GTAP-E: MEASURING THE IMPACT OF ENERGY POLICY

Andre Barbe
Wen “Jean” Yuan
Fernando Perobelli
Parth Goyal
Daniel Brown
Jodie Patron

WHAT IS GTAP-E?

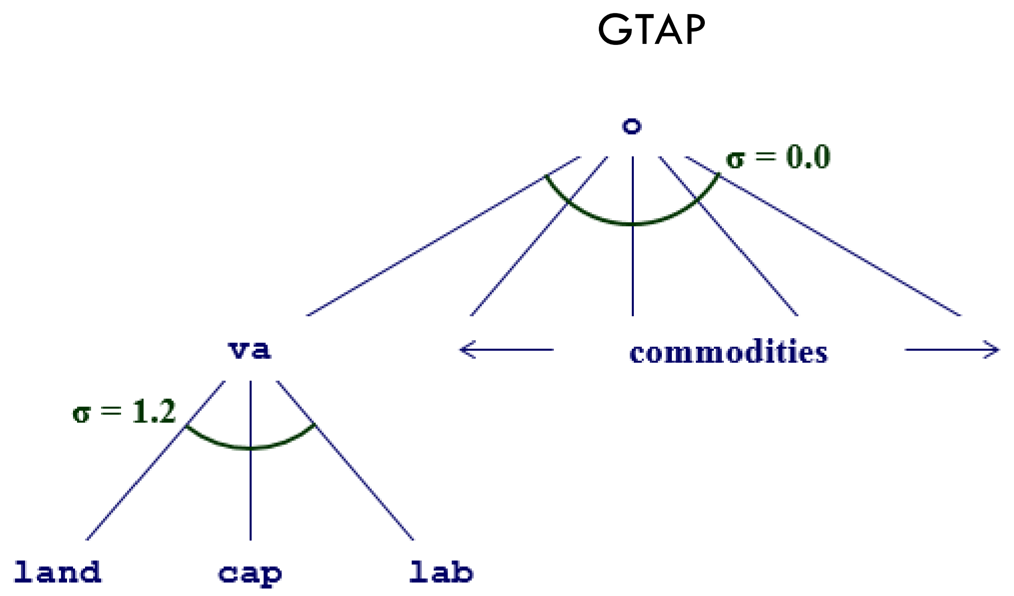
Energy and Environmental Policy Modeling:

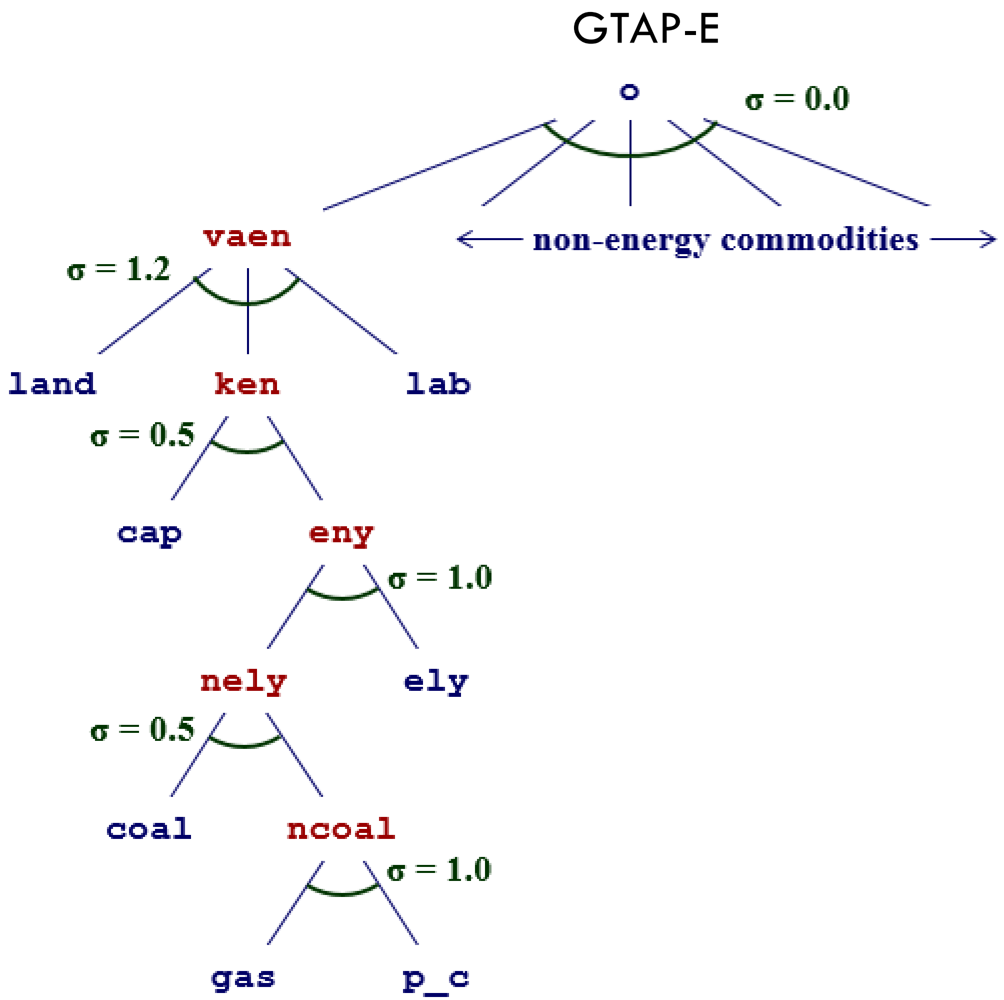
- Carbon Tax
- Cap and Trade

Key features:

- Detailed structure for energy production and consumption
- Accounting for CO_2 emitted by consumption of fossil fuels for each user and region

PRODUCTION STRUCTURE: MORE SUBSTITUTION





ORIGINAL PAPER

Research question: Who pays the cost of emission reductions? Can emission trading reduce these costs?

Experiment A: No flexibility. Developed countries cap carbon emissions. Developing countries do not. Emission trading between countries is not allowed.

Experiment B: Developed trading. As A but now emission permits can be traded within developed countries.

Experiment C: All trading. As A but developing countries cap emissions at 2007 levels. Permits can now be traded between any countries.

RESULTS

Emission reduction with no flexibility lowers everyone's welfare

- even developing countries who don't abate lose welfare

More flexibility in emission trading reduces the aggregate cost of emission reductions

- Many developing countries who can sell emission permits gain welfare

OUR EXTENSIONS

Extension 1: No longer assume fixed current accounts balance

Extension 2: The impact increasing energy efficiency

Extension 3: Coal-non coal substitution

FIXED OR FLEXIBLE CURRENT ACCOUNT BALANCE IN GTAP-E

Andre Barbe and Wen Jin "Jean" Yuan

FIXED CURRENT ACCOUNT BALANCE IN GTAP-E

Standard closure in the GTAP-E: Based on WALRAS/Green Modeling → Investment adjusting to Fixed Trade Balance (saving) for each country

Problem:

- Under fixed Current accounts balance, different countries can have (very) different rates of return

Solution:

- Turn Current Accounts balance endogenous

SIMULATIONS

Simulation with Fixed Trade

- Developed countries reduce emissions with no emission trading.
- Standard GTAP-E Closure (Fixed Trade Balance)

Simulation with Flexible Trade

- Developed countries reduce emissions with no emission trading. Alternative Closure
- Endogenous Trade Balance and RORDelta=1

WELFARE IMPACT OF DIFFERENT ASSUMPTIONS

($ millions)	Fixed Trade	Flexible Trade	Difference
1 USA	-10849	-13237	-2388
2 EU27	-26081	-22851	3230
3 EEFSU	-11006	-9968	1038
4 JPN	-29392	-40716	-11324
5 RoA1	-36295	-48796	-12501
6 EEx	-23814	-19902	3912
7 CHN	-3192	2248	5440
8 IND	2106	4160	2054
9 ROW	-176	10962	11138

CHINA: CAPITAL INFLOWS

Investment - Savings	Increase under Flexible Trade (%)
7 CHN	1.6

Macroeconomic Identity: M-X=I-S

I-S increases => M-X increases => factor prices increase

CHINESE FACTOR PRICES INCREASE

Factor	Price Increase under Flexible Trade (%)
1 land	1.232
2 Unsklab	1.154
3 Sklab	1.132
4 capital	1.336
5 NatRes	-0.857

CHINA: FOB PRICE OF CHINESE EXPORTS GOES UP

Sector	FOB Price Increase under Flexible Trade (%)
1 Agriculture	0.4
2 Coal	0.3
3 Crude Oil	0.26
4 Gas	0.26
5 Oil Products	0.26
6 Electricity	0.32
7 Energy Intensive Industry	0.27
8 Other Industries and Services	0.3

CHINA: TERM OF TRADE BREAK-DOWN

Disaggregated Impact of Terms of Trade on Welfare in China, by Sector ($ million)

	World Price Effect	Export Price Effect	Import Price Effect	Total
1 Agr	-22.53	26.14	-22.7	-19.1
2 Coal	-9.1	-32.8	3.5	-38.4
3 Oil	-1873	-10.7	112	-1771
4 Gas	-6.75	-1.16	1.98	-5.97
5 Oil_pcts	-74.4	7.65	-24.3	-91
6 Electricity	-32.2	60.5	-19.7	8.23
7 Energy Intensive Industries	837	1267	228.7	2333
8 Services	-156.9	2333	616.2	2793
Total	-1338	3650	897	3209

CHINA: DECOMPOSING CHANGES IN WELFARE

Increase in welfare when relaxing fixed trade balance assumption

Source	Welfare Increase ($millions)
CO2 Trading	0
Allocative	2690.5
Endowments	0
Technology	0
Population	0
Terms of Trade	3208
Investment-Savings	-460
Preferences	0
Total	5440

Increased Chinese welfare primarily from Terms of Trade improvement

CONCLUSION

If current accounts balance can’t change, terms of trade is less important

Terms of Trade can turn losers into winners

If you think rates of return change investment across regions, some countries benefit from climate change mitigation

Purdue University
GTAP
Global Trade Analysis Project

Sensitivity Analysis in the GTAP-E Model under worldwide emissions trading scenario

Fernando Perobelli – Brazil

Parth Goyal – India

under the guidance of Robert McDougall and Jeffrey Peters

Context and Background

Research Question	What is the impact of change in elasticity of substitution in non-electrical energy sub-production on: (i) costs of CO2 abatement (ii) Level of CO2 emissions – A case study for China (KEEP IT SIMPLE, STUPID!!)
Motivation	• More than 40% of the electricity generated in the world is sourced from **coal** • **China** is the world's largest consumer of coal with **~70%** of the electricity capacity fueled from coal • In this scenario is it reasonable to assume elasticity of substitution between coal and non coal for energy production σ_{NELY} = 0.50?
Experiment Design	**Design 1**: Standard GTAP-E closure, sensitivity analysis by changing elasticity of substitution between coal and non coal for energy production **Design 2**: Modified closure with worldwide carbon tax as exogenous and changing elasticity of substitution between coal and non coal for energy production
Summary of results	**Design 1**: A reduction (increase) in σ_{NELY} increases (reduces) the cost of abatement of CO2 emissions by ~10% (~8%) **Design 2**: In the case of China, a reduction (increase) in σ_{NELY} increases (reduces) CO2 emissions by ~1% (1%) on account of increased (decreased) use of coal for electricity generation

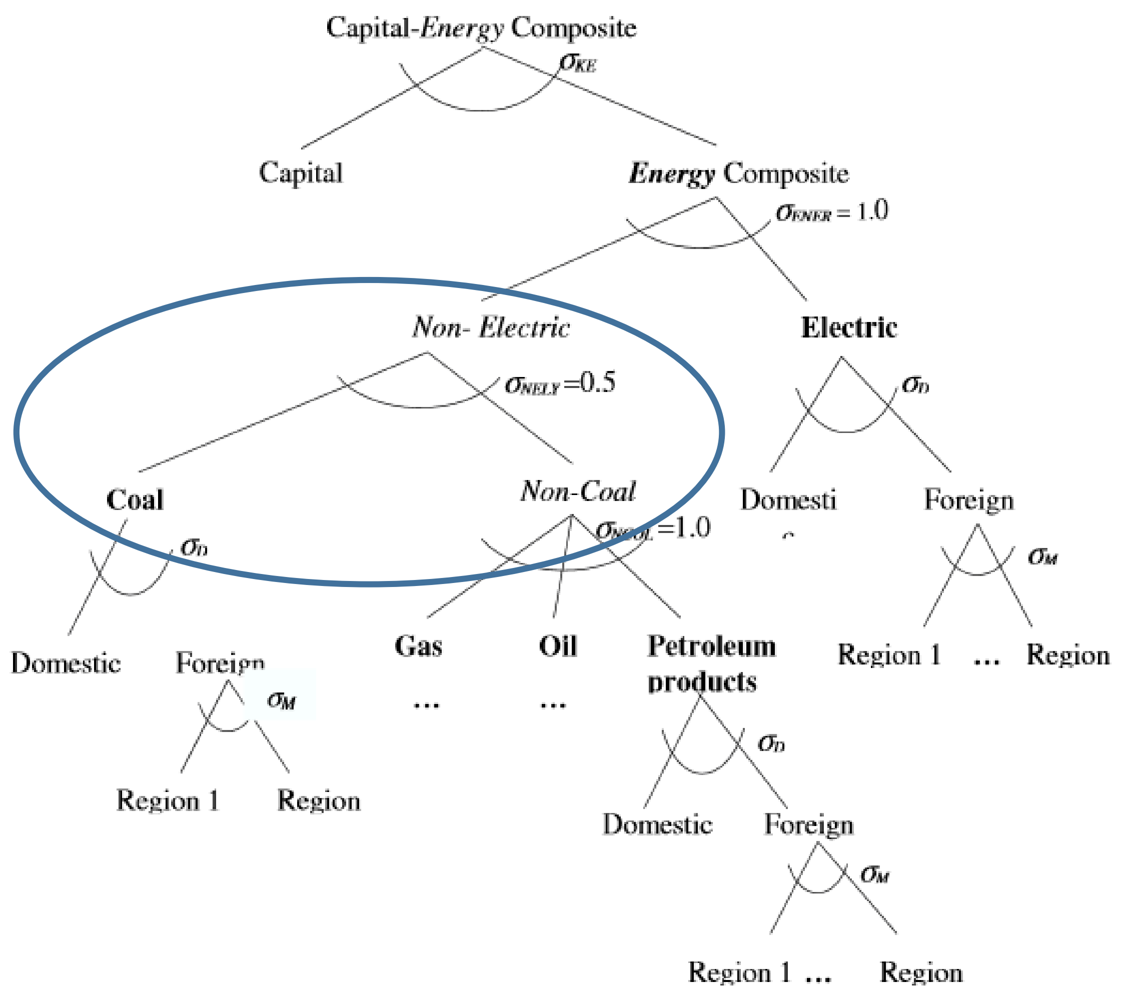
Structure of the experiment design

- Focus is on the *non-electric component* of **energy composite structure** under the GTAP-E capital-energy nested tree

- Conventional GTAP-E model assumes σ_{NELY} = elasticity of substitution in non-electrical energy sub-production = **0.50**

- The experiment tries to assess the impact of changing σ_{NELY}

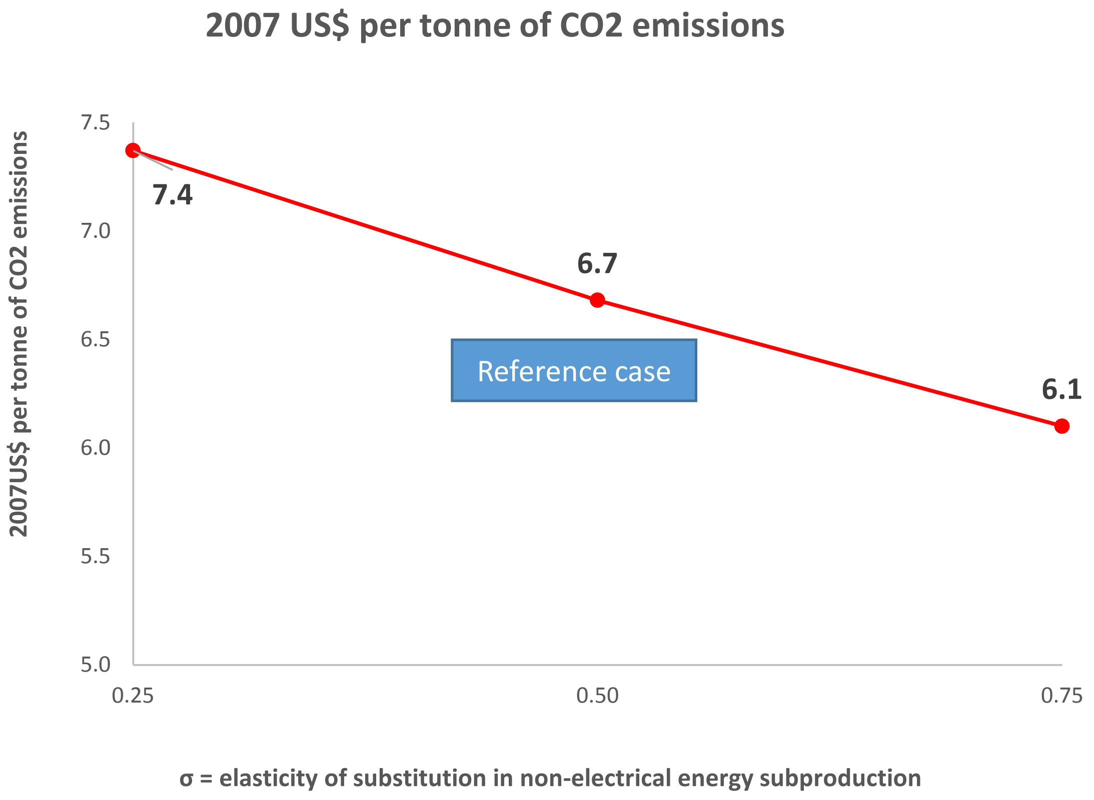
GTAP–E Capital-Energy Composite Structure



Source: Jean-Marc Burniaux* and Truong P. Truong, GTAP-E: An Energy-Environmental Version of the GTAP Model , GTAP Technical Paper No. 16 (Jan 2002)

Inverse relation between σ_{NELY} and cost of abatement of CO2 emissions

Standard Closure: shock gco2q* and estimate RCTAXB**



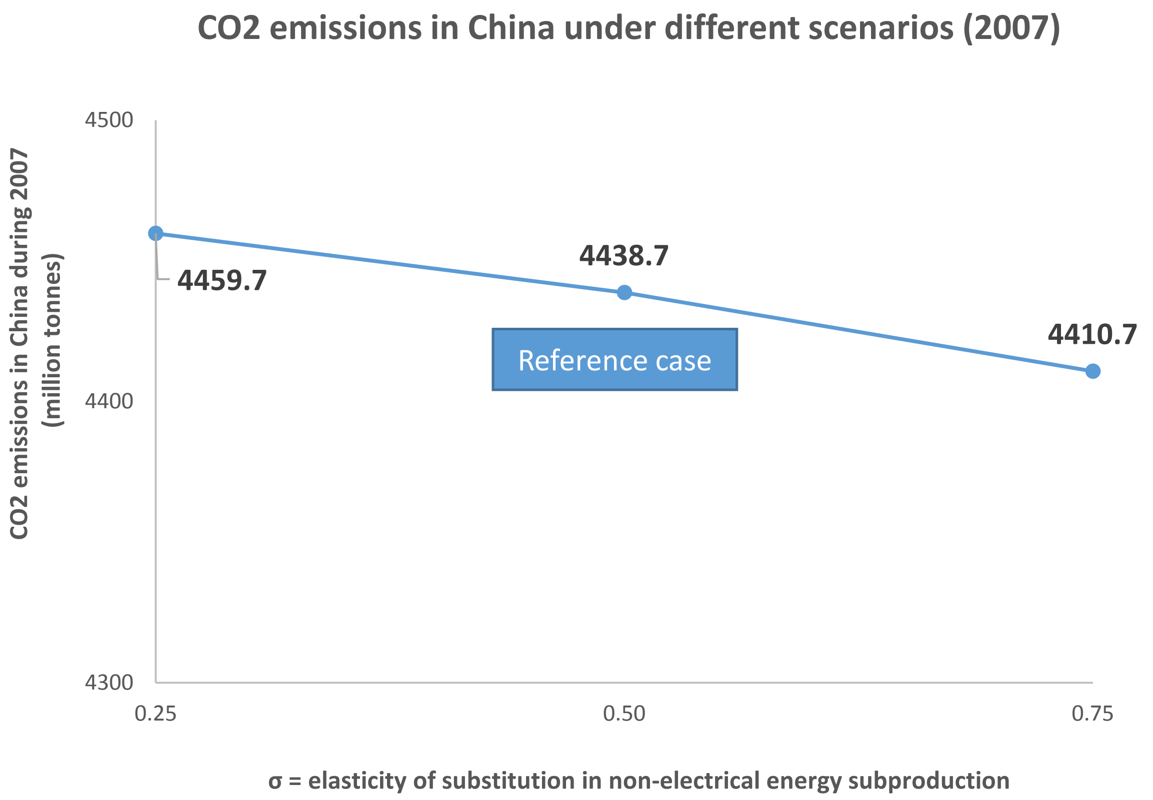
- For all countries (and regions), cost of abatement of CO2 emissions is **'same'** under each case due to worldwide emissions trading scenario
- As fuel substitution becomes **more rigid** (flexible) cost of abatement of CO2 emissions **increases** (decreases) due to **greater shift towards coal based electricity**
- **INSIGHT:** Cost of abatement of CO2 emissions are reasonably sensitive to changes in σ_{NELY}

Source: Internal analysis

gco2q = emissions quota, RCTAXB = real carbon tax rate (2007 USD per tonne of CO2)

A case study for China – impact on CO2 emissions

Modified Closure: RCTAXB is made exogenous to estimate gco2q



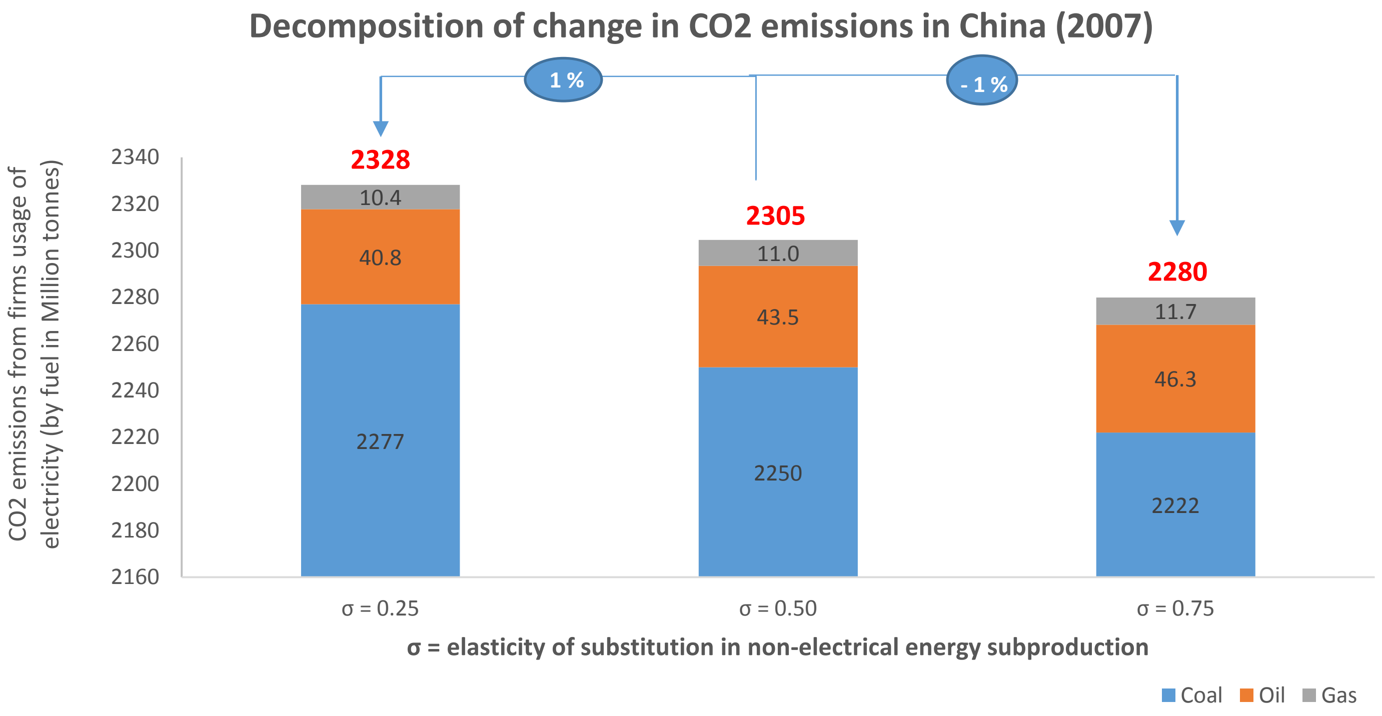
- Introduce an **exogenous carbon tax** as observed under the reference case of worldwide emissions trade scenario and **estimate the impact of change in σ_{NELY} on the total carbon emissions in China**
- As compared to the reference case, **China observes an increase in CO2 emissions** with a lower parameter value (σ_{NELY})

Source: Internal analysis

gco2q = emissions quota, RCTAXB = real carbon tax rate (2007 USD per tonne of CO2)

Decomposing the change in CO2 emissions in the electricity sector of China

CO2 changes in the firms usage of electricity from coal and non-coal fuel sources



- As predicted, China switches **towards coal** based electricity and **away from non-coal** – oil and gas ie less carbon intensive as elasticity of substitution on non-electrical energy sub-production σ_{NELY} = **0.25** < 0.50 (0.75> 0.50)
- **INSIGHT:** changes in carbon emissions are not very significant under different case, suggesting CO2 emissions are not very sensitive to changes in σ_{NELY}

Source: Internal analysis

Conclusions and key results

- Cost of abatement of CO2 emissions are **reasonably sensitive** to changes in σ_{NELY} - hence getting the parameter value is immensely important!
- For a lower σ_{NELY}, countries that are **highly dependent on coal** (and perhaps have fewer alternatives available) find it beneficial to ***switch away*** from relatively cleaner sources
- CO2 emissions are **inversely related** to the parameter value but are not significantly sensitive to any changes

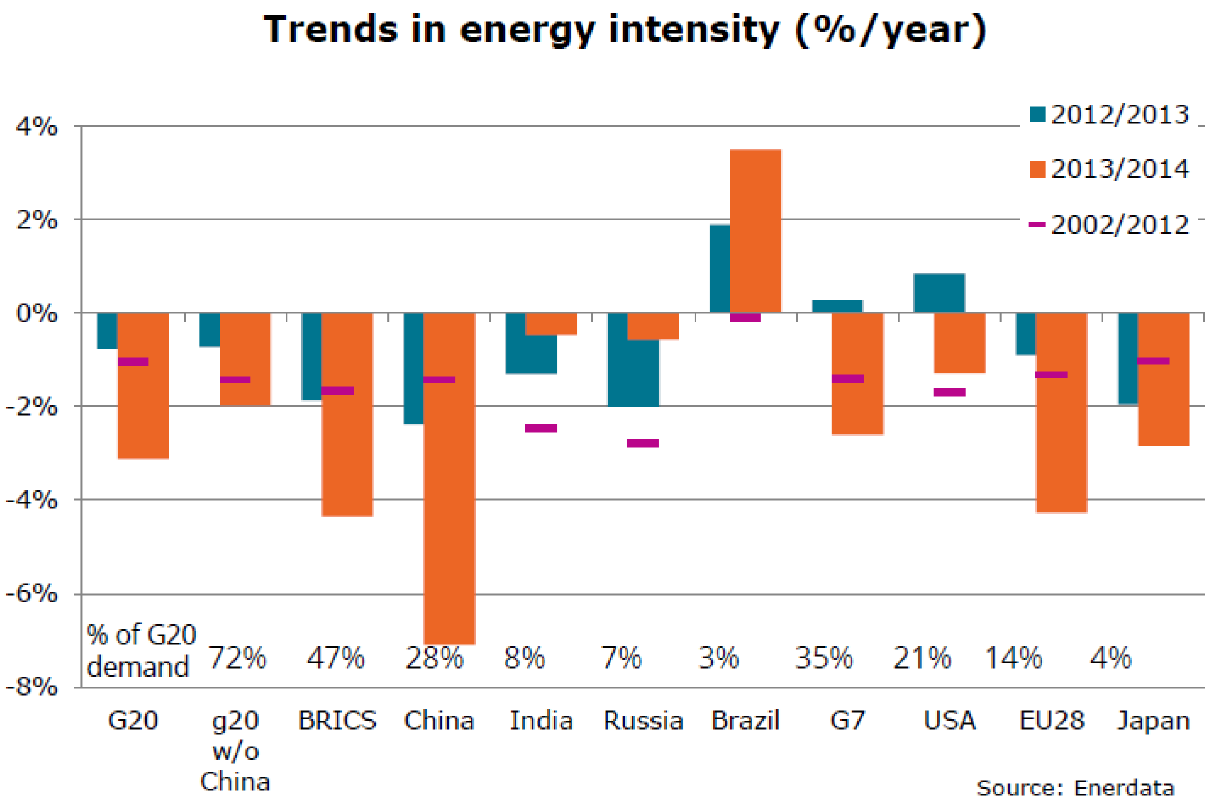
Areas of future research

- Estimate σ_{NELY} at a country (regional) level
  - costs of abatement of $CO2$ are materially sensitive to σ_{NELY}
  - countries like China and India are highly dependent on coal and have currently installed significant coal based power capacity

- Incorporating renewable energy data
  - significant emphasis on renewable technologies worldwide

GTAP-E: the impact of increasing energy efficiency

- Energy has been declining for many reasons
  - Sectoral composition
  - Investments in technology
  - Policy responses
- GTAP-E assumes a specific technology
  - No substitution between Capital and Energy for the fuel sectors (i.e. coal, gas, oil, petroleum, and electricity)
- How does an exogenous technological increase in the energy efficiency affect the trading of carbon permits? The economy in general?



Energy intensity:
energy consumption necessary to produce one unit of GDP

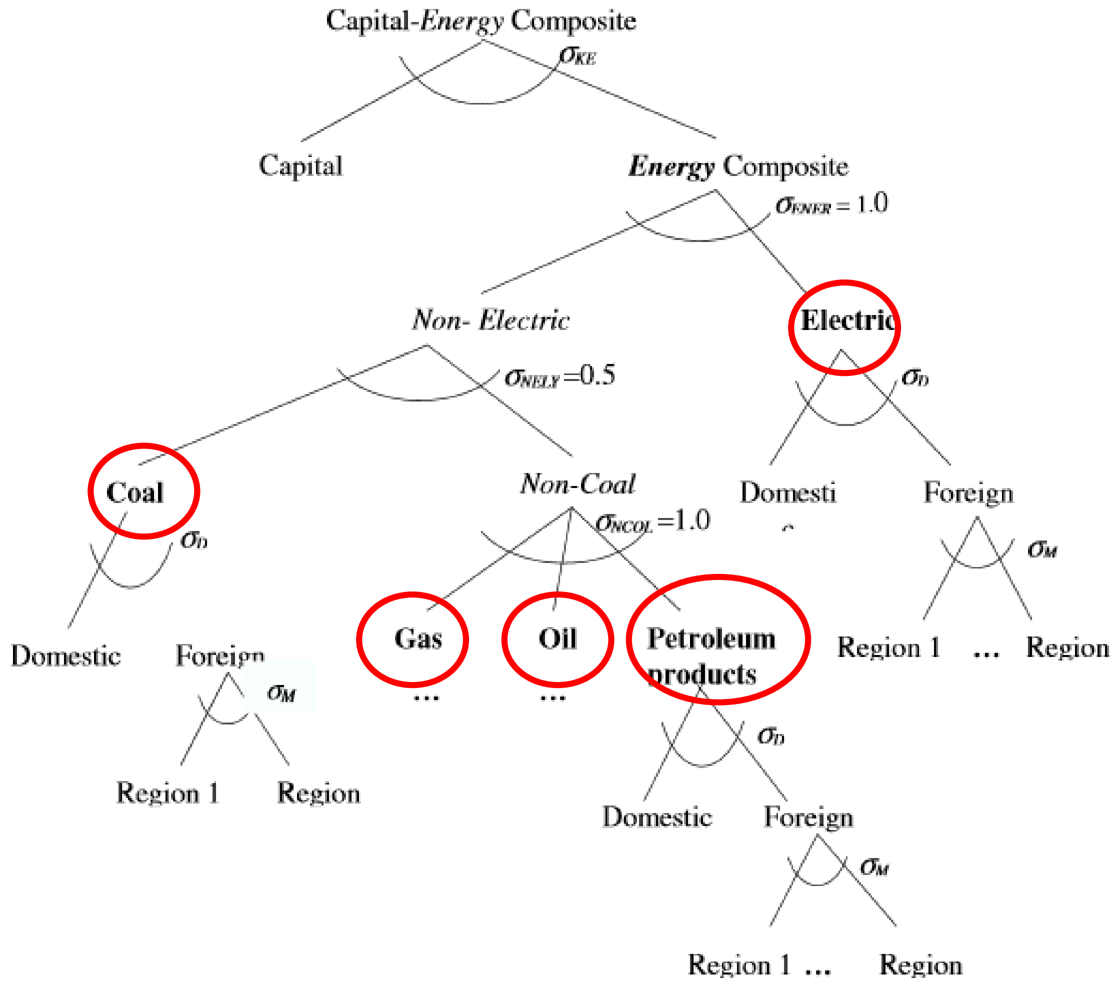
Source: Enerdata, 2014 Global Energy Trends

-5%

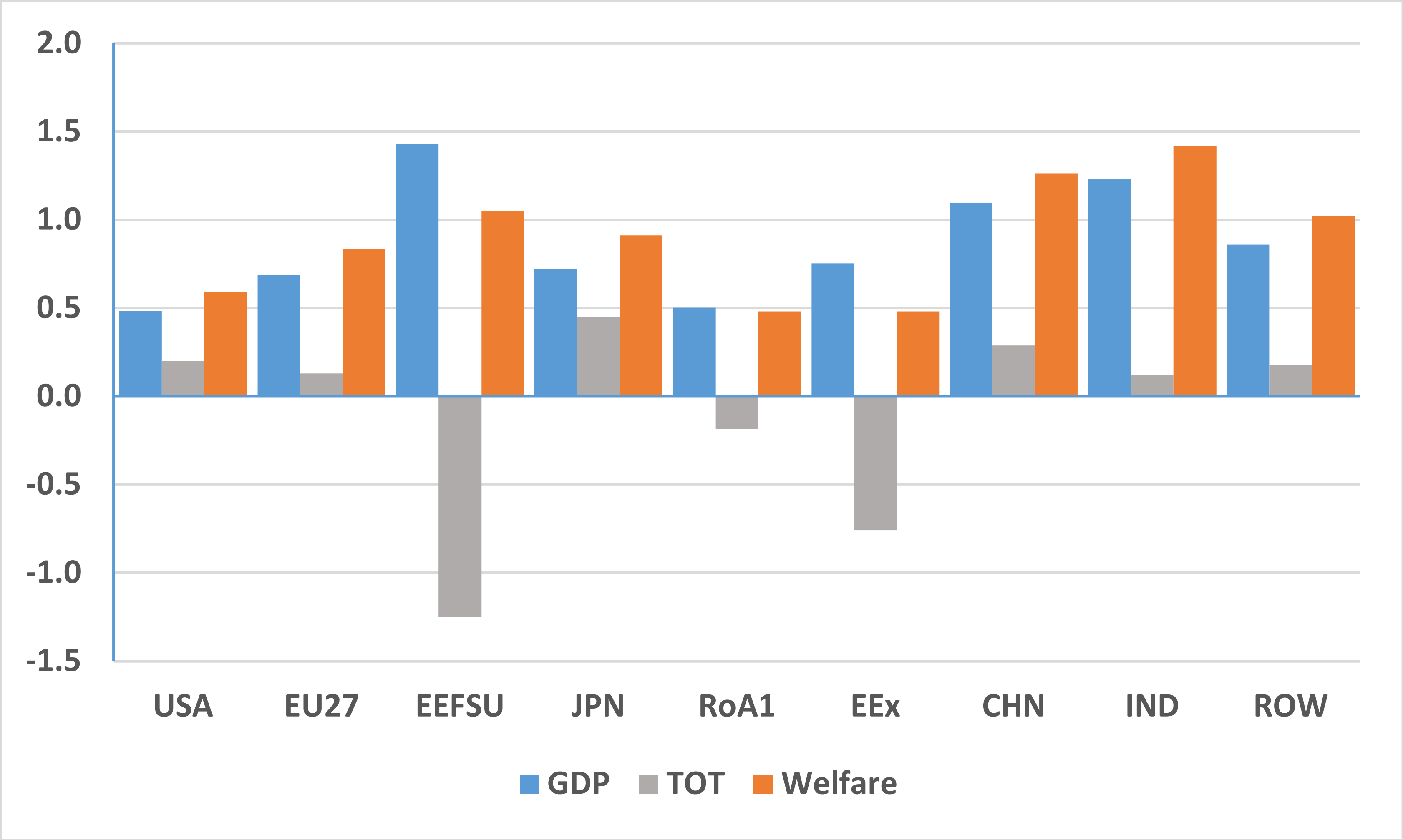
%Δ Demand for Inputs for Energy Subproduction

```
qf(i,j,r) = -af(i,j,r) + qf("eny",j,r)
       - ELFENY(j,r) * [pf(i,j,r) - af(i,j,r) - pf("eny",j,r)];
```

GTAP–E Capital-Energy Composite Structure

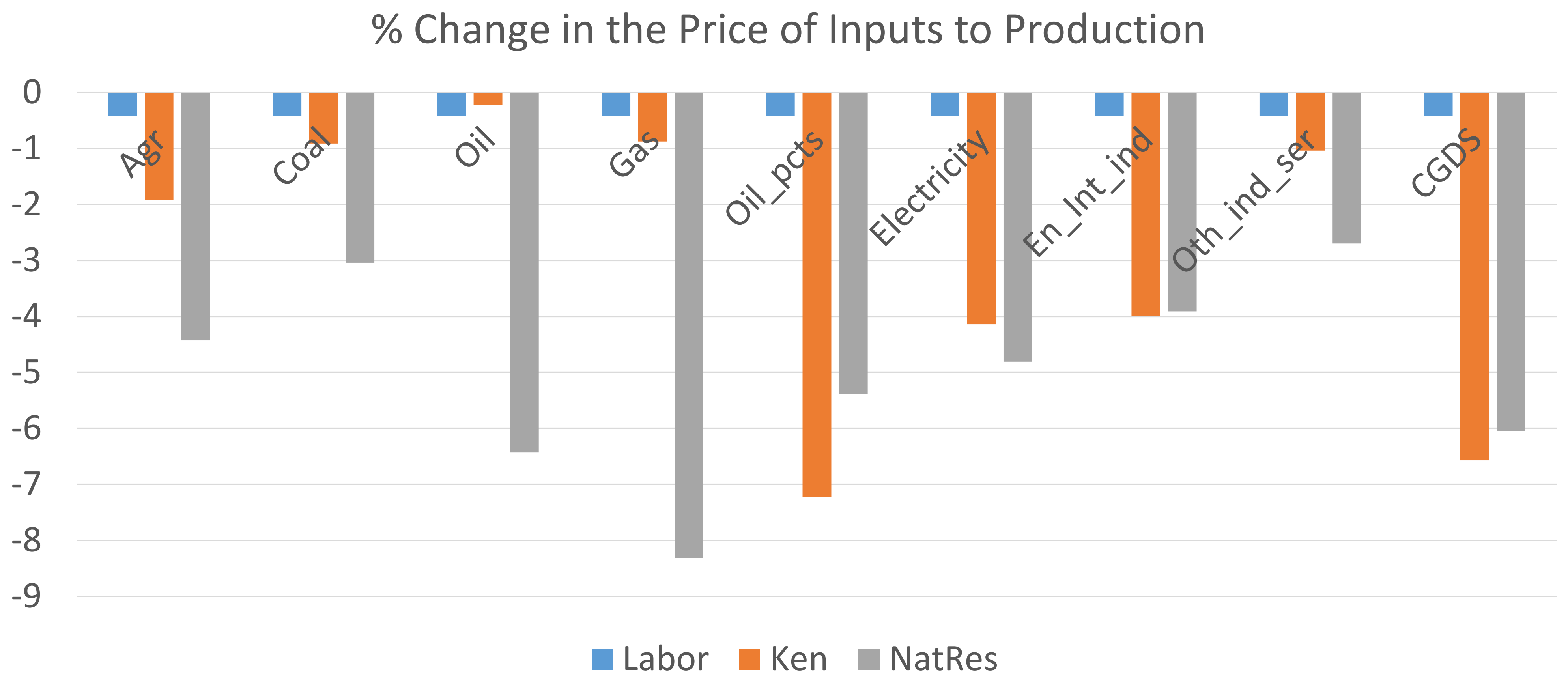


Macro impacts (% change)

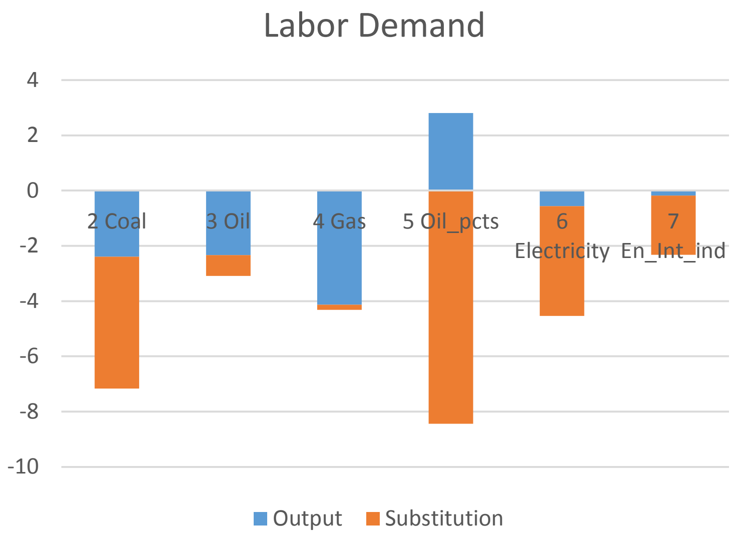


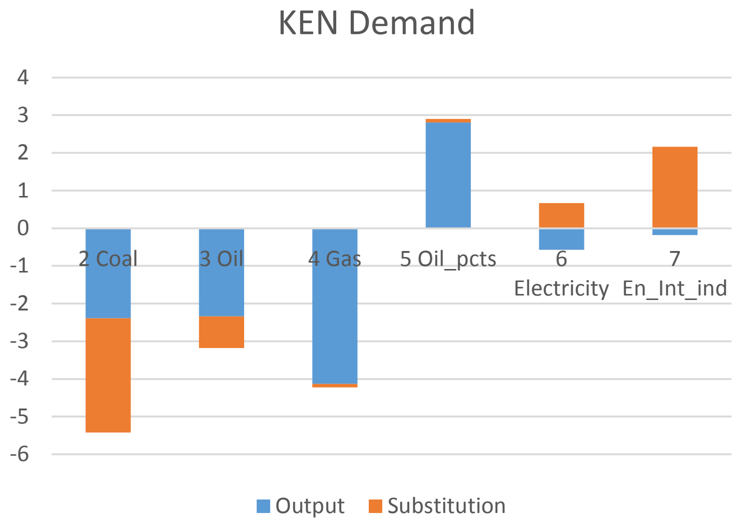
- More efficient energy use across the world;
- Reduced costs - positive impact on GDP;
- Reduced demand for energy – negative TOT impacts on exporters, positive TOT impacts on importers;
- Net positive impact all economies.

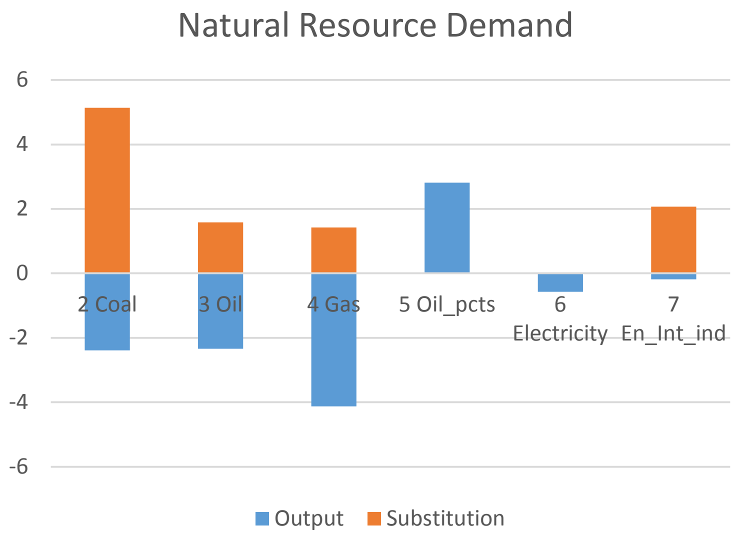
Which you would expect given the change in the input prices



Energy inputs are more efficient, so there are substitution effects towards KEN

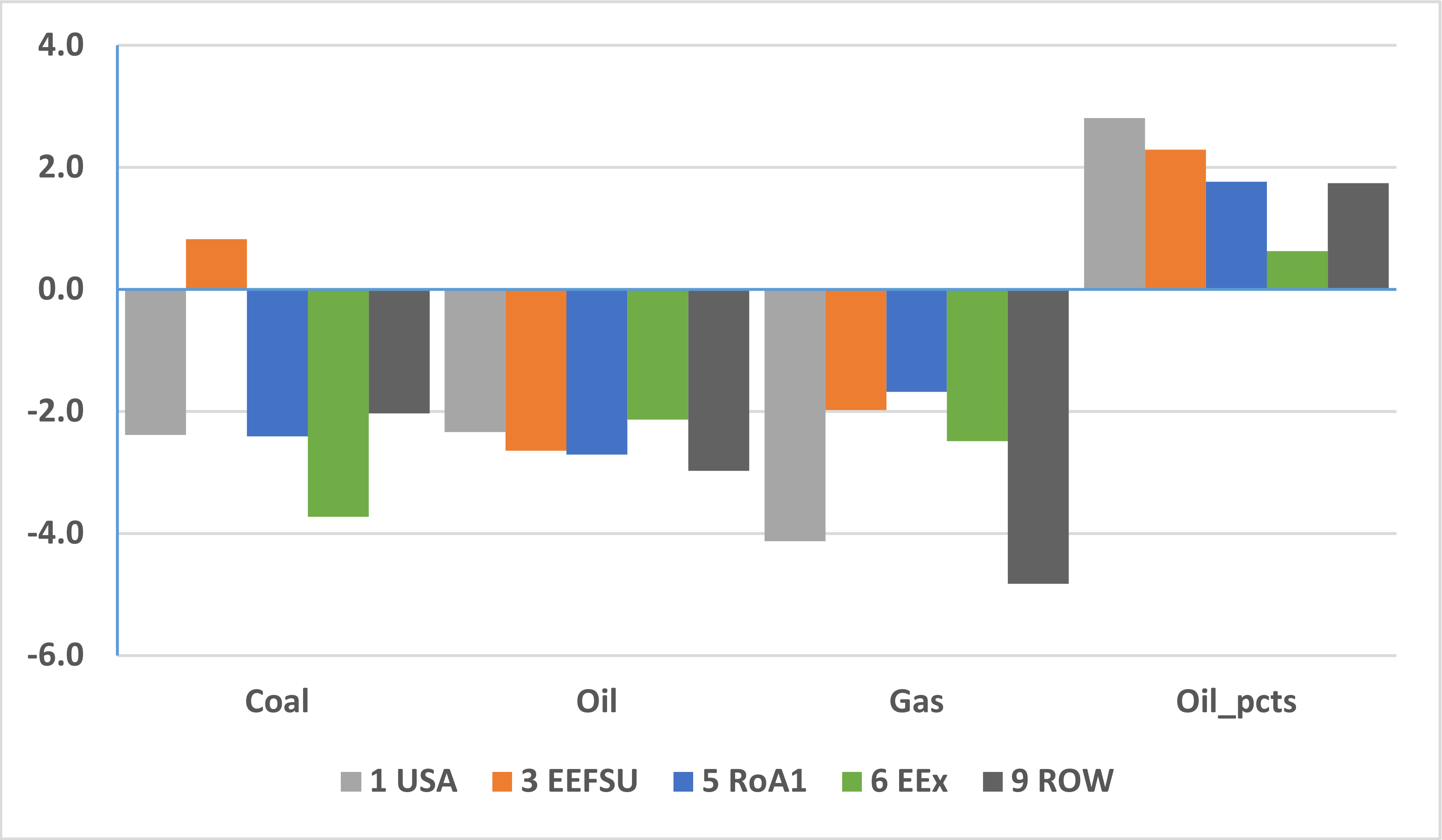




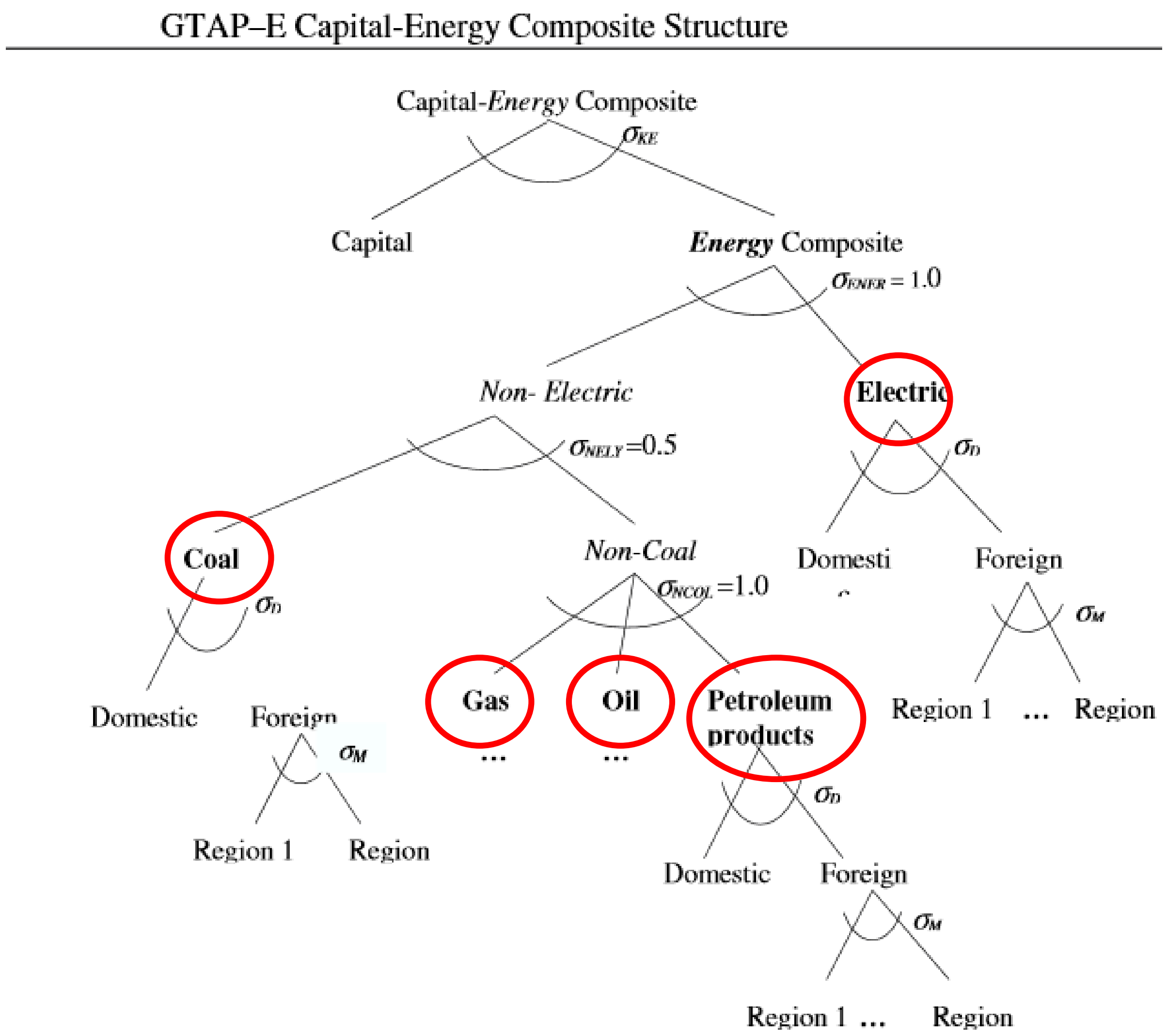


For KEN intensive industries, substitution away from labor and towards KEN and natural resources

Output effects (% change)



- Key energy Industries see a reduction in output due to less demand for the more efficient energy as an input;
- Oil products industry appears to “buck the trend”



Double-Tech Shock?

- Next steps
  - Examination of results may highlight issues with shock design – e.g double shock