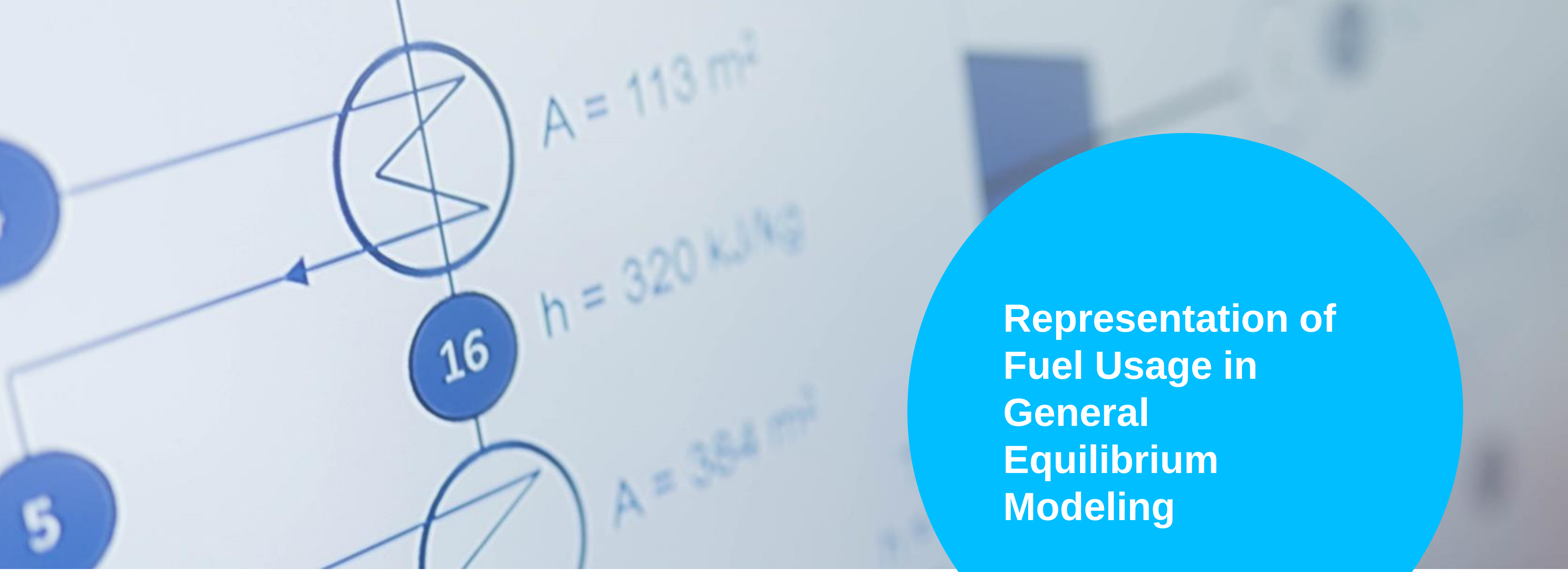

Representation of Fuel Usage in General Equilibrium Modeling

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Contents

1. Introduction

2. Problem Statement

3. Solution 1: Fuel Substitution Based on Physical Quantities
   - Methodology
   - Results
   - Discussion

4. Solution 2: Energy Efficiency Constraint
   - Methodology
   - Results
   - Discussion

Introduction

„Recently, I found an interesting behavior in our model…“

Mi 14.12.2022 16:21

SJ

Siegle, Jonathan

gas and oil usage in EPPA

An chenyh@mit.edu

Dear Dr Chen,

My name is Jonathan Siegle and I am a research assistant working with the CGE model NEWAGE at the University of Stuttgart, Germany. The NEWAGE model is written in GAMS/MPSGE and the main data source is GTAP 10, so there are quite some similarities to EPPA.

Recently, I found an interesting behavior in our model, and it might be present in the EPPA model as well:
Under carbon pricing, the use of gas declines faster than the use of oil.
This is counterintuitive, because the emission factor of gas is lower than that of oil.

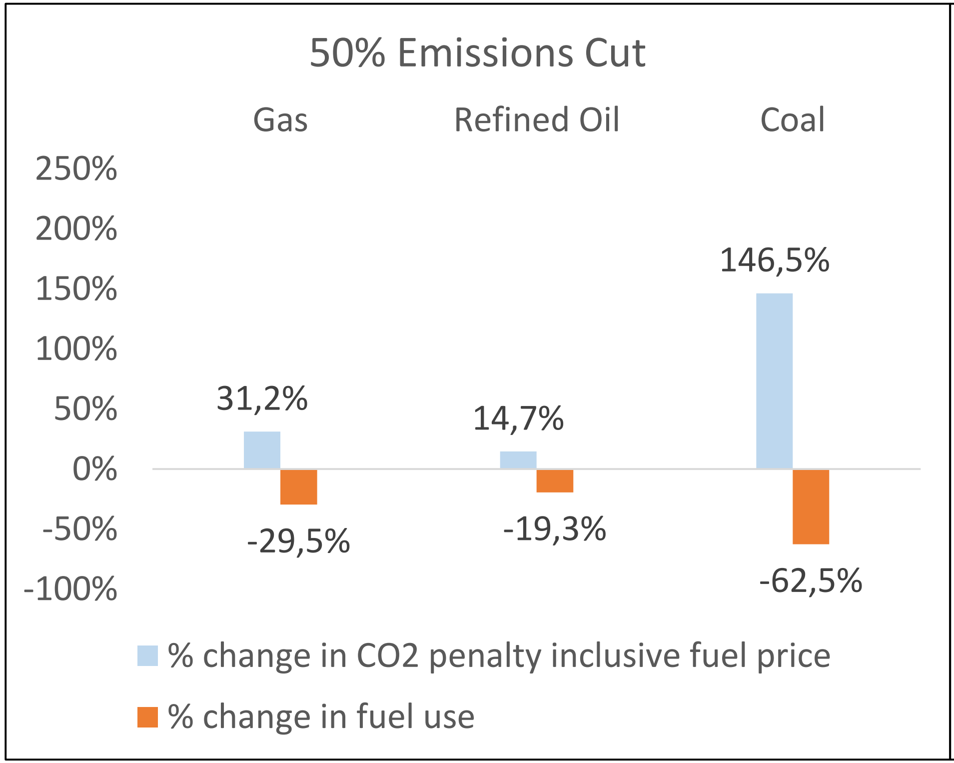
Simple Outline: SAM of the 1-2-4 model (Markusen, 2006)

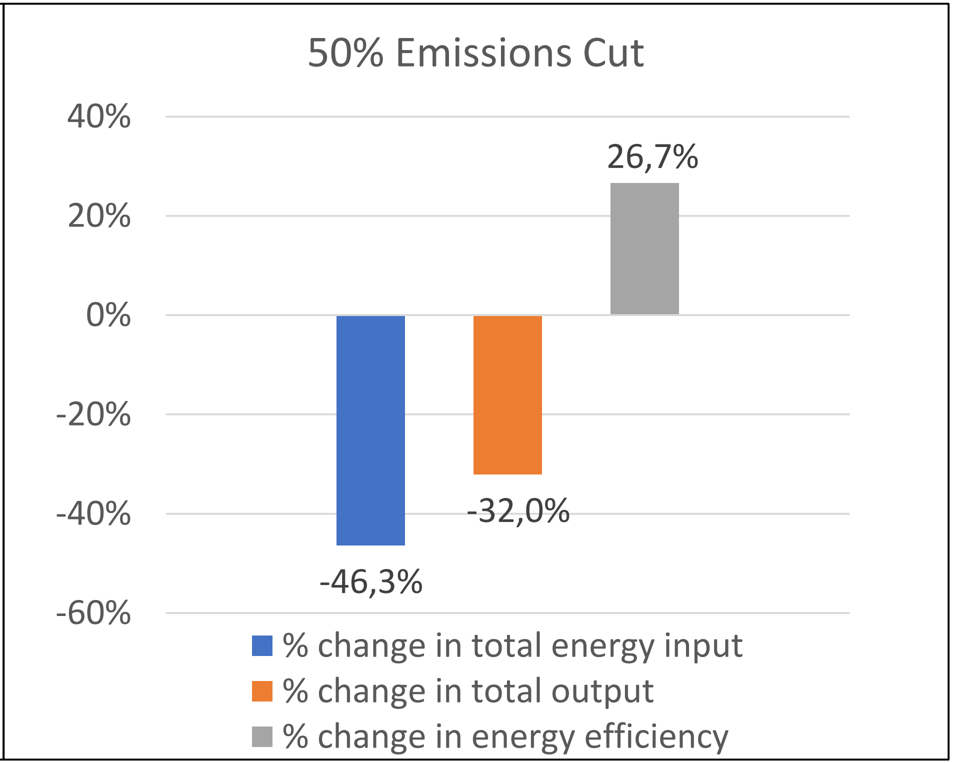
	Production sectors			Consumers
Markets	X	Y	W	CONS
PX	100		-100	
PY		100	-100	
PW			200	-200
PG	-25	-25		50
PO	-25	-25		50
PA	-25	-25		50
PK	-25	-25		50

Simple Outline: Input Structure of Sector X

		Source	G	O	A	K
[1]	Capital input (bn $)	assumed				25
[2]	Energy input (bn $)	assumed	25	25	25	
[3]	Energy input (EJ)	=[2]/[4]	6.08	2.60	10.69	
[4]	Energy price (bn $/EJ)	GTAP11	4.1	9.6	2.3	
[5]	Emissions per EJ (Mt-CO2/EJ)	EPPA	50.23	72.97	90.53	
[6]	Emissions (Mt-CO2)	= [3]*[5]	305.2	189.7	968.2	
[7]	Emissions /bn$ (Mt-CO2/bn $)	= [6]/[2]	12.2	7.6	38.7	

Simple Outline: Value-Related Emissions Factor determines Fuel Use under Carbon Pricing





Problem Statement

Problem Statement

1. The Substitution Pattern

Consider two fossil fuels.

A fossil fuel with a lower energy-related emissions coefficient can have a higher value-related emissions coefficient – if its energy price is lower.

Under carbon pricing, it therefore incurs a higher penalty. Consequently, its usage in a production function declines more.

2. Energy Efficiency Changes

Inter-fuel substitution in a production function can inadvertently change energy use levels in physical units.

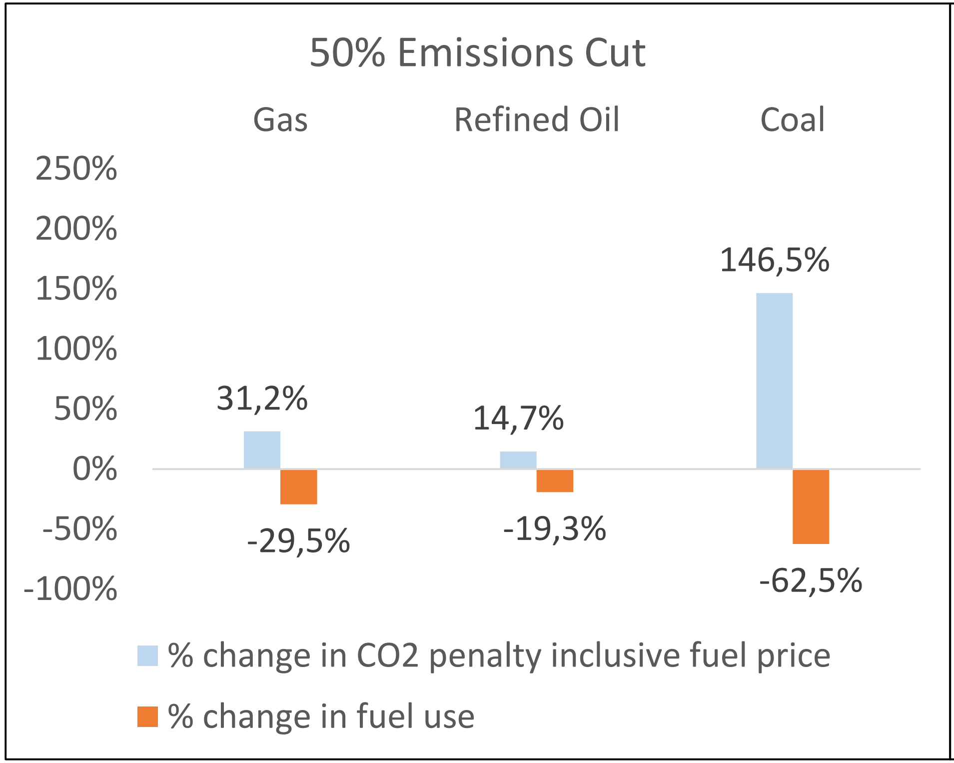
Energy efficiency of production is therefore more likely to get improved beyond physically realistic measures.

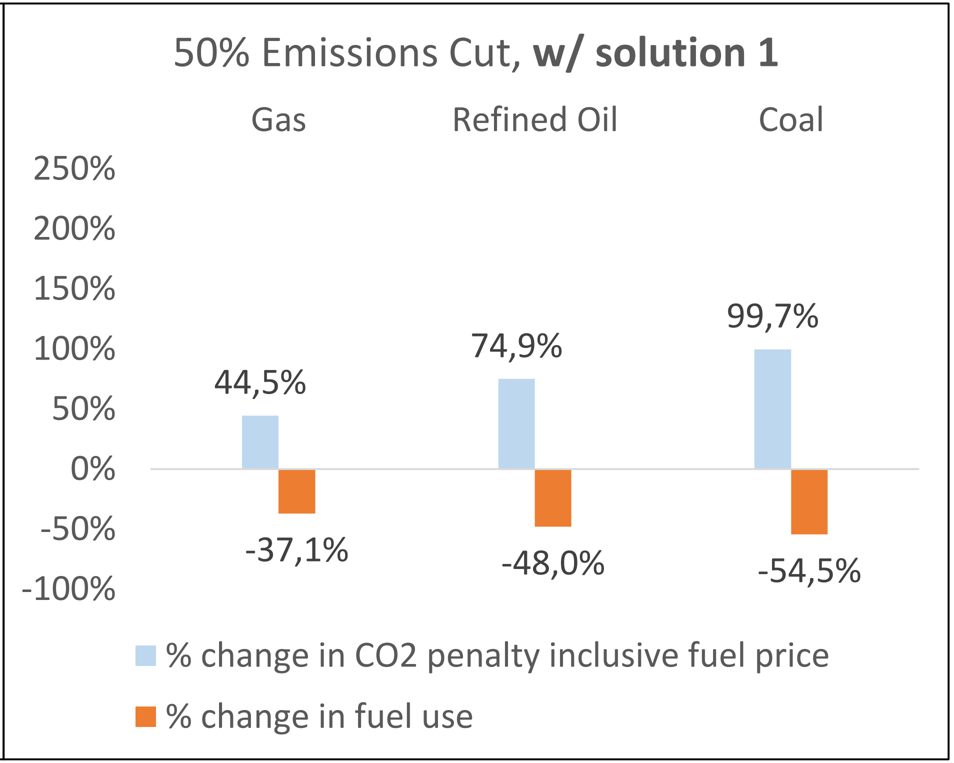
Solution 1:
Fuel Substitution Based on Physical Quantities

Solution 1: Fuel Substitution Based on Physical Quantities

Measure	Rationale
Eliminate the base year fuel price differences: Value all physical fossil fuel reference quantities with the same price	→ A "dollar-to-dollar" fuel substitution is now also a "joule-to-joule" exchange → under carbon pricing, the structure of emissions per dollar is consistent to that of emissions per joule
Impose taxes or subsidies on fuel consumption	→ In the base year, the after-tax consumer price of each fuel remains the same as the pre-adjusted level
Impose taxes or subsidies on fuel production For each fuel: If the pre-adjusted price is… …higher than the price used for valuation, use the tax revenue to subsidize the fuel's own production. …lower than the price used for valuation, raise the subsidy payment from a tax on the fuel's own production.	→ The corresponding zero-profit conditions are retained

Solution 1: Both Issues Resolved…





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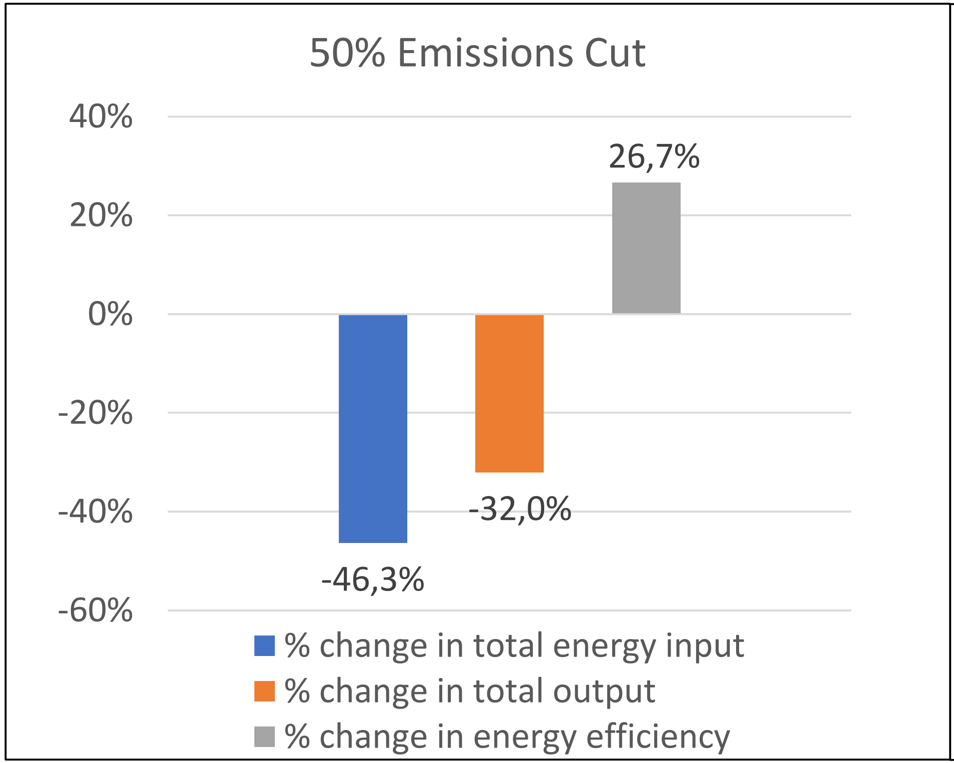

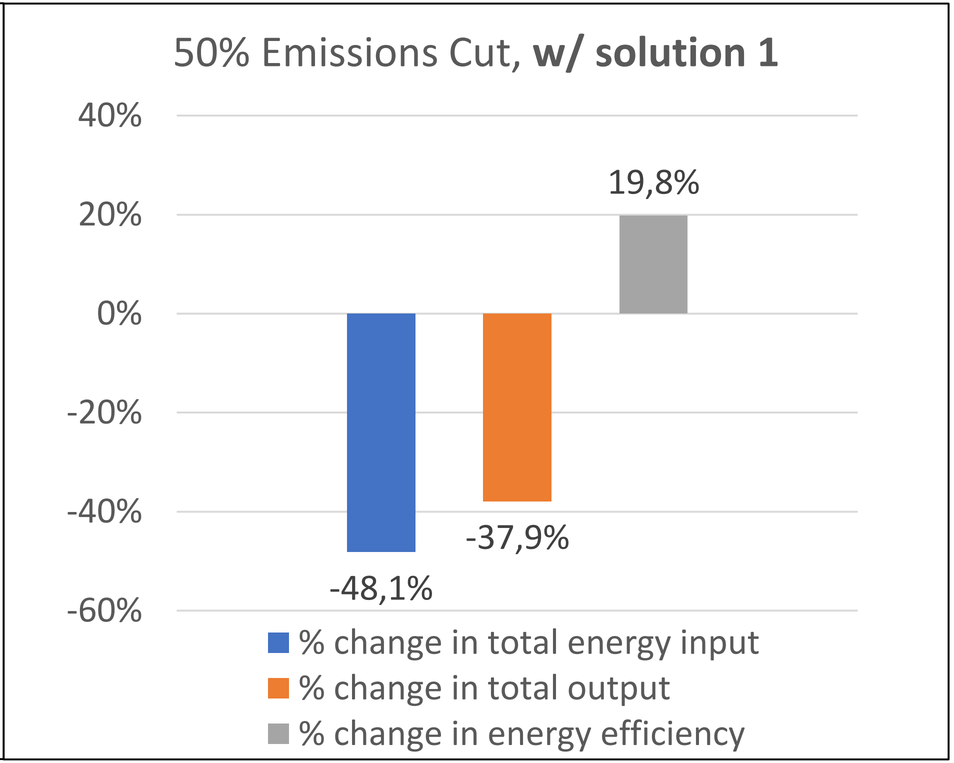

Solution 1: Both Issues Resolved…

1. The Substitution Pattern

Consider two fossil fuels.

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Solution 1: Discussion

1. **The Substitution Pattern**

Should this really get „resolved“?

- (Paltsev et al. 2005): Just as land prices assign different values to the size of different parcels, energy prices assign different values to the energy content of different energy carriers.
- (Cleveland et al. 2000): There are other factors besides energy content that lead to differentiated valuation of fuels.

Solution 1: Discussion

1. The Substitution Pattern

Does carbon pricing increase the relative importance of energy content among other value-determining attributes of fuels

?

Carbon pricing

↓

scarcity of energy carriers

↓

“core attribute” energy content increasingly important

↓

economic value getting aligned with energy content

?

Solution 2:
Energy Efficiency Constraint

Solution 2: Energy Efficiency Constraint

Energy Efficiency Index:

$$\gamma = \frac{X/(gxp \cdot GX + oxp \cdot OX + axp \cdot AX)}{1/(gxp + oxp + axp)}$$

- X is the output index for sector X
- GX, OX, and AX are the consumption indices of G, O, and A fuel inputs to X
- gxp, oxp, and axp are the energy contents of GX, OX and AX in physical units

Solution 2: Energy Efficiency Constraint

Energy Efficiency Index:

$$\gamma = \frac{X/(gxp \cdot GX + oxp \cdot OX + axp \cdot AX)}{1/(gxp + oxp + axp)} \leq 1.1$$

- X is the output index for sector X
- GX, OX, and AX are the consumption indices of G, O, and A fuel inputs to X
- gxp, oxp, and axp are the energy contents of GX, OX and AX in physical units

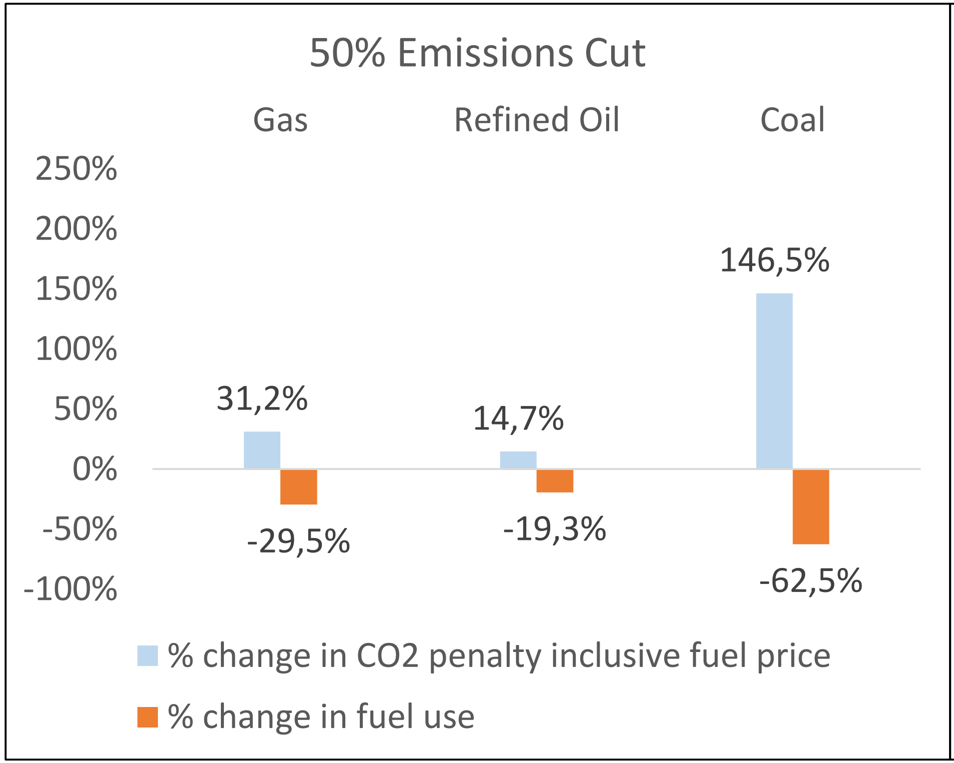
Solution 2: Energy Efficiency Constraint: Enable Adherence

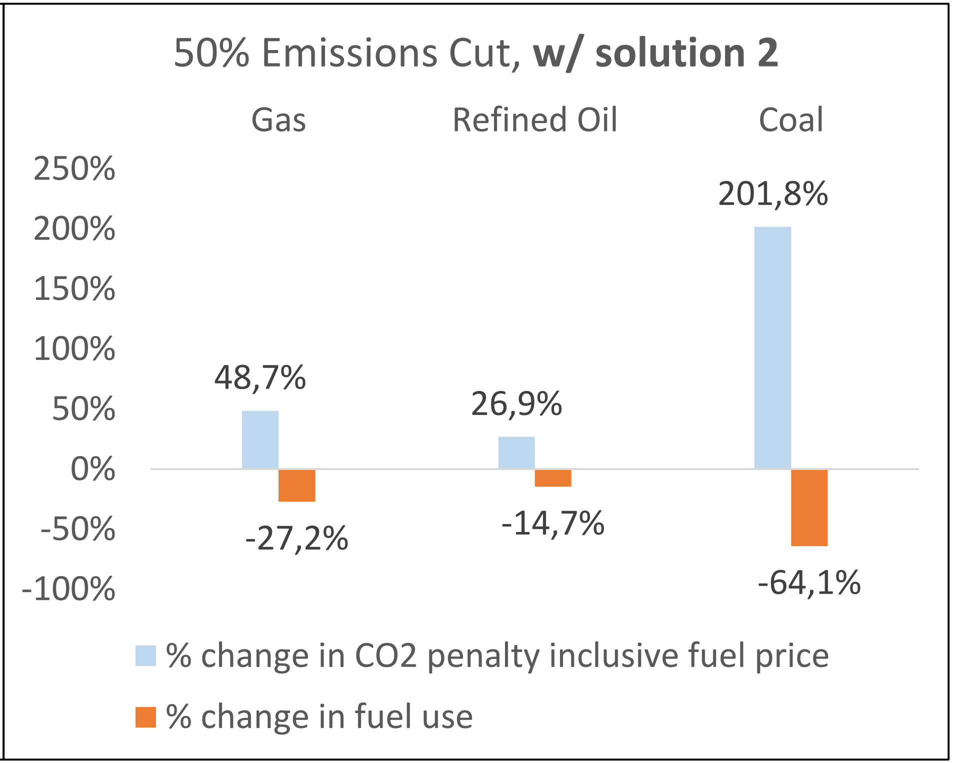
Output tax & input subsidy:

$$TX \cdot V_X \cdot P_X \cdot X \ = \ -SF \cdot (V_{GX} \cdot P_{GX} \cdot GX + V_{OX} \cdot P_{OX} \cdot OX + V_{AX} \cdot P_{AX} \cdot AX)$$

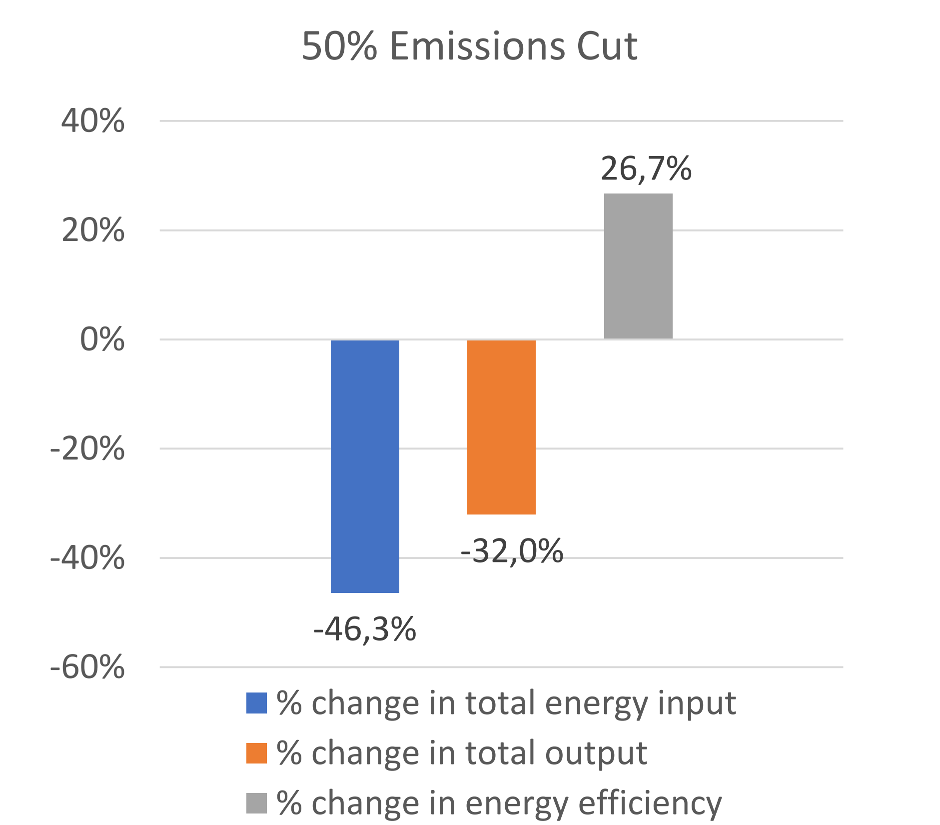
- TX is an output tax rate for sector X
- V_x is the baseline value of sector X output
- P_X is the price index of sector X output
- X is the output index for sector X
- SF is an input subsidy rate for fuel inputs to sector X
- V_{GX}, V_{OX} and V_{AX} are the baseline values of G, O, and A fuel inputs to sector X
- P_{GX}, P_{OX} and P_{AX} are the price indices of G, O, and A fuel inputs to sector X
- GX, OX, and AX are the consumption indices of G, O, and A fuel inputs to sector X

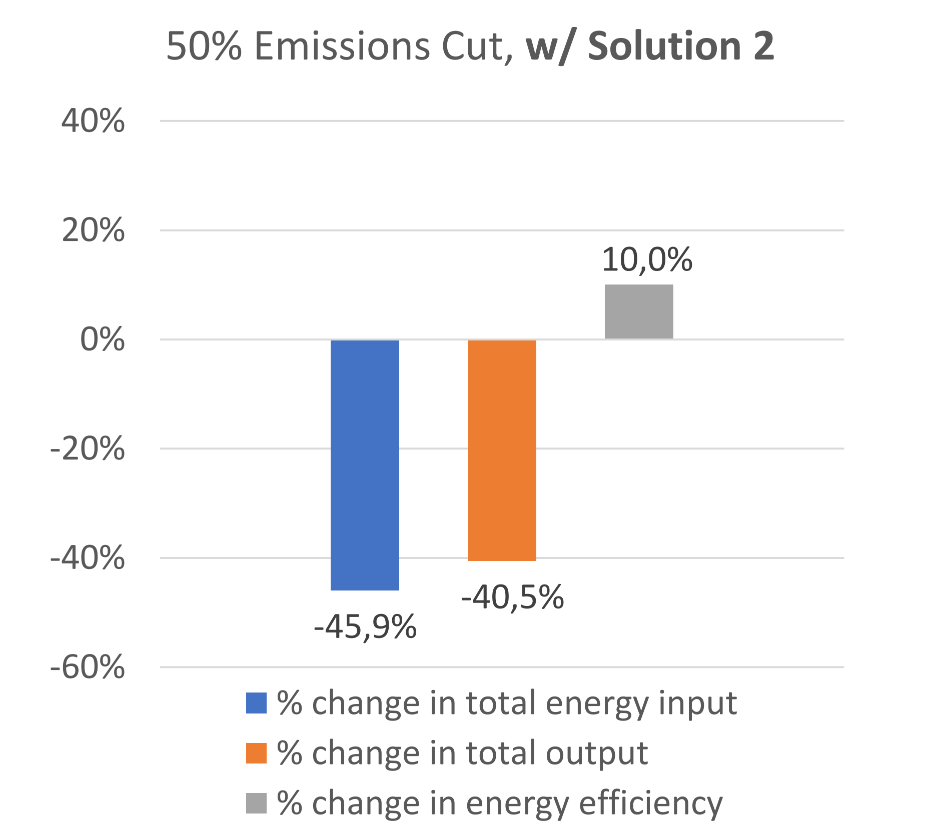
The Energy Efficiency Constraint changes Fuel Prices and Fuel Use





The Energy Efficiency Constraint affects Input and Output Levels





Solution 2: Energy Efficiency Changes Issue Resolved…

1. The Substitution Pattern

Consider two fossil fuels.

A fossil fuel with a lower energy-related emissions coefficient can have a higher value-related emissions coefficient – if its energy price is higher.

Under carbon pricing, it therefore incurs a higher penalty. Consequently, its usage in a production function declines more.

2. Energy Efficiency Changes

Inter-fuel substitution in a production function can inadvertently change energy use levels in physical units.

Energy efficiency of production is therefore more likely to get improved beyond physically realistic measures.

Solution 2: Discussion

- Introducing the energy efficiency constraint **requires** only **minimal revisions**.

- Nevertheless, the energy efficiency constraint deals with the issue in an **aggregate** manner:
  - Substitution between fossil fuels and electricity likely includes greater efficiency potentials than substitution among fossil fuels themselves. Such **fuel-specific differentiations are not considered** in the efficiency constraint.
  - The efficiency constraint **not only restricts efficiency improvement resulting from the inter-fuel-substitution itself**, but affects the overall efficiency improvement, which can also be induced by substitution between fuels and other inputs like capital.
  - The upper efficiency bound should be carefully set such that it will not rule out higher efficiency potential. For example, in a dynamic model, it can be increased over time.

- Future research may find ways to more precisely **constrain efficiency gains resulting purely from the substitution among fossil fuels**. However, our attempts with more specific formulations so far caused difficulties in solution finding.

Thank You for Your attention!

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Literature

Literature

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Link to the paper associated with this presentation:

https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=7196