Approximating Terms of Trade Effects in Single Country CGE Models

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Outline

1. Introduction

2. Numerical Evidence and Reduced Form Approach

3. Modeling Results

4. Discussion

Introduction

Introduction

- CGE modelers are often faced with dimensionality tradeoffs. Models typically designed for specific policy applications ("horses for courses").
- In single country models, the impacts of foreign trade are often simplified by assuming price taking behavior on the world market ("small open economy", or SOE).
- May be appropriate in some cases (e.g. smaller country, non-trade exposed sector). Not so in others (e.g. large country, heavily traded sector).
- **This paper:** suggest a simple approach for implementing a large open economy (LOE) representation in single country CGE models.

Motivation

- In 2020, the U.S. EPA's Science Advisory Board recommended that EPA relax the SOE assumption in its SAGE CGE model and represent the US as a large open economy, noting that: "...doing so will help ensure that the model is able to capture regulatory impacts on traded goods." (SAB, 2020).
- Studies have found that capturing rest of world price responsiveness can be an important welfare channel of domestic policy analysis (Bohringer et al., 2021; Bohringer and Rutherford, 2002).
- Limited empirical evidence on export demand and import supply price elasticities that can be readily adapted to a multi-sector single country CGE model.

Modeling Options

Many ways one could relax the small open economy assumption in a CGE model:

- Link to an existing international model
  - Advantages: capture the full richness of international economy
  - Disadvantages: would require national model to conform with international framework, extensive alteration and maintenance costs
  - Caron et al. 2015; WiNDC-GTAP
- Calibrate a reduced form mechanism to approximate terms of trade effects (i.e., does not model physical trade)
  - Advantages: simplify the rest of world (ROW), reduces burdens of maintenance
  - Disadvantages: unclear how well the reduced form mechanism would perform
  - Markusen 1995; Yuan et al., 2019; Rutherford and Tarr, 2003; Dixon et al., 1982; Dixon and Rimmer, 2002

What We Do

Main goals of the paper are 2 pronged:

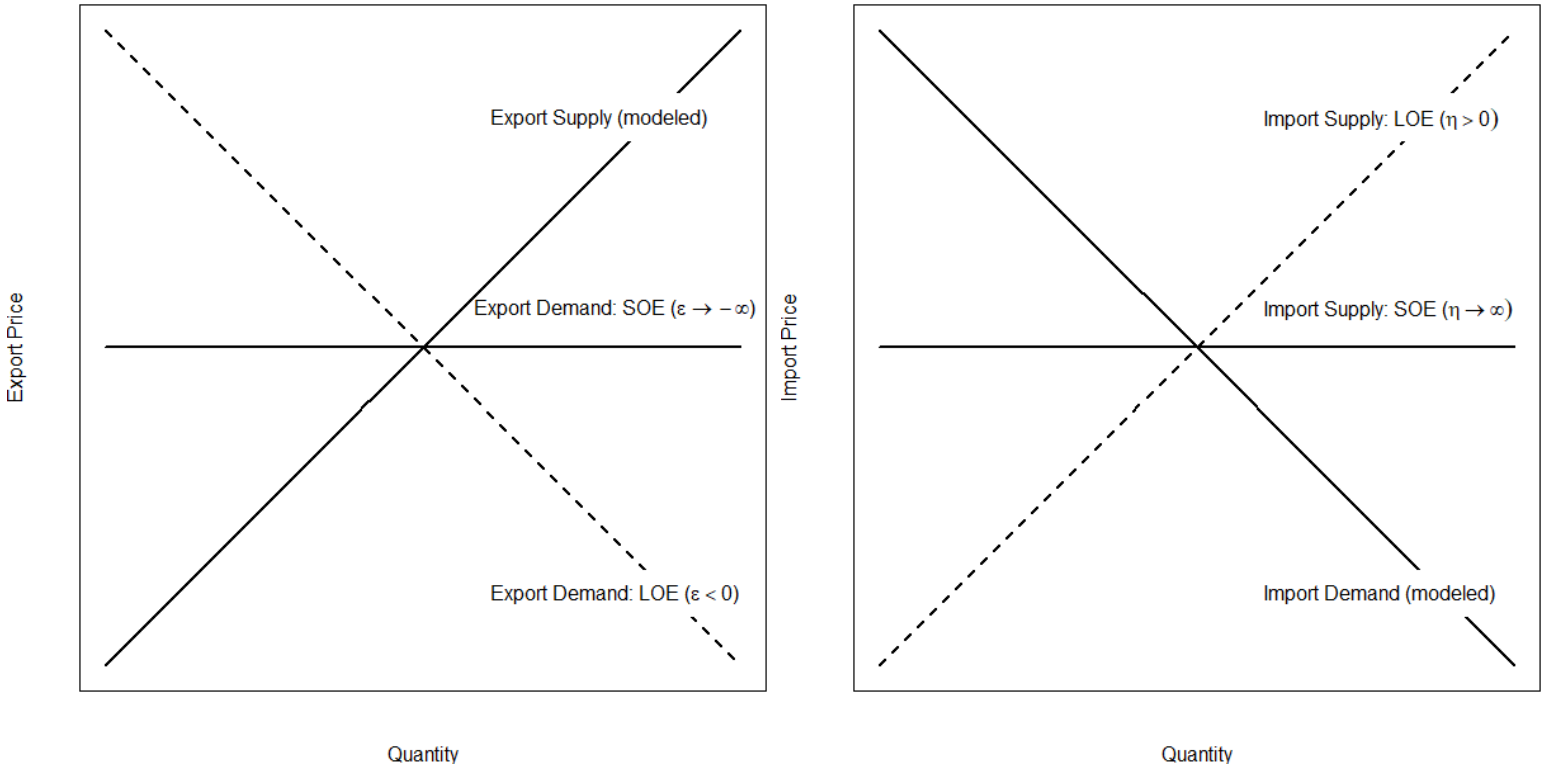
1. Use the GTAPinGAMS (Lanz and Rutherford, 2019) package to simulate and report export demand and import supply price elasticities for the entire GTAP9 database
2. Calibrate the reduced form approach from Markusen (1995) and Yuan et al., (2019) to test efficacy relative to multi-region GTAP model.

Preview of Results

- The SOE assumption may miss important impacts in export markets and some import markets.
- When calibrated to internally consistent elasticities, the reduced form approach performs well relative to a mutli-country model.
- The SOE model can under or over-estimate welfare costs depending on the direction of the terms of trade effect.
- Extending the reduced form approach to a dynamic model appears to be relatively insensitive to assumptions on differential growth in the international economy.

Numerical Evidence and Reduced Form Approach

Small Open Economy in Single Country Models



- ϵ_{ri}: Price elasticity of ROW demand for region *r*'s exports of good *i* (export demand)
- η_{ri}: Price elasticity of ROW supply of good *i* into region *r* (import supply)

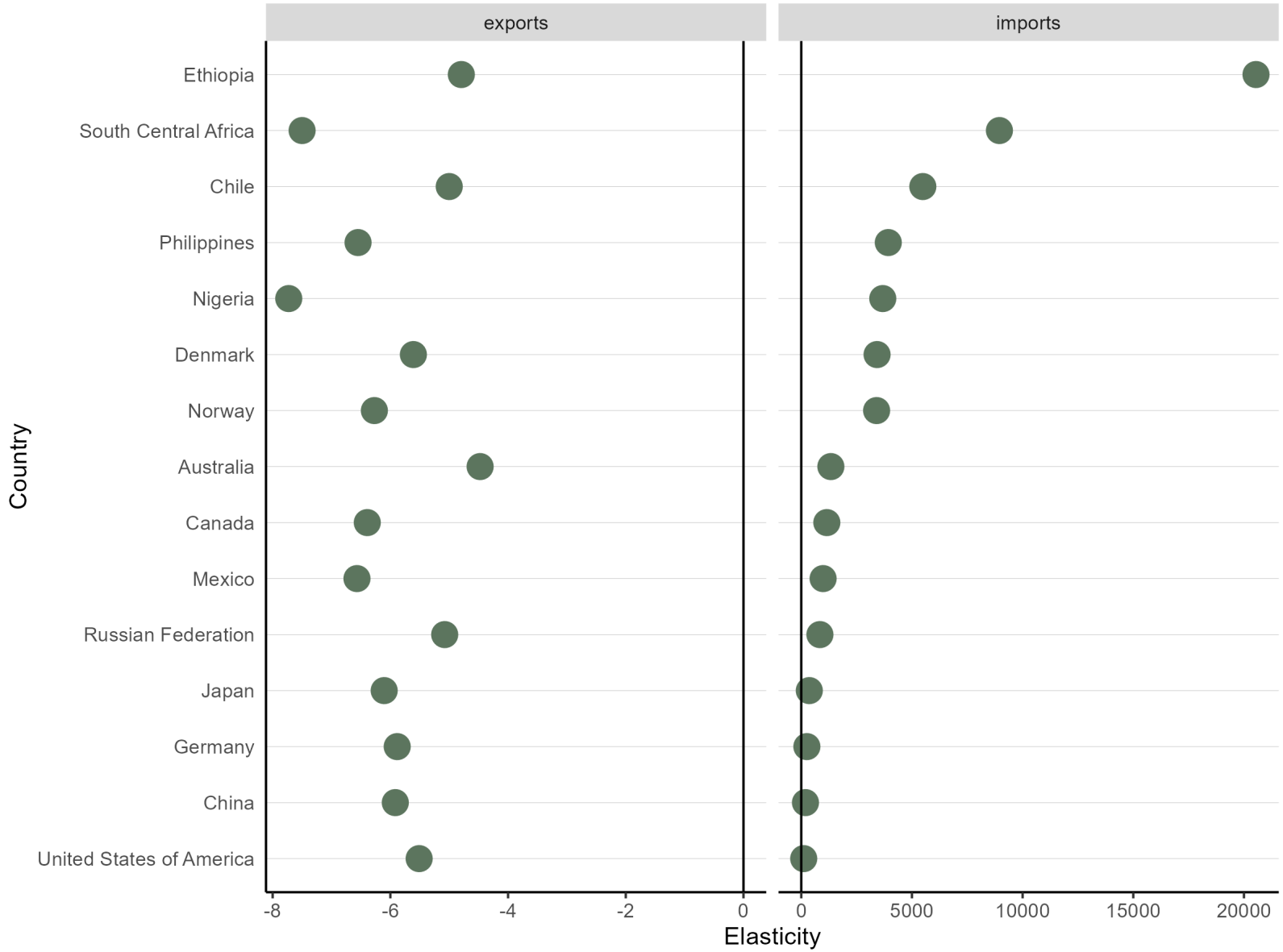
Generating Numerical Evidence

We simulate values of ϵ_{ri} and η_{ri} using the GTAPinGAMS package with GTAP9.

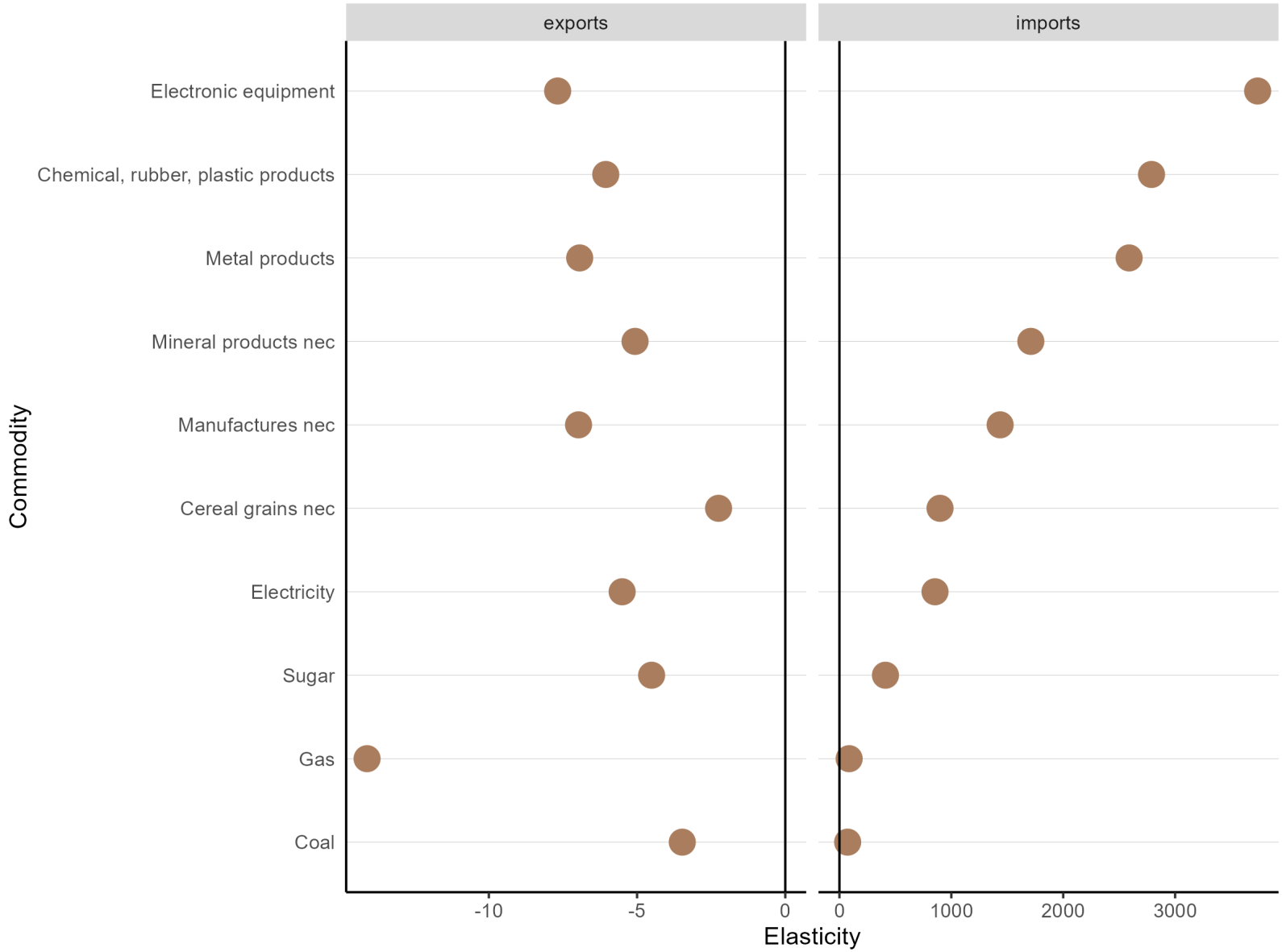
- Aggregate the model to 2 regions – *r* and ROW
- Verify benchmark equilibrium
- Perturb existing tax rates by 10^{-4} on imports and exports to approximate changes in the cost of supplying or demanding goods from foreign markets
- Run the counterfactual
- Calculate each elasticity at the the new equilibrium point as the percent change in export demand or import supply relative to the percent change in price

Code for producing these estimates are included in the supplemental files of the paper.

Averages for Handful of Countries



Averages for Handful of Commodities



Reduced Form Methodology

We adopt a methodology introduced by Markusen (1995) and later adopted by Yuan et al. (2019).

- Calibration approach relies on *fixed factors*.
- Letting pm_i denote the import price of commodity i, pe_i denote the export price, pfx be the price of foreign exchange, and $pfix_i$ and $pfim_i$ be the price for the export and import fixed factors respectively, the methodology is summarized as:

$$pm_i = pfx^{(1-\theta_i^m)} pfim_i^{\theta_i^m} \tag{1}$$

$$pfx = pe_i^{(1-\theta_i^x)} pfix_i^{\theta_i^x} \tag{2}$$

- Note that as $\theta_i^m \to 0$ and $\theta_i^x \to 0$, then $pm_i = pe_i = pfx$ which is the small open economy assumption.
- We can calibrate the fixed factors as (proofs in the paper):

$$\theta_i^x = \frac{1}{-\epsilon_i}, \quad \text{and} \quad \theta_i^m = \frac{1}{1+\eta_i}$$

Modeling Results

Illustrative Policy Scenario Definition

Illustrative policy scenarios:

- $1 billion sector specific Hicks-Neutral productivity shock.
- Mimics an illustrative environmental regulation whose compliance requires additional inputs to produce the same amount of output.
- Chosen sectors that have historically been regulated under the Clean Air Act and/or represent a significant share of U.S. exports.

Model comparison:

- `2 country`: Two region GTAPinGAMS model, endogenizes trade responses between U.S. and ROW
- `loe`: One region GTAPinGAMS model of the U.S. with calibrated reduced form framework
- `soe`: One region GTAPinGAMS model of the U.S. assuming a small open economy

U.S. Elasticities

Sector Index	*Description*	*Import Supply Elasticity*	*Export Demand Elasticity*
agf	Agriculture, forestry, fishing and hunting	72.8	-4.0
cru	Crude oil	19.5	-10.2
col	Coal mining	494.7	-5.0
min	Metal ore and nonmetalic mineral mining	161.6	-1.4
ele	**Electric generation, transmission and distribution**	**155.4**	**-5.6**
gas	Natural gas	118.9	-28.2
wsu	Water, sewage, and other utilities	88.4	-5.6
con	Construction	225.7	-3.8
fbm	Food and beverage manufacturing	99.5	-4.6
wpm	Wood product manufacturing	90.7	-5.6
ref	**Petroleum refineries**	**90.4**	**-3.8**
chm	**Chemical manufacturing**	**149.5**	**-5.8**
cem	Cement manufacturing	100.2	-5.2
pmm	Primary metal manufacturing	171.2	-6.8
fmm	Fabricated metal product manufacturing	133.6	-7.0
cpu	Electronics and technology manufacturing	145.0	-8.1
tem	Transportation equipment manufacturing	116.3	-5.7
bom	**Balance of manufacturing**	**138.8**	**-7.3**
trn	Transportation	263.9	-3.6
ttn	Truck transportation	70.2	-3.8
srv	Services	54.5	-3.8
hlt	Healthcare services	27.1	-3.7

Notes: Bolded rows indicate sectors that are shocked in the suite of scenarios.
Source: Authors' calculations using GTAP9 and Lanz and Rutherford (2016).

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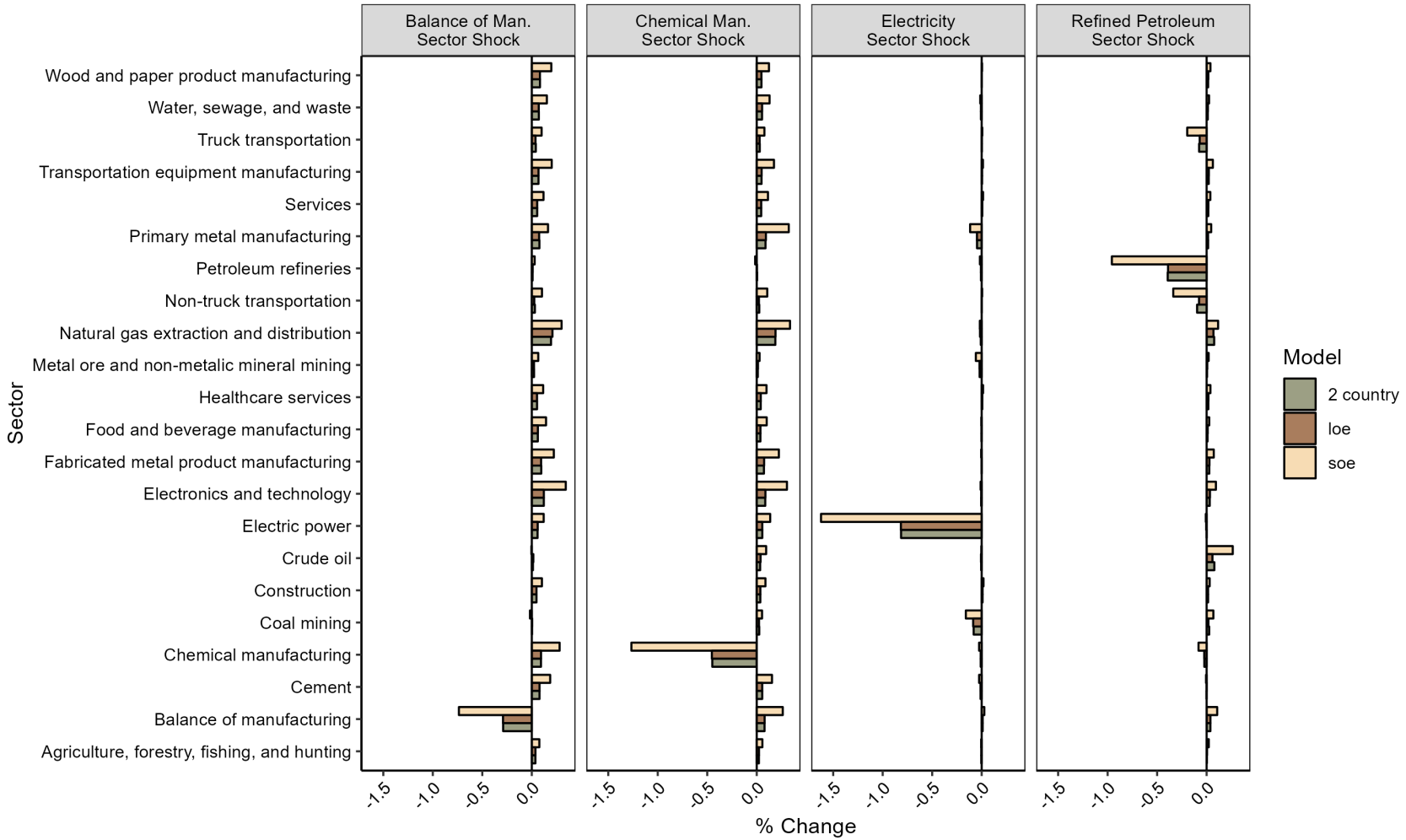
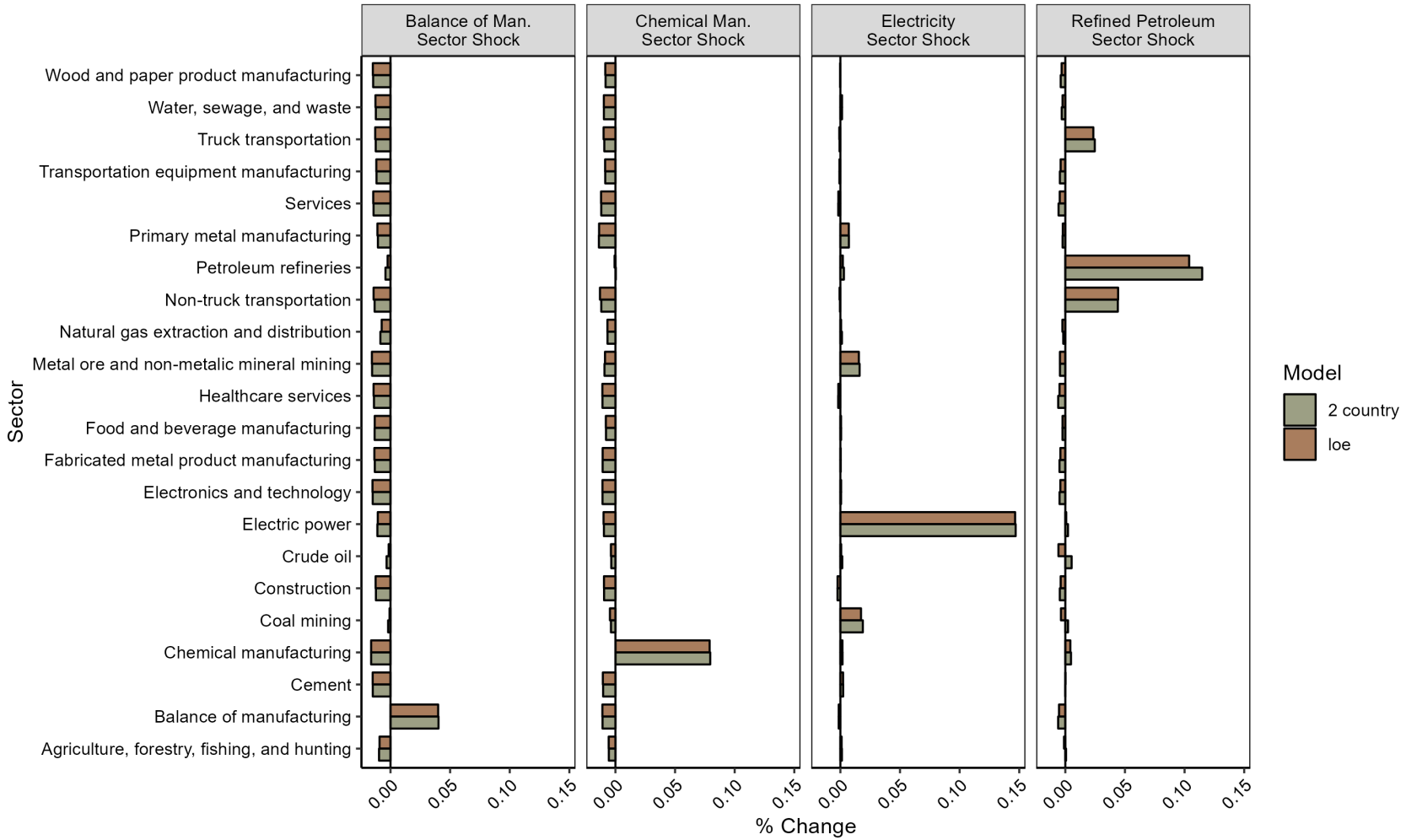
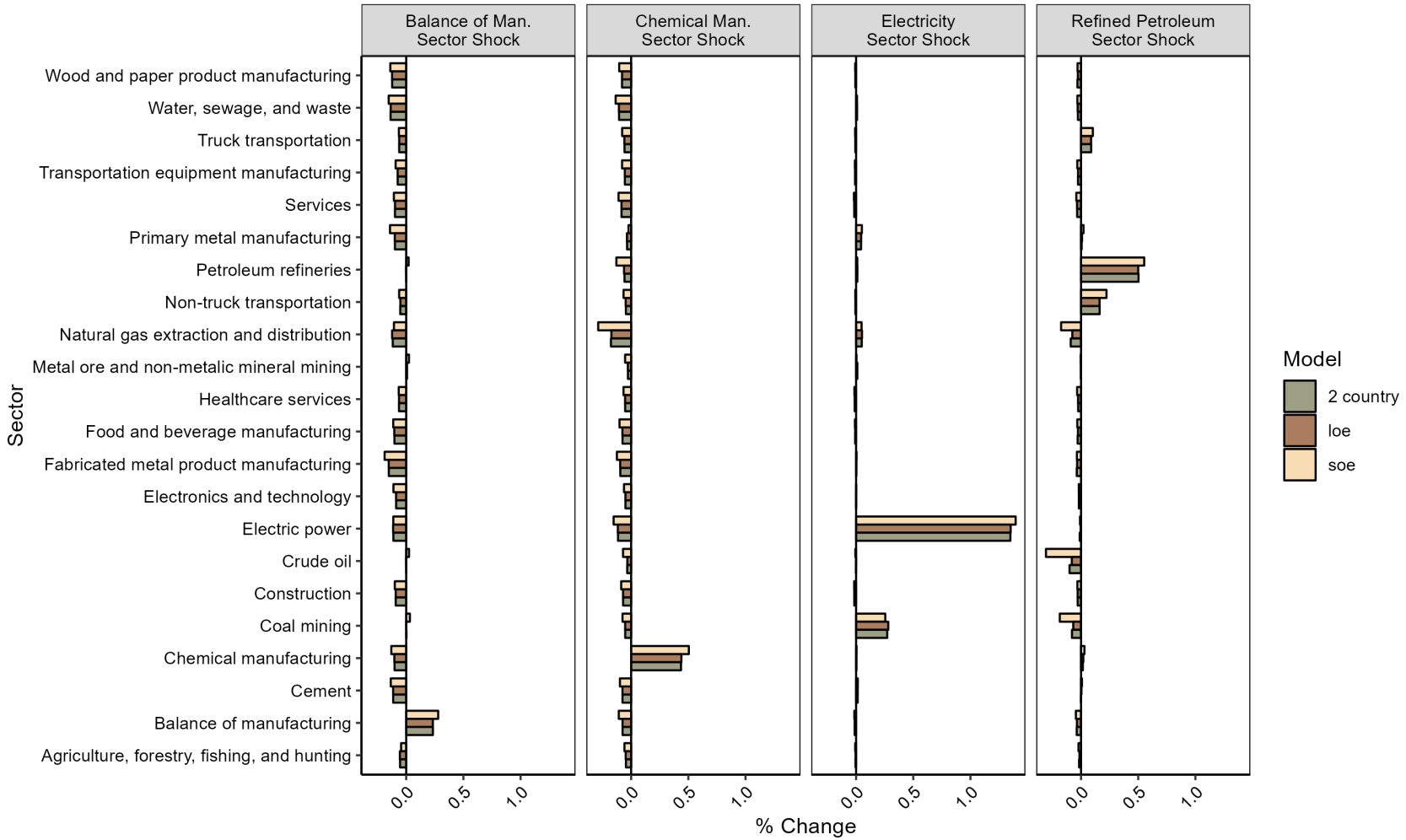
Model Results: Export Quantities



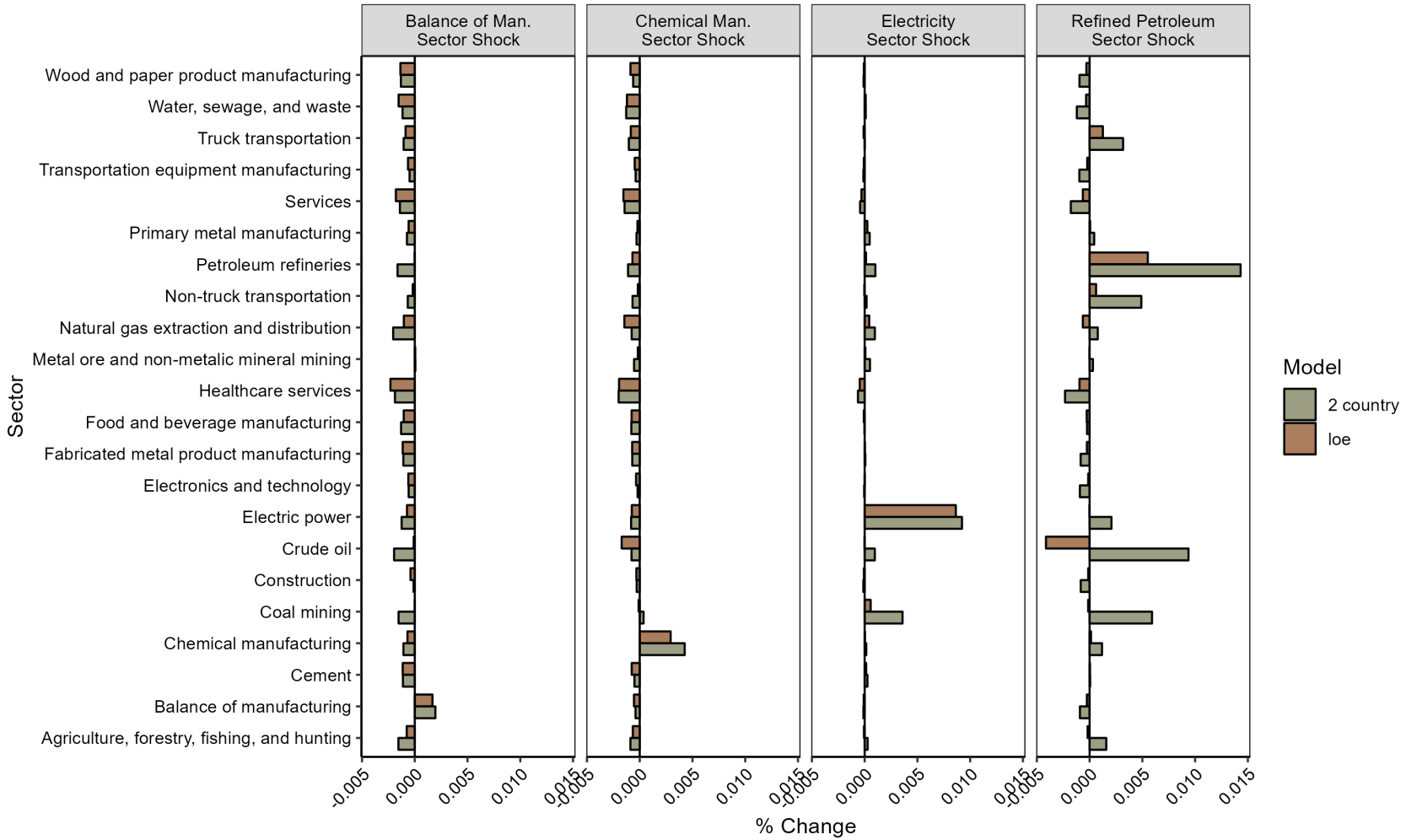
Model Results: Export Prices



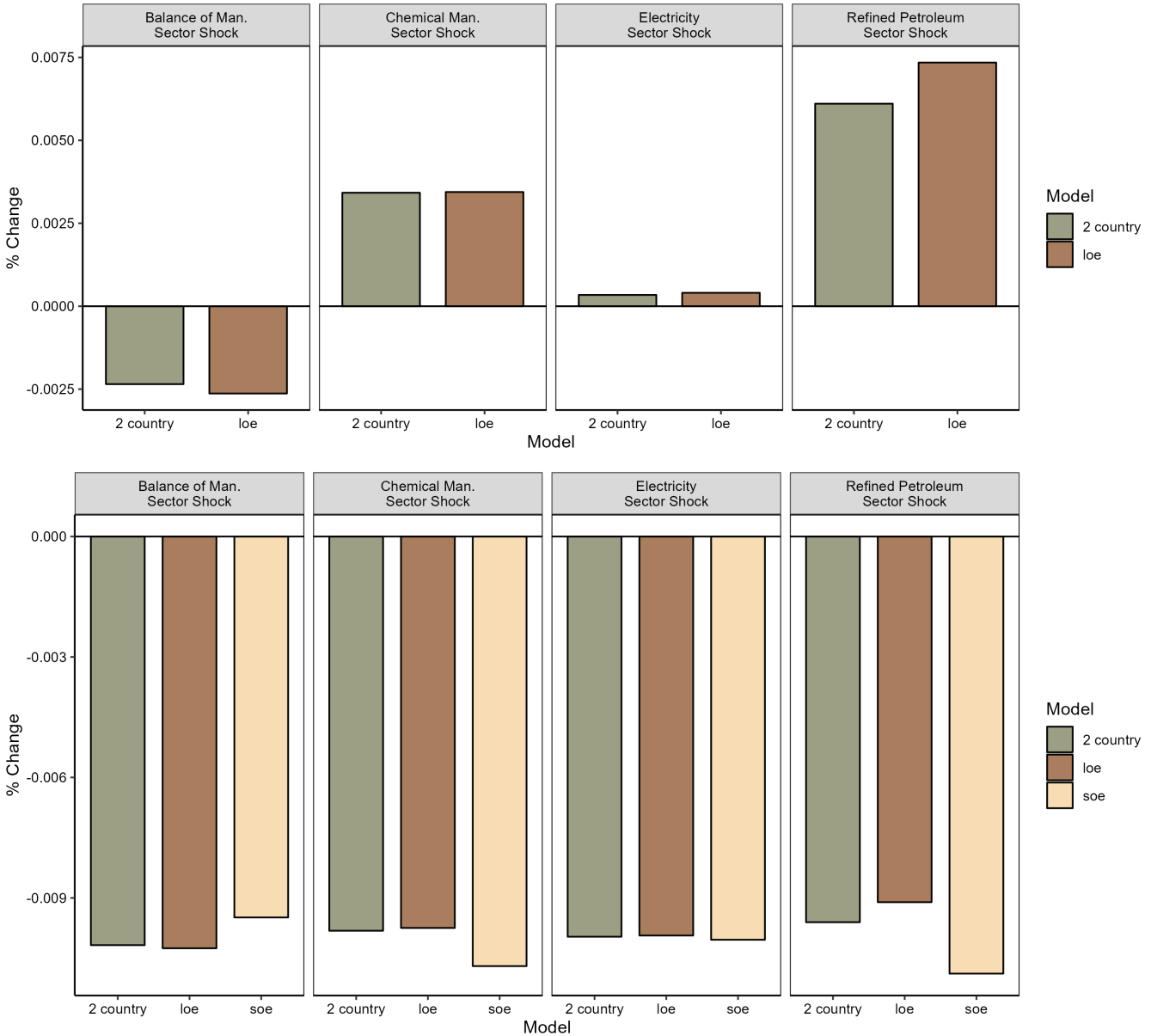
Model Results: Import Quantities



Model Results: Import Prices



Model Results: Terms of Trade and Welfare



Modeling Extension: Dynamics

- We extend this framework to the U.S. EPA's CGE model, SAGE (SAGE is an Applied General Equilibrium model, Marten et al., 2024).
- Test the importance of differential growth assumptions between the U.S. and the ROW into the future.
- Approximate how export demand and import supply elasticities may change using the static GTAPinGAMS model by hitting differential GDP growth targets.
- Bottom line: differential growth assumptions do not appear to significantly influence simulated welfare changes from illustrative environmental regulatory shocks in the U.S. economy. See paper for more details.

Discussion

Summary of the Paper

- Simulate export demand and import supply elasticities for the entire GTAP9 database using the GTAPinGAMS model.
- Use estimates to calibrate the approach from Markusen (1995) and Yuan et al., (2018).
- Compare model outcomes from illustrative environmental regulatory shocks using internally consistent model variants of the GTAPinGAMS package.
- We find that the LOE reduced form approach approximates the multi-regional model outcomes well in a static setting.
- We then extend the calibration approach to a dynamic setting assessing the importance of differential economic growth on equilibrium outcomes of domestic policy scenarios.

Concluding Thoughts

- Evidence generated with GTAP9 and GTAPinGAMS revealed that virtually any single country SOE model may miss important price impacts in export markets and some import markets depending on the region/commodity of interest.
- The importance of the LOE assumption relative to an SOE assumption is relatively understudied in non-trade modeling applications. In our illustrative scenarios, introducing the LOE framework produced any from a -16% to 8% welfare change relative to the SOE model. Effect dependent on policy scenario.
- The reduced form approach requires little additional modeling/parameters relative to an SOE model. Can translate an SOE model into an LOE model with 2*n parameters and check importance of welfare channel by setting $\theta = 0$.
- Approach is dependent on Armington elasticities in the GTAP database.

Thank you for listening.

Please feel free to contact me with any questions or comments at:
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