CGE Linkage with AIM/Enduse: Assessing Energy Intensity Reduction Target in China

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Background

- Energy consumption in China is large in volume and shows rapid growth in the past 20 years.
- Therefore, in 11th Five-Year Plan (2006-2010) Chinese government set the target that energy consumption per GDP should be ***20%*** decline in 2010 from the level of that at the end of 2005.
- This experiment is to link Top-down model with Bottom-up model and analyze the possibility of the above target and propose policy suggestions.

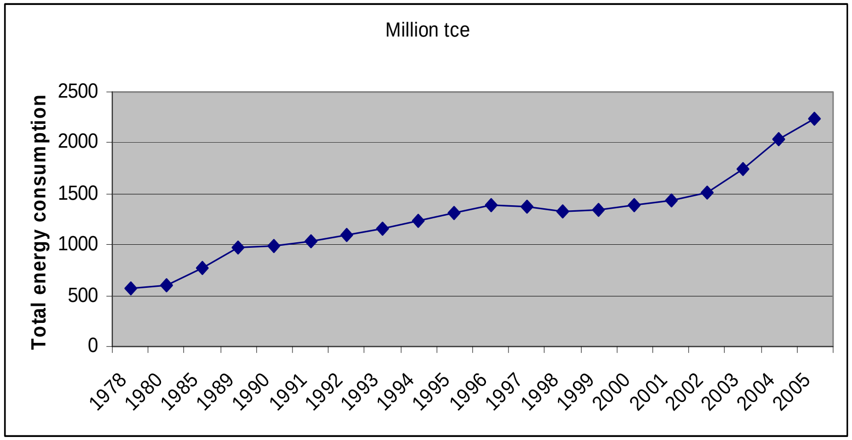


Fig 1: Energy consumption from 1978 to 2005

Why to Link Two Models (1)

Bottom-up vs. Top-down

- Two basic approaches to examine the linkages between the economy and energy system.
- Conventional Bottom-up (BU) models:
  - describe current and prospective competition of energy technologies *in detail*, both on the ***supply-side*** (substitution possibility between primary energies) and on the ***demand-side*** (end-use energy efficiency and fuel substitution), e.g. MARKAL
- Conventional top-down (TD) models:
  - dominated by Computable General Equilibrium (CGE) models since 1980's,
  - represent real-world micro-economic responsiveness to policies, such as substitutability of energy for other inputs or consumption goods (Hourcade, 2006).

Why to Link Two Models (2)

BU and TD Limitations

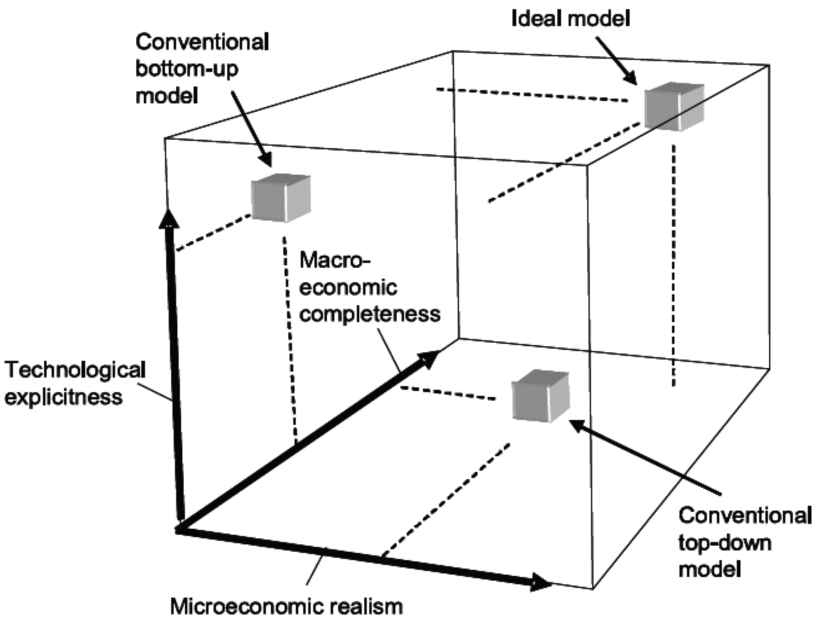


Fig. 2: Three-dimensional Assessment of Energy-Economy Models (Hourcade, 2006)

- BU models do well in terms of technological explicitness, but less well in terms of macro-economic completeness and general micro-economic realism.
- TD models do well in the latter terms, but they fail to represent detailed technology information and thus fail to represent the potential for no-regret options over the short run and substantially different technological futures over the long run.

Why to Link Two Models (3)

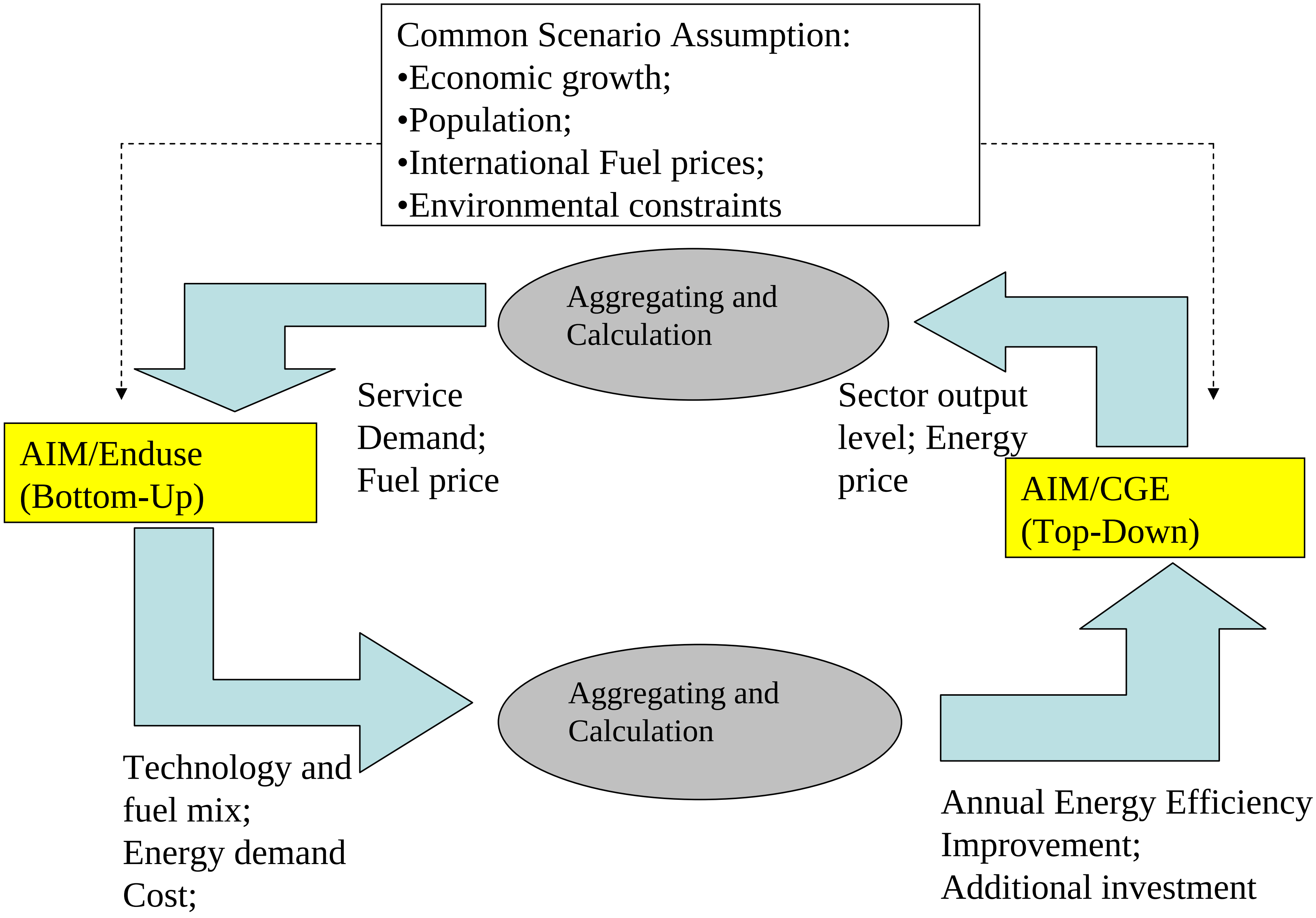
- In order to compensate for the limitations of one approach or the other, a number of researchers have tried to develop “hybrid” models.

- The first example was reported by Hoffman and Jorgensen in 1977. They linked the Brookhaven energy system optimization model and an econometric model;

- Since 1990’s, more teams are making efforts in building hybrid model

How to Link Two Models

Methodology in Our Study


Common Scenario Assumption:
•Economic growth;
•Population;
•International Fuel prices;
•Environmental constraints
Aggregating and Calculation
Service Demand; Fuel price
Sector output level; Energy price
AIM/Enduse (Bottom-Up)
AIM/CGE (Top-Down)
Aggregating and Calculation
Technology and fuel mix; Energy demand Cost;
Annual Energy Efficiency Improvement; Additional investment

Advantages and Disadvantages

- The advantages of this procedure are:
  - It is cost-effective to link existing well-documented and tested models than designing new models for the whole system or interconnection of systems;
  - it is more flexible, leaving the constituent model intact for independent runs, thus making further model development an easier work;
- Comparing to hard-linking, it has the following Shortcomings:
  - Difficulties in uncertainty analysis
  - Problem of maintaining the quality of the soft-linking when it is transferred to other users
- Soft-linking seems the most practical starting point for linking models.

AIM/CGE China Model Description (1)

Static Part

- Production & Consumption: Nested CES function
- International Trade:
  - Small open economy assumption
- Environment: CO_2 & SO_2
- 2002 Input-Output (IO) table
  - Historical data: 2003-2005;
  - Simulation period: 2006-2010;
- 38 sectors, including 8 energy goods

  Coal, raw oil, natural gas, oil products, coke, electricity, heat, and coal gas
- Software: GAMS/MPSGE

AIM/CGE China Model Description (2)

Recursive Dynamic

- Simulation is iterated year by year. The main driving forces of the economic growth are the labor force, capital accumulation, and technology change.
- Total investment is decided from expected GDP growth rate in the next period, present capital stock, and technology change
- The total investment is distributed into each sectors based on logit function taken into account profit from capital.
- The capital stock in each sector is estimated from the investment.

$$I_{TOT,t} = CAP_t * \left[\delta + \left\{ \frac{(1+g_{t+1})}{(1+l_t)^{\alpha_L}} \right\}^{\frac{1}{\alpha_K}} - 1 \right] \quad (1)$$

$$I_{j,t+1} = I_{TOT,t+1} * \frac{\left(\frac{PK_{j,t}}{PK_{j,t=1}}\right)^{\gamma} * I_{j,t=1}}{\sum_j \left\{ \left(\frac{PK_{j,t}}{PK_{j,t=1}}\right)^{\gamma} * I_{j,t=1} \right\}} \quad (2)$$

$$CAP_{j,t+1} = CAP_{j,t} * (1-\delta) + I_{j,t} \quad (3)$$

AIM/CGE China Model Description (3)

Scenarios

	Reference Case (BAU)		
	Scenario1	Scenario2	Scenario3
Annual GDP Growth Rate	7.5%	8.5%	9.5%
Additional Policy Measures	None	None	None

- Scenarios
- Other assumptions:
  - Labor supply;
  - Productivity change of labor;
  - Future international price;
  - Depreciation rate for capital stock: 5%
  - Change of preference in household sector
  - Energy efficiency improvement;

AIM/Enduse China Model

- Energy end users are divided into five sectors:
  - the industrial, agricultural, services, residential and transport sectors.
- Every sector is split into several sub-sectors, or products or services mode. Totally, there are about 60 sub-sectors and 160 kinds of service demands.
- Different technologies related to the demand for services are collected for every sub-sector and product.
  - Technologies for services production
  - Technologies for energy recovery utilization
  - Technologies for energy conversion
- More than 500 technologies have been collected for the analysis, which cover the major technologies used in every sector.

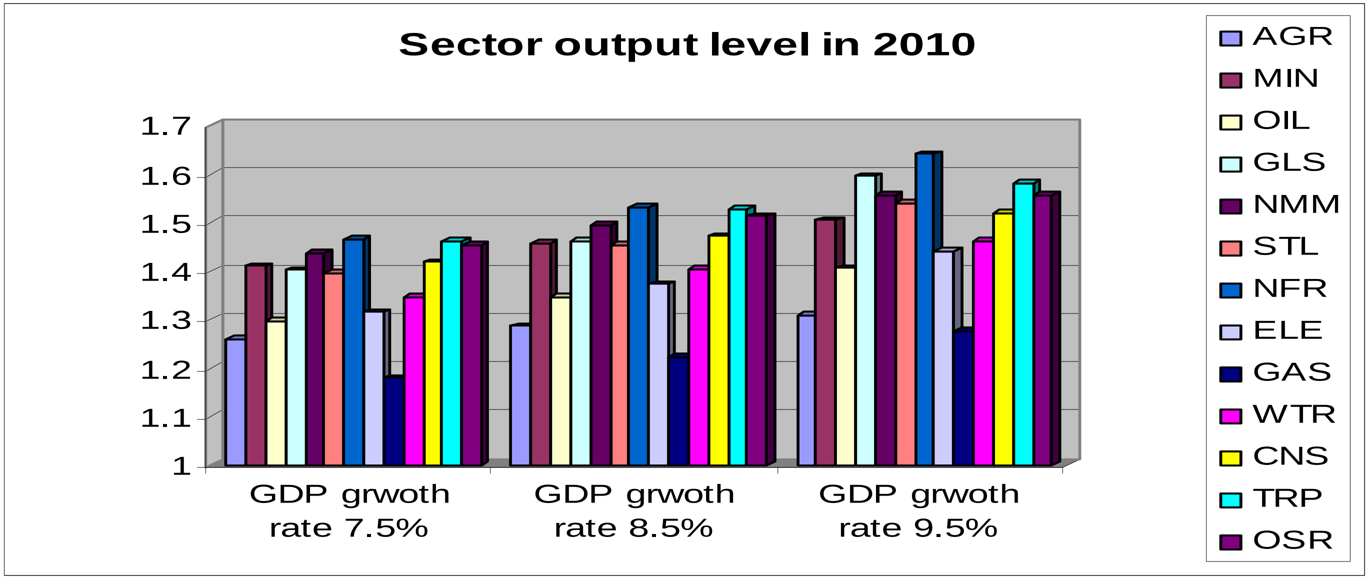
Preliminary Simulation Results

First Run of CGE (1)

- Annual Energy Efficiency Improvement (AEEI): 2.5%;
- Run CGE for the first time

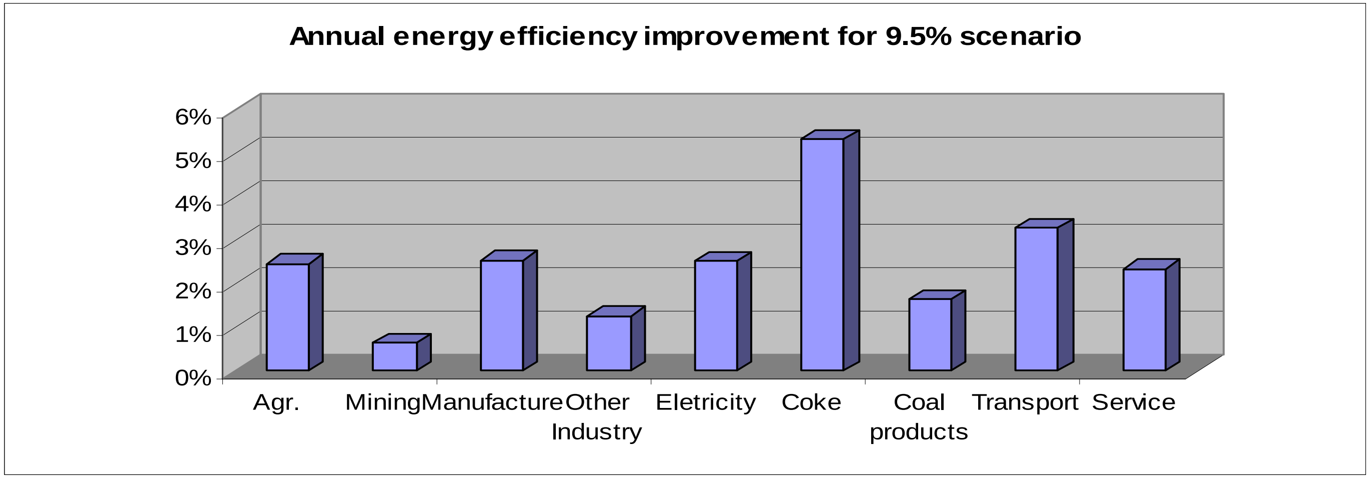
First Run of CGE (2)

Important Results for AIM/Enduse



Note: Sector output level in 2005 =1;

Feedback from AIM/Enduse



Based on energy demand from Enduse model and output level from CGE model

$$AEEI_j = 1 - \sqrt[5]{ED_{2010,\ j} / ED_{2005,\ j}}$$

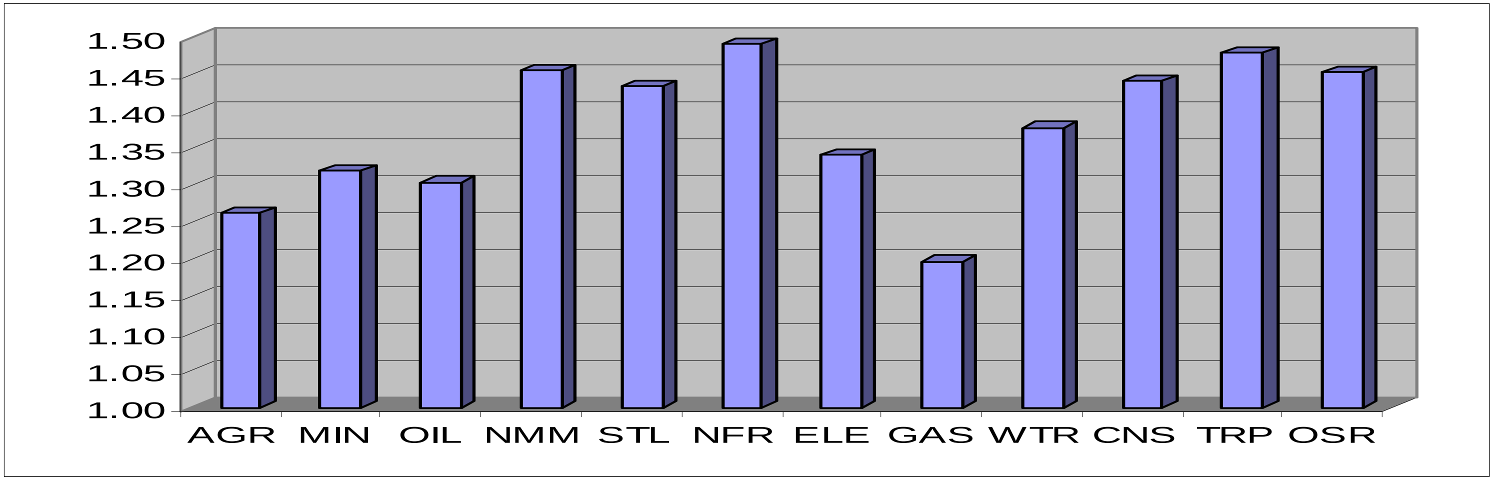
ED_{2010}, ED_{2005}: Energy demand per unit output in the year of 2010 and 2005 respectively;
j: sector

Second Run of CGE

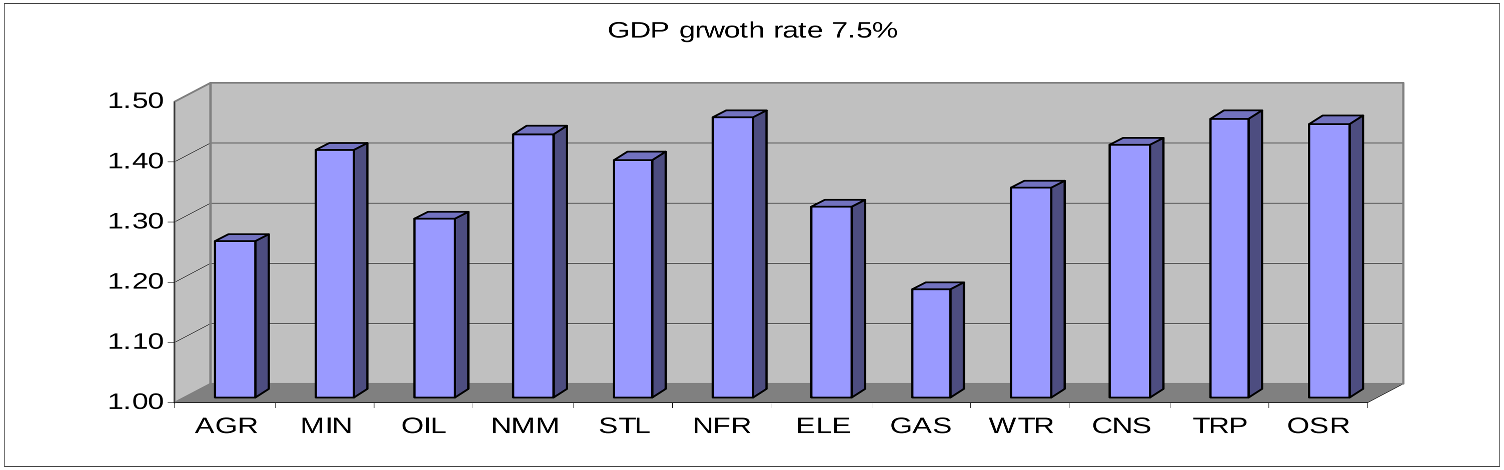
- Update assumption on AEEI
- Run CGE for the second time

Comparison between First Run and Second Run

Sector Output Level



Second Run



First Run

Comparison between First Run and Second Run

Energy Consumption

Unit: Mtce

	GDP growth rate 7.5%	GDP growth rate 8.5%	GDP growth rate 9.5%
2005	2067.81	2067.81	2067.81
2006	2162.014	2179.109	2182.192
2007	2266.386	2312.941	2328.179
2008	2377.507	2456.767	2488.148
2009	2496.276	2612.894	2663.778
2010	2623.004	2781.972	2854.71

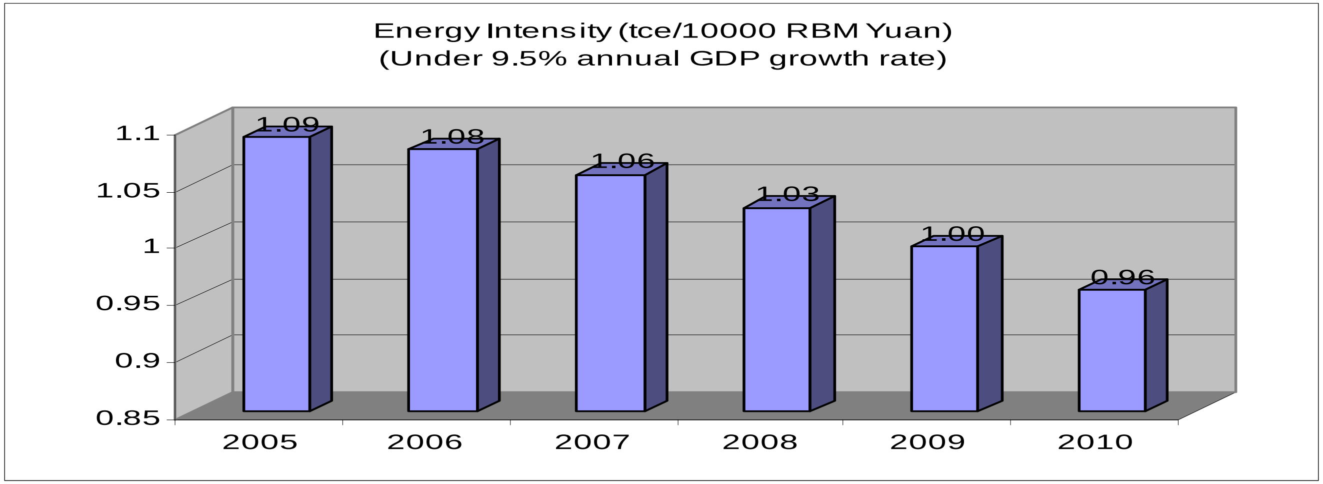
Second Run

	GDP growth rate 7.5%	GDP growth rate 8.5%	GDP growth rate 9.5%
2005	2067.81	2067.81	2067.81
2006	2189.025	2205.762	2207.364
2007	2296.847	2334.505	2375.308
2008	2406.587	2466.718	2555.811
2009	2519.133	2604.326	2750.339
2010	2634.721	2747.584	2958.765

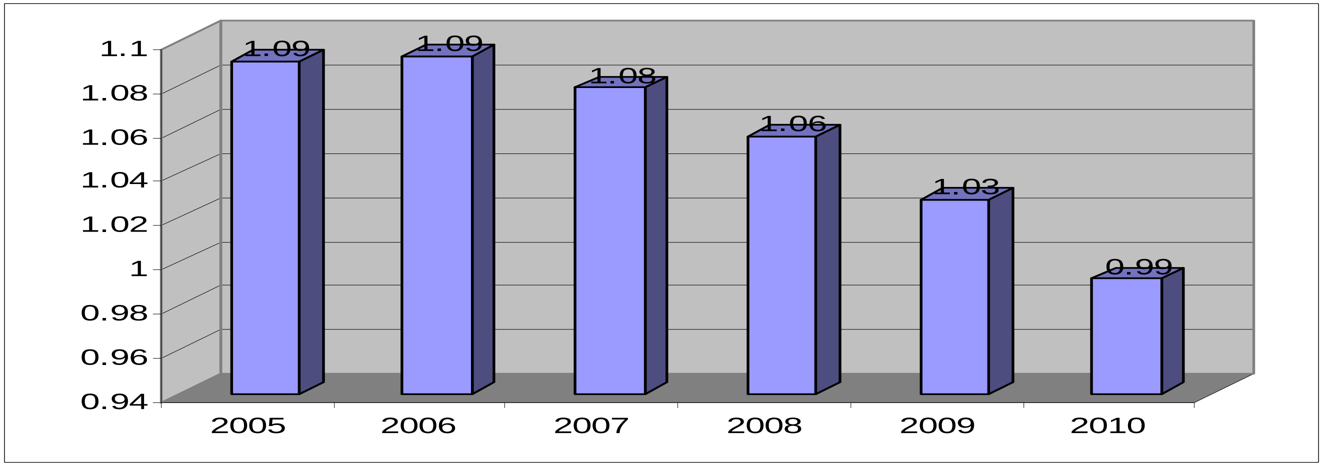
First Run

Comparison between First Run and Second Run

Energy Intensity

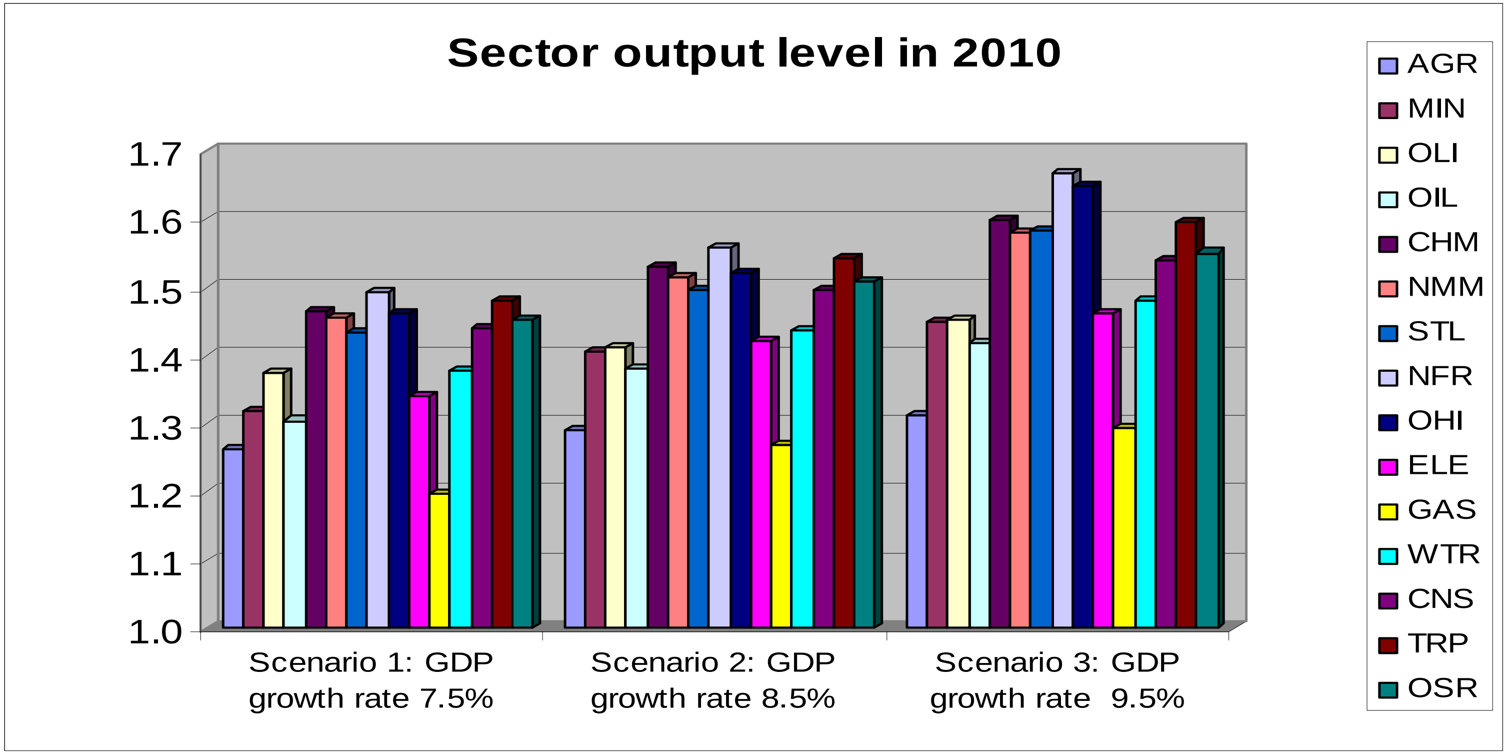


Second Run, EI reduction: 12.8%



First Run, EI reduction: 9.1%

Feekback from Second Run of CGE to AIM/Enduse



Note: Sector output level in 2005 =1;

Further Iteration

- Second run AIM/Enduse
- Update assumptions in CGE and run CGE for the third time, and so on
- Until the differences between last run and present run are very small

Primary Findings

Unit: tce/10000 RMB Yuan

	Energy Intensity for 9.5% Scenario in Reference Case
2005	1.091
2006	1.08
2007	1.058
2008	1.029
2009	0.995
2010	0.957
Energy intensity reduction	12.28%

- Under the reference case, the 20% reduction target can't be achieved.
- It is necessary to take some policies to achieve that target.
  - Investment policies;
  - Subsidies
  - Energy efficiency standard
  - Energy tax

Further Work

- Improve and complete the simulation for three scenarios under reference case

- Introduce policy measures into the hybrid model
  - Investment policies;
  - Export tax
  - Energy tax/Environmental tax

- Provide suggestions for next Five-year Plan

Thank you!

Your comments are welcome!

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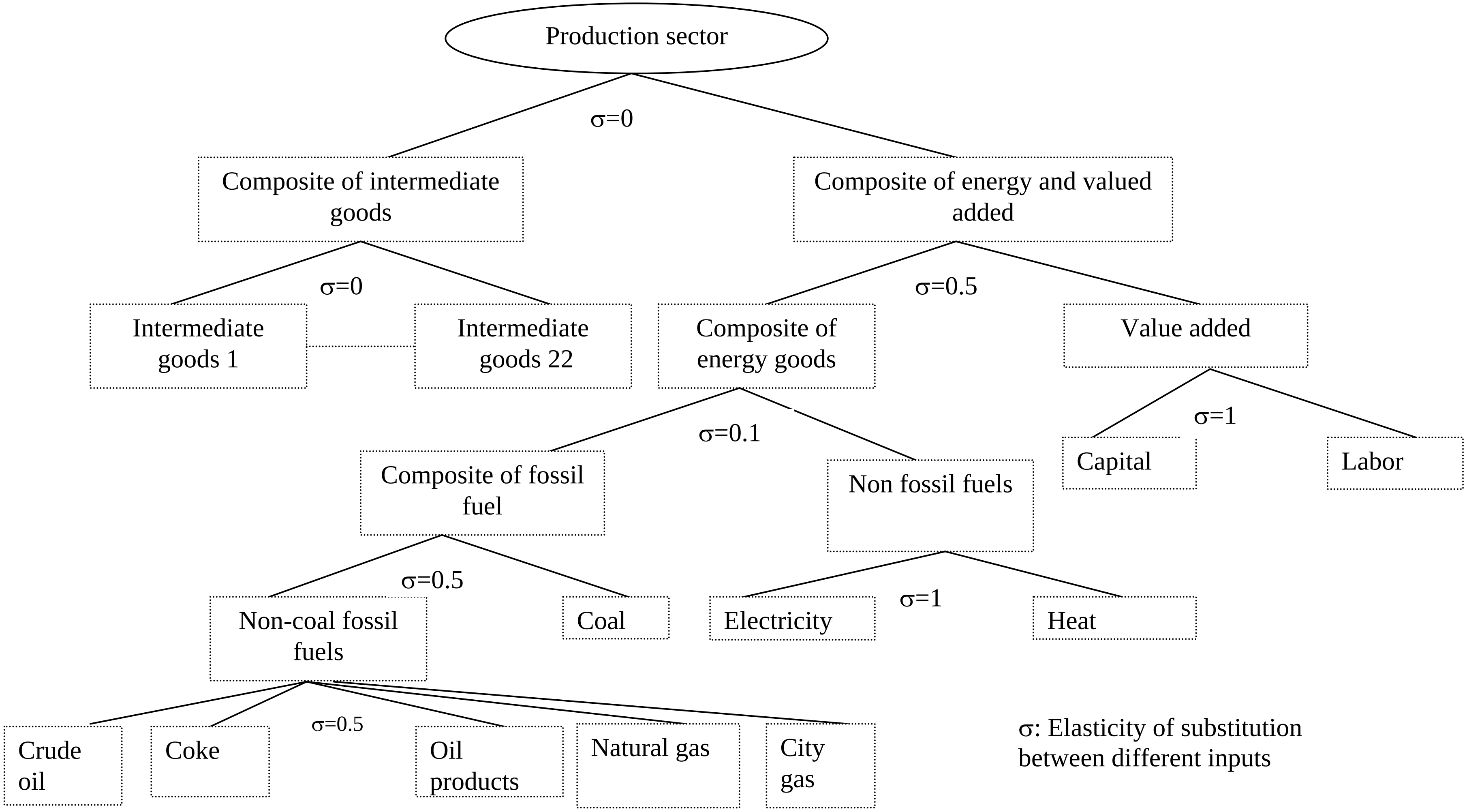
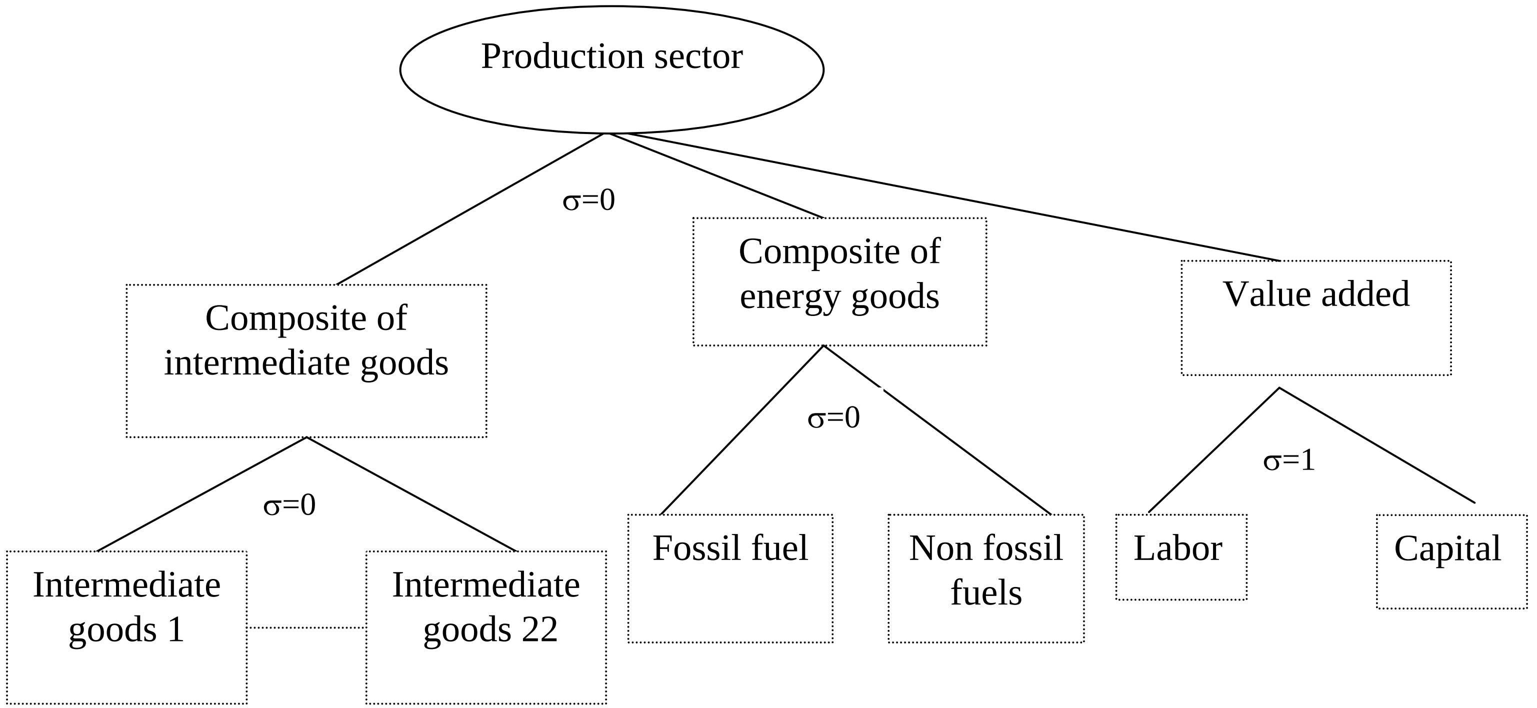
Appendix: Nesting of the production structure in non-energy sector

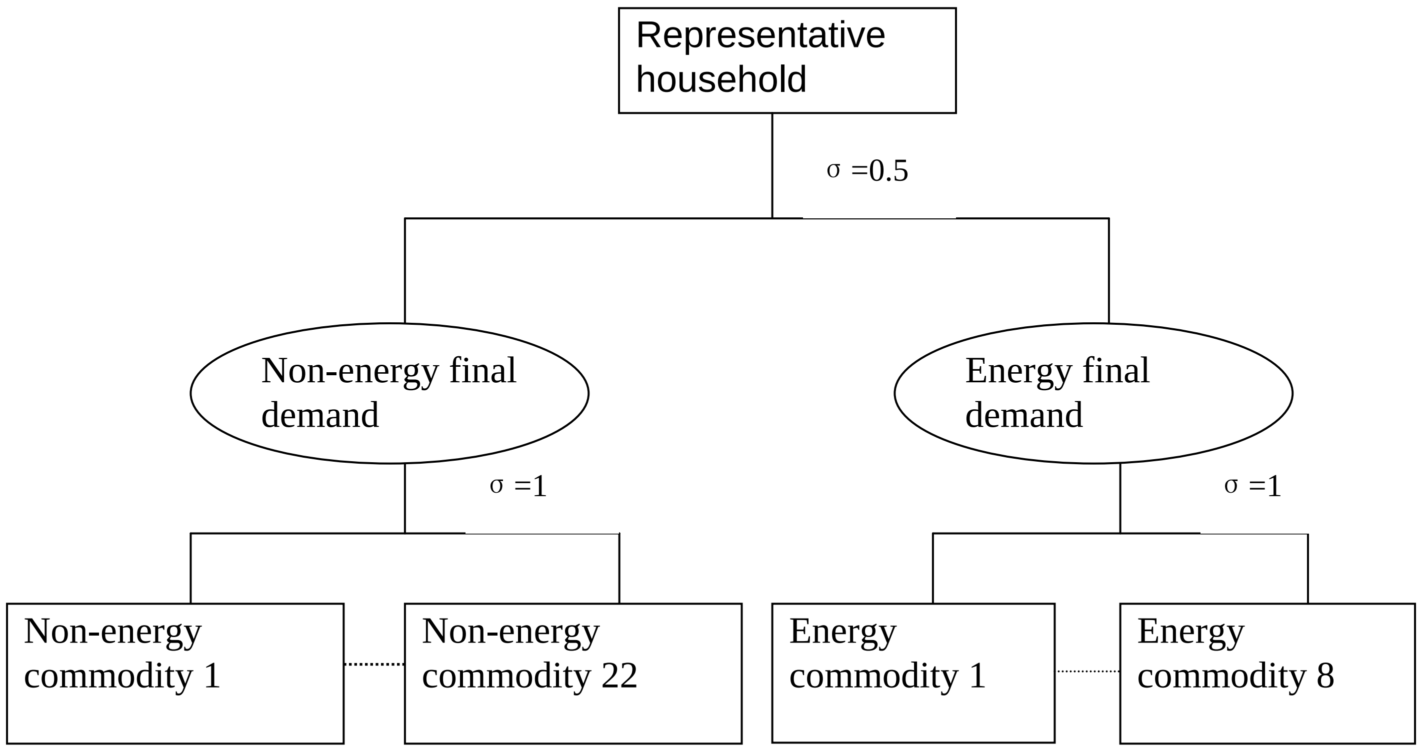


Nesting of the production structure in energy sector



σ: Elasticity of substitution between different inputs

Nesting of the consumption structure



Relationship between domestic market and international market