An Economy-wide Analysis of
Increasing Bio-Ethanol Production in Taiwan

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Abstract

This article figures out the economic impacts on macroeconomy, industrial output, new energies and environment when the advantageous bioethanol and its feedstock production increase and replace the usage of gasoline in the future. A CGE model, called "Taiwan General Equilibrium Model-Energy, (TAIGEM-E), was a linear/dynamic, linearized percentage change simulation tool used especially in the economic evaluation of environment policies. Results indicated that macroeconomic and environmental variables will all benefit with scenarios. Government should instantly encourage the production of bioethanol (and biodiesel) and it's producing resource because it truly can reduce the pressure of CO2 emission mitigation, and also can active agricultural fallow lands. It is an important long term issue.

Keywords: Bioethanol, Biodiesel, Computal General Equilibrium (CGE), TAIGEM-E

1. Introduction

High oil prices and the Kyoto Protocol induce countries in the world to develop new energy sources like biofuels, wind and solar. People in the world strongly want to develop biomass energy technology to reduce demand for oil and protect environment recently when many disasters broken out everywhere because of serious global warming effects today. Biofuels (usually includes bioethanol and biodiesel) are environmental friendly, higher energy independence and efficiency, curb greenhouse gas emission, create jobs, reduce government budget deficit, support crop prices, and strengthen farm economy [1,2]. They produced from biomass as a clean energy source with lower greenhouse gas emission [3-5]. So countries emphasize developments of biofuels, like George W. Bush, President of the United States, encourages Americans to pursue the goal of reducing U.S. gasoline usage by 20 percent in the next ten years by renewable and alternative energies like biofuels- 20 in 10 fact for energy security [6].

Gasoline is also the major oil-refining product in Taiwan. Bioethanol can replace the usage of gasoline, reduce lots of CO2 emission like Brazil, protect environment, and activate agricultural fallow land. Bioethanol can be produced by agricultural feedstock like corn (more than 90% of bioethanol produced in the U.S. by corn), sugarcane (Brazil), sweet potatoes, sweet beets (Germany), and so on. Because of the advantages of planting sweet potatoes including highest backward linakage effect, easy planting, low production cost, shorter growing period (150 days), mechanical gathering, higher ethanol-transforming rate (12.5%), government in Taiwan will encourage farmers plant sweet potatoes to be the major resource to produce bioethanol. So in this article, we want to figure out the economic impacts on macroeconomy, industrial output, new energies and environment when the bioethanol and its feedstock production increase and replace the usage of gasoline in the future.

Because the biofuels and new energies have exerted a full-scale impact on an entire country, it appears suitable to examine the issue according to a full set of economic computable general equilibrium (CGE) model, which is founded by [7] and [8], is a suitable tool to evaluate. CGE models are a kind of economic model that use input-output table or social accounting matrix to estimate how an economy might react to changes in policy, technology or other external factors. A CGE model, called "Taiwan General Equilibrium Model-Energy, (TAIGEM-E), which is derived from ORANI [9] and MONASH [10,11] models by Monash University in Australia, is a linear/dynamic, linearized percentage change forecast tool used especially in the economic evaluation of environment policies. Therefore, the purpose of this study is to evaluate the impact of raise production of biofuels especially bioethanol on Taiwan's economy using TAIGEM-E model. The critical factors that affect macroeconomic variables, environmental variables and industrial output, were discussed.

2. Model

2.1 Basic Model

The TAIGEM-E model has been described elsewhere [12-16]. A brief description of the model, and particularly the biofuels (includes bioethanol and biodiesel) and other new energies (includes solar cell, solar heating, wind, hydrogen, fuelcell, IGCC) , are presented as follows.

TAIGEM-E is the most comprehensive model available for Taiwan’s economy, which consists of 170 sectors, six types of labor, eight types of margin, and 182 commodities. The assumption of input-output separability for model simplification implies the generalized production function for some industries: F(inputs, output) = 0 can be written as: G(inputs) = Activity = H(outputs). The H function is derived from two nested constant elasticity of transformation (CET) [17] aggregation functions, while the G function is broken into five nested constant elasticity of substitution (CES) [18]. Each nested CES structure displays the optimization problem that firms choose cheapest input combination to minimize total cost subject to the CES production technology. Each nested CET structure displays the optimization problem that distributors choose optimal output combination to maximize total profit subject to the CET production transformation ratio. CET is identical to CES, except that the transformation parameter in the CET function has an opposite sign to the substitution parameter in the CES function. The nested structure displayed in Fig. 1 shows multi-input and multi-output production specifications. The input demand for industry production is represented as a five-level nested structure, and the operation of each level is decided independently. On the top level, commodity composites and a primary-factor composite are combined using a Leontief production function. Therefore, the demand is directly proportional to the industry activity. On the second level, each commodity composite is represented using a CES function incorporating domestic supply and imported equivalents [19]. The energy and primary-factor composites are CES aggregates of energy composites and primary-factor composites. On the third level, the primary-factor composite is a CES aggregation of labor, land, capital and the energy composite. The energy composite, the key part of bioethanol and new energy modeling, is modeled as a CES aggregate of bioethanol, biodiesel with oil products, and coal products, natural gas products, electricity and new energy. New energy is modeled as a CES aggregate of solar cell, solar heating, hydrogen, fuelcell and IGCC. It means if fossil fuels are going to be more expensive, biofuels and new energies are going to be cheaper, or penalty of greenhouse gas emission, firms will choose biofuel or new energies to substitute the usage of fossil fuels for lower production and environmental cost. On the fourth level, the coal product composite is a CES aggregation of coal and coal products; the oil product composite is a CES aggregation of gasoline, diesel oil, fuel oil and kerosene; the natural gas product composite is a CES aggregation of refinery gas, gas and natural gas, and electricity. On the bottom level, energy is a CES aggregation of domestic and imported supplies. In the output level, CET profit maximization behavior demonstrates how industry outputs transform to commodity outputs in the first level, and also presents how a distributor decides to sell a commodity to the local or export market in the second level.

The power sector of TAIGEN-E is modeled as a technology bundle (Fig. 2) derived from the MEGABARE model developed by Australian Bureau of Agricultural and Resource Economics (ABARE) [20], which is composed of 12 power generation technologies, namely hydro, stream turbine-oil, stream turbine-coal, stream turbine-gas, combined cycle-oil, combined cycle-gas, gas turbine-oil, gas turbine-gas, diesel, nuclear, cogeneration and wind. The power sector is able to switch between different power technologies in response to changes in their relative costs through the CES production function. The output of the end-use electricity is a minimized cost behavior subject to a CES aggregate of each electricity technology. All electricity thus generated is sent to end-users.

2.2 Database

The database for TAIGEM-E model is presented in the IO table [21] in 2001 (Fig. 3). Column data in the table denotes the "supply side" and the row data represents the "demand side." It shows that aggregate supply is equaled to aggregate demand for the entire economy equilibrium. Supply side includes intermediate and primary input for industries, demand side includes intermediate demand for industries and final demand for household consumption, government expenditure, investment, net export and inventory.

The costs of bioethanol and other energies are obtained from a recent survey conducted by the Taiwan Institute of Economic Research (TIER). The costs of wind, cogeneration and other ten power generation sectors are obtained from the cost structure report by Taiwan Power Company (TPC) [22,23].

An energy balance sheet was used to estimate a CO_2 emission matrix from 15 emission commodities, including coal, natural gas, other non-metallic minerals, gasoline, diesel fuels, aviation fuels, fuel oils, kerosene, lubricants, naphtha, refinery gas, asphalt, other refining products, coal products and gas. The elasticities in TAIGEM-E model are gathering from ORANI model, and also we estimate armington elasticity by local data. We use these above data to build required input-output data for this article needs.

2.3 Input-output inter-relationship analysis

We usually use forward linkage effects or so-called “sensitivity” to analyse sectoral final demands changes to one unit, the change in its demand for specific sectoral output, and use backward linkage effects or so-called “dispersion” to analyse every department’s ultimate specific sectoral final demands changes to one unit, the total outputs of all sectors increase/decrease. It can show which sector is the most important sector in a economy. In Table 1 , we calculate forward and backward linkage effects of different kinds of production resources for bioethanol and biodiesel. We found that sweet potatoes bioethanol has highest index at 1.7469, it is why we focus on this sector in this article. We also find forward linkage effects of biofuels are all small because it is a new born sectors here. It will be more important when time goes by.

3. Scenario Design

Because of the advantages of planting sweet potatoes, government in Taiwan will encourage farmers plant sweet potatoes to be the major resource to produce bioethanol. We adopt the policy timeline in Taiwan for sweet-potato bioethanol from 2009 to 2012. Sugarcane is also a suitable resource to producing bioethanol in the world, but it is not Taiwan’s priority (because sugarcane has a lower ethanol-transforming rate (9.95%), longer growing period (2.5 to 3 years) than sweet potatoes). As Table 2 reveals, the planned farmland for sweet potatoes will increase at 9600 hectare in 2009 to 60000 hectare in 2012. We calculate it will produce 262.5 thousand kiloliters and NT 6476 million dollars output value of bioethanol, and NT 3885 million dollars output value of sweet potatoes.

For model simplicity, TAIGEM-E adopt linearization method first introduced by [7]. We calculate the policy impacts from levels to percentage change form for TAIGEM-E. First, government increasing production of sweet potatoes to produce bioethanol. It will substitute usage of gasoline by introducing E10, E85 or E100 to consumers and force refueling stations to add new service for bioethanol. Second, although cost of bioethanol may higher than gasoline, policy will force consumer to refuel bioethanol. It will substitute the usage of gasoline. We calculate the percentage change which gasoline quantity be replaced. The shocks are shown as Table 3 below.

4. Results

4.1 Results of macroeconomic variables

Simulation results of TAIGEM-E modeling are shown in Table 4. Year 2009 through 2012 revealed that the positive macroeconomic effect in the event of the raise the production of bioethanol is gradually significant. From year 2009's impact on real GDP, consumption, employment, export, import and investment at 0.136% to 0.853%, 0.150% to 0.940%, 0.094% to 0.588%, 0.045% to 0.284%, 0.027% to 0.172%, and 0.07% to 0.437%, respectively. The overall positive impact on the macroeconomy is considered very important.

The results also shows the raise of bioethanol production will reduce CO2 emission, and also energy density. From year 2009's impact on these two environmental indices at -0.259% to -1.618% and -0.086% to -0.531%, respectively. We can conclude that government invest or subsidize more on bioethanol and its related industries, whole economy and environment will benefit from these kind of policy.

4.2 Results of industrial output

The effect of raise production of bioethanol and sweet potatoes sectors exogenously is illustrated in Table 5. Year 2009 through 2012's effect on agricural industries is largest for other livstocks (at 0.338% to 2.122%), following by paddy rice, hogs, and other special crops. As we predicted, all the agricultural sectors are benefit with the policy. We also concern the impacts of food processing sectors' output. Year 2009 through 2012's effect on food processing industries is largest for flour (at 0.529% to 3.321%), following by diary products, canned foods, slaughter, seasonings and rice. As we predicted, all the agricultural sectors are benefit with the policy.

The effect of new energy when raise production of bioethanol and sweet potatoes sectors exogenously is illustrated in Table 6. Year 2009 through 2012's effect on new energy sectors is largest for biodiesel (at 0.161% to 1.013%), following by solar heating, fuelcell and hydrogen. Biodiesel is an very import alternative energy. Just like bioethanol, they all use agricultural resources to be procduced. Bioethanol and biodiesel are good for reducing agricultural fallow land.Results reveals when we encourage production of bioethanol will increasing production of other new energies, including the most important future clean energies, hydrogen and fuelcell.

5. Conclusions

This study examined the economic impact of an raise of production of sweet potatoes and bioethanol in Taiwan according to a famous CGE model, named TAIGEM-E. We conducted a 4 years' simulation. Results indicated that macroeconomic and environmental variables will all benefit with our scenarios. Government should instantly encourage the production of bioethanol (and biodiesel) and it's producing resource especially sweet potatoes and sugarcane because it truly can reduce the pressure of CO2 emission mitigation, and also can active agricultural fallow lands. It is an important long term issue.

Table 1. Forward and backward linkage effects for biofuels and related agricultural producing resources

Sectors	Forward Linkage Effects (Sensitivity)	Backward Linkage Effects (Dispersion)
Rape biodiesel	0.5652	1.3588
Sunflowers biodiesel	0.5651	1.3612
Soybeans biodiesel	0.5651	0.9025
Recycled cooking oils biodiesel	0.5673	0.9670
Sweet potatoes bioethanol	0.5690	1.7469 *
Sugarcane bioethanol	0.5680	1.5343
Sugarcane	1.1123	1.1695
Sweet potatoes	1.9337	1.5806
Soybean	0.6830	1.2478
Other Common Crops	0.7141	1.2392

Table 2. Policy for planned production of sweet potatoes and bioethanol

	2009	2010	2011	2012
Planned plant farmland (hectare)	9600	20000	40000	60000
bioethanol production (10 thousand kiloliters)	4.2	8.75	17.5	26.25
Sweet potatoes production (NT million dollars)	622	1295	2590	3885
Bioethanol production (NT million dollars)	1033	2153	4305	6476

Table 3. Scenario Design for development of bioethanol

Unit : %

	2009	2010	2011	2012
Sweet potatoes production increase	5.87	12.22	24.44	36.66
Bioethanol production increase	18.04	37.60	75.18	113.10
Gasoline usage substitution	-0.41	-0.85	-1.70	-2.54

Table 4. Raise production of bioethanol and sweet potatoes on Taiwan's macroeconomic variable using TAIGEM-E model

Unit : %

Macroeconomic Variables	2009	2010	2011	2012
Real GDP	0.136	0.284	0.568	0.853
Consumption	0.150	0.313	0.626	0.940
Employment	0.094	0.196	0.391	0.588
Export	0.045	0.095	0.189	0.284
Import	0.027	0.057	0.114	0.172
Investment	0.070	0.145	0.291	0.437
Primary factor usage	0.095	0.198	0.396	0.595
Government expenditure	0.150	0.313	0.626	0.940
GDP deflation	0.014	0.029	0.058	0.087
Capital price	0.161	0.336	0.671	1.008
Wage rate	0.023	0.049	0.098	0.147
Export price	-0.001	-0.002	-0.004	-0.006
Exchange rate	0.019	0.039	0.078	0.117
Wealfare	0.273	0.570	1.139	1.712
CO2 emission	-0.259	-0.538	-1.076	-1.618
Energy density	-0.086	-0.178	-0.356	-0.531

Table 5. Raise production of bioethanol and sweet potatoes on Taiwan's Agricultural and Food Processing Sectors Output using TAIGEM-E model

Unit : %

Industrial Output	2009	2010	2011	2012
Agricultural Sector				
Paddy_Rice	0.334	0.698	1.396	2.098
Other Common Crops	5.745	12.084	24.168	36.253
Other Special Crops	0.203	0.425	0.849	1.276
Fruits	0.111	0.231	0.462	0.694
Vegetables	0.106	0.221	0.442	0.664
Other Horticultural Crops	0.064	0.133	0.266	0.399
Hogs	0.270	0.565	1.130	1.698
Other Livestock	0.338	0.706	1.412	2.122
Forestry	0.039	0.081	0.163	0.245
Fisheries	0.044	0.091	0.182	0.273
Food Processing Sector				
Slaughter	0.303	0.632	1.264	1.899
Edible Oil & Fat By-Products	0.282	0.590	1.179	1.772
Flour	0.529	1.106	2.211	3.321
Rice	0.285	0.596	1.191	1.790
Animal Feeds	0.271	0.566	1.131	1.699
Canned Foods	0.410	0.856	1.712	2.572
Frozen Foods	0.248	0.517	1.034	1.554
Monosodium Glutamate	0.133	0.278	0.556	0.835
Seasonings	0.294	0.614	1.227	1.844
Dairy Products	0.430	0.898	1.796	2.698
Sugar Confectionery & Bakery Products	0.263	0.549	1.097	1.648
Misc. Food Products	0.285	0.595	1.189	1.787
Non-Alcoholic Beverages	0.170	0.353	0.707	1.062
Alcoholic Beverages	0.147	0.306	0.613	0.921
Tobacco	0.089	0.185	0.369	0.555

Table 6. Raise production of bioethanol and sweet potatoes on Taiwan’s New Energy Sector Output using TAIGEM-E model

Unit : %

Industrial Output	2009	2010	2011	2012
New Energy Sector				
Wind Power	0.032	0.066	0.132	0.198
Solar Cell	0.041	0.085	0.170	0.255
Slolar Heating	0.115	0.240	0.479	0.720
Biodiesel	0.161	0.337	0.674	1.013
Bioethanol	18.040	37.600	75.180	113.100
Hydrogen	0.078	0.163	0.326	0.489
FuelCell	0.095	0.197	0.394	0.592
IGCC	0.009	0.019	0.038	0.057
Cogeneration	0.011	0.023	0.046	0.069

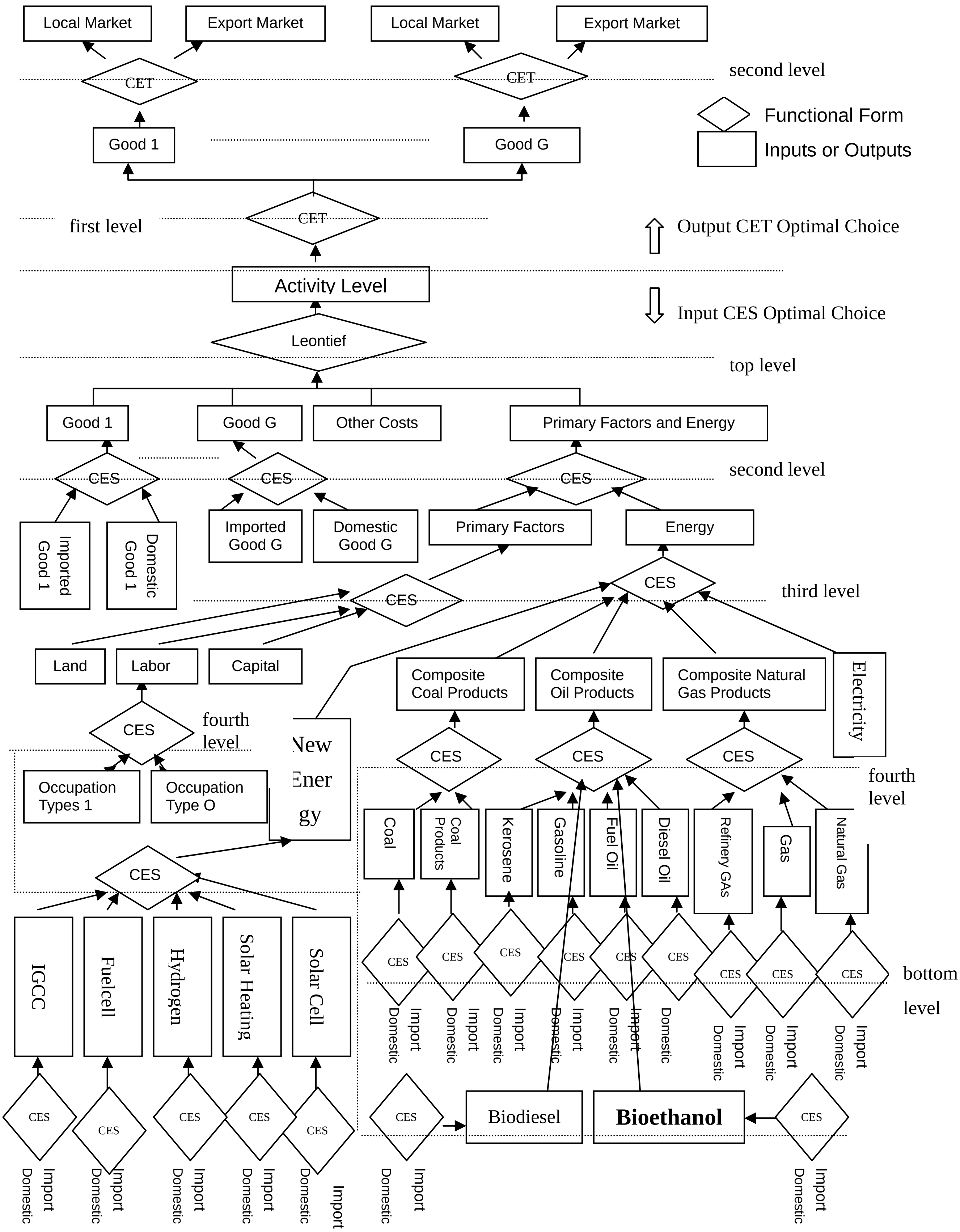

Figure 1. Structure of production function: non-electricity sectors

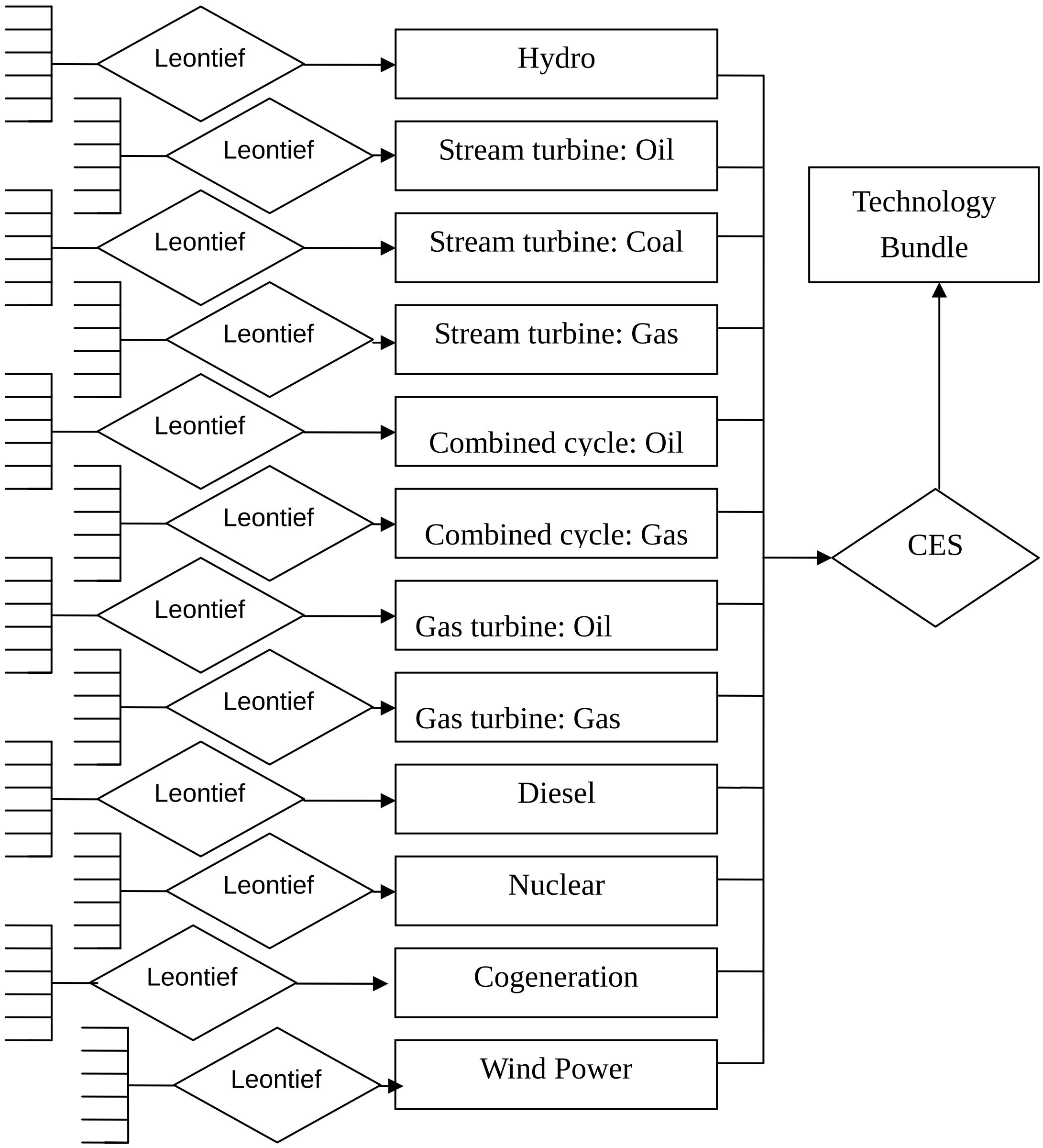

Figure 2. The technology bundle of TAIGEM-E model for electricity sectors.

		Absorb Matrix					
		1	2	3	4	5	6
		Producer	Investor	Household	Export	Government	Inventory
	Dimension	I	I	1	1	1	1
Basic Flow	C×S	***V1BAS***	***V2BAS***	***V3BAS***	***V4BAS***	***V5BAS***	***V6BAS***
Tax	C×S	***V1TAX***	***V2TAX***	***V3TAX***	***V4TAX***	***V5TAX***	
Labor	O	***V1LAB***					
Capital	1	***V1CAP***					
Land	1	***V1LND***					
Other Cost	1	***V1OCT***					

I = Industry
C = Commodity
S =Domestic or Imported
O = Occupation
Bads = commodity emits CO2

	Producer
Dimension	I
Bads*S	*CO_2 Emission*

	Capital Accumulation
Dimension	1
I	*STOK*

	Production
Dimension	I
C	***MAKE***

	Tariff
Dimension	1
C	***V0TAR***

Figure 3. Input-output database for TAIGEM-E model.

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Figure Captions

Fig. 1. Structure of production function: non-electricity sectors

Fig. 2. The technology bundle of TAIGEM-E model for electricity sectors.

Fig. 3. Input-output database for TAIGEM-E model.

Table Captions

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