TRA	SER	INV	GOV
Imports	72.19	1308.42	243.07	152.16	94.63	273.13	990.23	0.87
Tariffs	1.69	45.29	10.48	0.71	0	3.86		
Tariff Rates(%)	2.341044	3.461427	4.311515	0.466614	0	1.413246	0	0
Total Output	1095.43	6094.37	1463.08	823.31	818.03	3367.47	2759.29	783

4.4 Policy Experiments 2: Results & Discussion

Table 5 shows the results for this set of policy experiments. Indeed, the unemployment rate is highly inelastic. The output levels in the sectors that are import-intensive change slightly. Distortion due to increased tariff rates leads to higher energy consumption is some sectors.

Table 5: Results for Policy Experiments 2

Energy	Variable \ Policy	Benchmark	Pol AGR	Pol ENI	Pol ENN	Pol PRI	Pol TRA	Pol SER
	Unemployment	0.04	0.04	0.04	0.04	0.04	0.04	0.04
8005	Welfare	1	1	1.009	1.002	1	1	1.001
2181	Eff AGR	1	0.999	0.999	1.002	1	1	0.999
18471	Eff ENI	1	1	0.995	1	1	1	0.999
368	Eff ENN	1	1	0.997	0.997	1	1	1
368	Eff PRI	1	1	0.999	0.999	1	1	0.999
18242	Eff TRA	1	1	1.003	1	1	1	0.999
2270	Eff SER	1	1	1.003	1.001	1	1	0.999
0	Eff INV	1	1	1.001	1.001	1	1	1.001
	Energy Consumption	49,905	49,895	49,930	49,928	49,899	49,905	49,879

Table 6: Tariff Rates for Policy Experiments 2

Sectors	Tariff Rates						
	Benchmark	Pol AGR	Pol ENI	Pol ENN	Pol PRI	Pol TRA	Pol SER
AGR	0.023	**0.046**	0.023	0.023	0.023	0.023	0.023
ENI	0.035	0.035	**0.07**	0.035	0.035	0.035	0.035
ENN	0.043	0.043	0.043	**0.086**	0.043	0.043	0.043
PRI	0.005	0.005	0.005	0.005	**0.01**	0.005	0.005
TRA	0	0	0	0	0	**0**	0
SER	0.014	0.014	0.014	0.014	0.014	0.014	**0.028**

4.5 Policy Experiments 3: Indifference Tax Rate Hyper-Surface

In this policy experiment, we aim to find the tax rate configurations that result in the same welfare. To be more simplistic, we only look at the scenarios when the tax rate on only one sector is changed at a time.

To do this in GAMS, we change the tax rates so that the welfare is the same to the third decimal place.

4.6 Policy Experiments 3: Results & Discussion

The results are in Table 7 and 8 for the level of welfare $0.995, 0.990$ respectively.

Table 7: Results for tax configurations with welfare level 0.995

	AGR	ENI	ENN	PRI	TRA	SER	HH
Corresponding Tax Multiple	114	1.535	2.495	1.19	48.5	1.555	1.285
Corresponding Tax Rate	0.090402	0.04912	0.132235	0.17255	0.097	0.04976	0.057825
Unemployment	0.065	0.064	0.066	0.048	0.055	0.057	0.058
Welfare	0.995	0.995	0.995	0.995	0.995	0.995	0.995
Energy Consumption	49631	49154	49534	49667	**48450**	49767	49664

Table 8: Results for tax configurations with welfare level 0.990

	AGR	ENI	ENN	PRI	TRA	SER	HH
Corresponding Tax Multiple	190	2.015	3.49	1.365	81.5	2.065	1.565
Corresponding Tax Rate	0.15067	0.06448	0.18497	0.197925	0.163	0.06608	0.070425
Unemployment	0.083	0.085	0.083	0.056	0.67	0.072	0.075
Welfare	0.990	0.990	0.990	0.990	0.990	0.990	0.990
Energy Consumption	49416	48490	49258.21	49441	**47481**	49634	49426

Both tables suggest that, given the same level of welfare, increasing the tax rate on transportation is the most effective measure in reducing the energy consumption.

Table ?? offers some explanation.

Table 9: Energy Cost per Unit Output

Sector	Energy Consumption	Output	Energy Cost per Unit Output
Agriculture	2181	1095.43	1.990999
Energy Intensive Industry	18471	6094.37	3.03083
Energy Non-Intensive Industry	368	1463.08	0.251524
Primary	368	823.31	0.446976
Transportation	18242	818.03	22.29992
Services	2270	3367.47	0.674097
Investment	0	2759.29	0
Households	8005	4857.83	1.647855

We can see that transportation sector is the most energy-intensive sector per unit output. Imposing an increase in tax rate for a given sector has the largest effect (negative) on its corresponding sector output, compared to all other sectors. Higher tax in the transportation sector leads to lower consumption on household but even lower energy consumption because the transportation sector is very energy-intensive.

In the next policy experiment, we will show that there exists some configuration taxes that are not the boundary solution of only transportation taxes that minimizes the energy consumption.

5 Policy Analysis: Energy Optimization

5.1 Questions and Methodology

We are interested in minimizing energy consumption for a given level of welfare. This process involves using GAMS to find equilibrium solutions for a large set of policy experiments. Table 10 shows the policy experiment sets.

Table 10: Iteration Sets

	Tax Multiples				
Tax on Sector	It. 1	It. 2	It. 3	It. 4	It. 5
AGR	1	25	50	75	100
ENI	1	1.14	1.28	1.42	1.56
ENN	1	1.35	1.70	2.05	2.40
PRI	1	1.05	1.10	1.15	1.20
TRA	1	12	24	36	48
SER	1	1.12	1.24	1.36	1.48
HH	1	1.1	1.2	1.3	-

Due to limitation on running speed, we can afford only 5 iterations of tax changes for each sector. [3] We pick the tax multiples for each sector based on the welfare sensitivity. For the level of welfare 0.995, below is an abridged version of Table 7 from the Policy Experiment 3 that shows the tax multiple on each sector that results in 0.995 level of welfare. For each sector, we pick the last tax iteration (5^{th}) so that it is approximately the figure in Table 10. This is to ensure that we won't miss the corner solution if it happens to be the case. The constant increment of tax increase for each sector is chosen to fit the desired last iteration.

Below shows the GAMS code that iterates through all experiments specified in

[3] This is already a very large collection of experiments to be done in using GAMS. The number of experiments is $5^6 \cdot 4 = 62500$. The runtime is roughly 9 hours.

Table 11: (Part of Table 7) Results for tax configurations with welfare level 0.995

	AGR	ENI	ENN	PRI	TRA	SER	HH
Tax Multiple	114	1.535	2.495	1.19	48.5	1.555	1.285

Table 10. This is the policy experiment part after $OFFTEXT.

```
*****************  Energy Consumption Optimization   *****************
* This section lists the set scenarios for policy experiments
SET
                 SCAGR   Scenarios for agricultural sector        /SCAGR1*SCAGR5/,
                 SCENI   Scenarios for energy intensive sector   /SCENI1*SCENI5/,
                 SCENN   Scenarios for energy non intensive sector       /SCENN1*SCENN5/,
                 SCPRI   Scenarios for primary                    /SCPRI1*SCPRI5/,
                 SCTRA   Scenarios for transportation             /SCTRA1*SCTRA5/,
                 SCSER   Scenarios for services sector            /SCSER1*SCSER5/,
                 SCW     Scenarios for income tax                 /SCW1*SCW4/;

PARAMETER
                 TXAGR(SCAGR)   Values of tax multiples by agricultural sector scenario         /
                         SCAGR1  1.00
                         SCAGR2  25.0
                         SCAGR3  50.0
                         SCAGR4  75.0
                         SCAGR5  100.0
                 /

                 TXENI(SCENI)   Values of tax multiples by energy intensive sector             /
                         SCENI1  1.00
                         SCENI2  1.14
                         SCENI3  1.28
                         SCENI4  1.42
                         SCENI5  1.56
                 /

                 TXENN(SCENN)   Values of tax multiples by energy non intensive sector   /
                         SCENN1  1.00
                         SCENN2  1.35
                         SCENN3  1.70
                         SCENN4  2.05
                         SCENN5  2.40
                 /

                 TXPRI(SCPRI)   Values of tax multiples by energy intensive sector             /
                         SCPRI1  1.00
                         SCPRI2  1.05
                         SCPRI3  1.10
```

```
                        SCPRI4  1.15
                        SCPRI5  1.20
                /

                TXTRA(SCTRA)   Values of tax multiples by energy intensive sector              /
                        SCTRA1  1.00
                        SCTRA2  12.00
                        SCTRA3  24.00
                        SCTRA4  36.00
                        SCTRA5  48.00
                /

                TXSER(SCSER)    Value of tax multiples by services sector scenario       /
                        SCSER1 1.00
                        SCSER2 1.12
                        SCSER3 1.24
                        SCSER4 1.36
                        SCSER5 1.48
                /

                TXW(SCW)      Value of tax multiples for income tax /
                        SCW1    1.00
                        SCW2    1.10
                        SCW3    1.20
                        SCW4    1.30
                /,

        WELFARE(SCAGR,SCENI,SCENN,SCPRI,SCTRA,SCSER,SCW)   Household Welfare,
        YLevel(SCAGR,SCENI,SCENN,SCPRI,SCTRA,SCSER,SCW,j)        Effective output level
        ENERGYCON(SCAGR,SCENI,SCENN,SCPRI,SCTRA,SCSER,SCW)     Energy Consumption for each househ
        UNEMP(SCAGR,SCENI,SCENN,SCPRI,SCTRA,SCSER,SCW)             Unemployment Rate;

LOOP(SCAGR,
LOOP(SCENI,
LOOP(SCENN,
LOOP(SCPRI,
LOOP(SCTRA,
LOOP(SCSER,
LOOP(SCW,
** install tax rates for the current scenario
        taxMul("AGR")   =       TXAGR(SCAGR);
        taxMul("ENI")   =       TXENI(SCENI);
        taxMul("ENN")   =       TXENN(SCENN);
        taxMul("PRI")   =       TXPRI(SCPRI);
        taxMul("TRA")   =       TXTRA(SCTRA);
        taxMul("SER")   =       TXSER(SCSER);

        incTRMul  = TXW(SCW);

$INCLUDE        TH_v1.gen
SOLVE   TH_v1 using mcp;
```

```
**      Put the solution value in fields
        WELFARE(SCAGR,SCENI,SCENN,SCPRI,SCTRA,SCSER,SCW) = W.L;

        YLevel(SCAGR,SCENI,SCENN,SCPRI,SCTRA,SCSER,SCW,j) =
                ( (Y.L(j)*domProd(j) + Imp.L(j)*import(j))/(domProd(j) + import(j))  );
        EnergyCon(SCAGR,SCENI,SCENN,SCPRI,SCTRA,SCSER,SCW) =
                ( sum(j, ( EffYLevel(j)*sam(j,"EnergyCost")  ))  + W.L*sam("HH","EnergyCost") );
        UNEMP(SCAGR,SCENI,SCENN,SCPRI,SCTRA,SCSER,SCW) = U.L;

); ); ); ); ); ); );
execute_unload %matout%;
```

The line below is added at the beginning of the GAMS file to write the variables into the binary .gdx file, from which MATLAB can import.

```
SET matout "'PolExp4WelfMod.gdx', WELFARE, YLevel, ENERGYCON, UNEMP, SCAGR, SCENI, SCENN, SCPRI, S
```

In MATLAB, we extract the fields welfare, output levels, energy consumption, unemployment rates, and the policy experiment indices. First, we construct a structure called 'struct' that will store the name of the variable we are interested in.

```
>> welfare.name = 'welfare';
```

Then, we assign each GAMS variable to a MATLAB variable. The format of the MATLAB variable will be a cell in which we can extract its value (array form).

```
>> WelfareCell = rgdx('PolExp3',welfare);

>> WelfareMat = WelfareCell.val;
```

WelfareMat is a 1 by 2 array. The first 'column' stores the index from 1 to 62500. The second 'column' contains a 1 by 7 array containing the indices for SCAGR, SCENI, SCENN, SCPRI, SCTRA, SCSER and the welfare.

We repeat this extraction process for YLevel (effective output level), EnergyCon (energy consumption), UnEmp (unemployment rate), SCAGR (the iteration index for tax on the aggregate agricultural sector), SCENI, SCENN, SCPRI, SCTRA, and SCSER. Finally, we find the level of welfare that is above 0.995 and find the policy experiment that minimizes the energy consumption.

Mathematical Framework

Let w be the level of welfare, t_i be the tax rate of sector i, y_i be output level of sector i, and e_i be the energy consumption on sector i. The question is to find t_j such that for a given $\overline{w}$,

$$w(t_j) \geq \overline{w}, \qquad \min \sum_i y_i(t_j) \cdot e_i.$$

The code below iterates through all the results and finds the experiment with welfare greater or equal to 0.995 such that the energy consumption is minimum.

```
>> sizeE = size(EnergyConMat)
>> MinEnergy995 = 100000000;
>> for i = 1:sizeE(1)
      if (WelfareMat(i,8) >= 0.995) && (EnergyConMat(i,8) <= MinEnergy995)
         MinEnergyIndex = i;
         MinEnergy995 = EnergyConMat(i,8);
      end
   end
>> MinEnergyIndex


?? put OUTPUT HERE  ***************************
```

5.2 Results and Discussion

6 Sensitivity Analysis

6.1 Elasticity of Household Welfare

A 1998 Thailand Social Accounting Matrix

Table 12: 1998 Social Accounting Matrix For Thailand (10 billion Baht) [2002]

	AGR	ENI	ENN	PRI	TRA	SER	INV	HH	G	ROW	SUM
AGR	87.28	206.74	191.11	0	0.34	129.3	28.95	235.68	0.83	215.2	1095.43
ENI	133.9	2272.61	326.69	32.23	57.1	295.28	626.21	864.53	15.84	1469.98	6094.37
ENN	52.47	106.2	185.91	0.84	18.96	96.59	117.22	421.14	8.03	455.72	1463.08
PRI	45.58	149.26	21.06	284.33	143.56	60.88	7.55	54.14	5.65	51.3	823.31
TRA	22.96	180.01	30.22	8.04	100.69	69.36	10.44	248.62	7.92	139.77	818.03
SER	127.56	689.29	155.02	37.68	107.14	456.02	94.16	846.45	462.42	391.73	3367.47
INV	0	0	0	0	0	0	884.53	1203	281.44	390.32	2759.29
G	0	0	0	0	0	0	0	762.32	0	20.68	783
ROW	72.19	1308.42	243.07	152.16	94.63	273.13	990.23	0	0.87	0	3134.7
Labor	181.67	428.42	99.14	76.29	66.78	605.67	0	2.67	0	0	1460.64
Capital	369.32	556.72	136.68	133.63	227.49	1278.44	0	0	0	0	2702.28
Output Taxes	0.81	151.41	63.7	97.4	1.34	98.94	0	219.28	0	0	632.88
Tariffs	1.69	45.29	10.48	0.71	0	3.86	0	0	0	0	62.03
SUM	1095.43	6094.37	1463.08	823.31	818.03	3367.47	2759.29	4857.83	783	3134.7	

Source: [?]

B GAMS Code