A Computable General Equilibrium Model of Energy Taxation

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International Association for Energy Economics
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Motivation

Background:
- Corporate income tax reform is always a hot topic
- Obama’s 2014 budget eliminates deductions for fossil fuels
- Administration says these deductions favor fossil fuels

Complication:
- Current energy tax models are missing key issues
Key problems:

- Does the budget improve social efficiency?
- How important are the issues previous models are missing?

Solution

- Create new energy tax model
- Include all key issues of energy taxation in my model
- Use model to determine the social efficiency of the budget proposal
1 Introduction
   - What are the proposed changes?
2 Model
   - How does my model improve on previous literature?
3 Results
   - Tax reform increases social welfare if carbon externalities are at least $14 per ton
   - My model’s innovations are important
## Changes in the budget proposal

<table>
<thead>
<tr>
<th>Proposed Change</th>
<th>Revenue ($ Billions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIFO inventory accounting</td>
<td>78.3</td>
</tr>
<tr>
<td>Domestic manufacturing deduction</td>
<td>19.9</td>
</tr>
<tr>
<td>Intangible drilling costs</td>
<td>13.7</td>
</tr>
<tr>
<td>Cost depletion</td>
<td>11.1</td>
</tr>
<tr>
<td>Superfund excise taxes</td>
<td>8.2</td>
</tr>
<tr>
<td>Dual capacity rules</td>
<td>7.9</td>
</tr>
<tr>
<td>Other</td>
<td>5.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>144.2</strong></td>
</tr>
</tbody>
</table>

Source: Joint Committee on Taxation (2013)
Model
Overview of commodity flows in my model

- **Household**: Consumption, Investment
- **22 Composite Goods**: Exports, Imports
- **Rest of the World**: Consumption
- **22 Industries**: Intermediate Inputs, Domestic Goods
- **Energy Resource**: Labor
- **Government**: Consumption
- **Capital**: Energy Resource
Overview of commodity flows in my model

- Household
- 22 Composite Goods
- Rest of the World
- 22 Industries
- Government
- Capital
- Labor
- Energy Resource
- Intermediate Inputs
- Domestic Goods
- Consumption
- Exports
- Imports
Overview of commodity flows in my model

- Household
  - Consumption
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- Composite Goods
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  - Imports
  - Consumption
  - Government

- Industries
  - 22 Industries
  - Oil

- Labor
  - Energy Resource

- Capital

- Rest of the World
  - Exports
  - Imports
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- **Capital**
- **Labor**
- **Government**
3 main issues determine the social efficiency of energy taxes

1. **Input Substitution**
   - Taxing fossil fuels at different rates than other goods leads to productive inefficiency due to substitution away from the more taxed goods.

2. **Energy resource supply**
   - If energy resources are inelastically supplied, there is little inefficiency to taxing them.

3. **Externalities**
   - Taxes internalize costs from climate change.
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3. Externalities
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Input Substitution
Cost and expenditure functional forms

Fixed coefficient (Leontief)
- No substitution
- Cannot capture productive inefficiency at all

Constant elasticity of substitution (CES)
- Restricts all inputs to have the same elasticity of substitution

Translog
- Allows for different elasticities of substitution for each pair of inputs
- Can accurately model productive inefficiency
Energy Resource
An energy resource is required to produce fossil fuels

This resource has isoelastic supply

Determine impact of resource supply by running simulation multiple times with different elasticities
Externalities
There is disagreement about carbon externalities so I avoid the debate entirely.

Calculate social cost of carbon for which budget has no net effect on welfare.

\[
\text{Social cost of carbon} = \frac{\text{Equivalent variation}}{\text{Reduction in emissions}}
\]
Results
The budget proposal decreases household welfare, capital stock, and employment, but also emissions.

Social cost of carbon must be at least $14 for the budget proposal to be welfare neutral.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Percent Change in</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Welfare</td>
<td>Capital Stock</td>
</tr>
<tr>
<td>Baseline</td>
<td>-0.50</td>
<td>-0.04</td>
</tr>
</tbody>
</table>

Table 1: The Effects of the Budget Proposal
What is the intuition behind these results?
Budget decreases productivity

Table 2: The Effects of the Budget Proposal on Productivity

<table>
<thead>
<tr>
<th>Specification</th>
<th>Percent Change in Productivity of Capital</th>
<th>Percent Change in Productivity of Labor</th>
</tr>
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<tbody>
<tr>
<td>Baseline</td>
<td>-0.09</td>
<td>-0.06</td>
</tr>
</tbody>
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Costs of the budget proposal come from decreased productivity.
Worse allocation of capital, labor, and consumption across uses.
Lower productivity means lower income, output, and welfare.
Fossil fuel production decreases

Table 3: Effects of the Budget Proposal on Selected Industries

<table>
<thead>
<tr>
<th>Industry</th>
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<td>-2.65</td>
</tr>
<tr>
<td>Petroleum and coal products manufacturing</td>
<td>-2.40</td>
</tr>
<tr>
<td>Pipeline transportation</td>
<td>-0.62</td>
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Decrease in output due to higher taxes is mitigated by substitution
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Decrease in output due to higher taxes is mitigated by substitution
How robust are these results?
Results are robust

Results are robust to changes in assumptions for:
- Capital
- Labor
- Energy resource
- Imports
- Instrumental variables
- Cost function parameters

Energy resource and substitution affect the size of the costs of the budget proposal
Conclusions

Budget is not social efficiency enhancing on purely tax criteria

Budget proposal needs a social cost of carbon higher than $14 per ton to be socially efficient

Important factors:

- Flexible substitution
- Externalities
- Energy resource supply
- General equilibrium modeling
Contact Information

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Website: barbe.rice.edu
Are taxes higher or lower on fossil fuels than other sectors?

Marginal Effective Tax Rate (METR) on investment is the metric used by the literature to measure tax rates:

- CBO (2005): 9% to 25% for fossil fuel assets and 24% for all business assets
- Mackie (2002): 25% to 36% for fossil fuel industries and 20% for entire economy
LIFO and FIFO govern inventory deductions

Firms can use either LIFO (Last-in, First-out) or FIFO (First-in, First-out) to determine their tax deduction when selling from inventories

This tax deduction is either the amount the firm paid for the:
- newest unit in inventory under LIFO or
- oldest unit in inventory under FIFO

LIFO is more desirable if prices are increasing over time

Budget Proposal:

All firms must use non-inflation indexed FIFO instead of LIFO
Revenue estimate: $78 billion over 10 years
LIFO inventory accounting changes

Table 4: Taxation of Inventory Appreciation

<table>
<thead>
<tr>
<th></th>
<th>Inflationary Appreciation</th>
<th>Real Appreciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Law</td>
<td>No Tax</td>
<td>No Tax</td>
</tr>
<tr>
<td>Budget Proposal</td>
<td>Tax</td>
<td>Tax</td>
</tr>
<tr>
<td>Neutral Tax System</td>
<td>No Tax</td>
<td>Tax</td>
</tr>
</tbody>
</table>

Current law taxes too little, budget proposal too much
LIFO change disproportionately affects petroleum refining

Energy companies own 82% of LIFO reserves on S&P 500 Index (Pryzbyla, 2011)

Firms using LIFO own:
- 73% of petroleum refining inventories (Knittel, 2009)
- 23% of all corporate inventories (Knittel, 2009)

Mean of value of LIFO reserves by firm:
- $2.6 billion and 119% of inventories for oil and gas (Tipton, 2012)
- $13 to $150 million and 2% to 28% of inventories for all other sectors (Tipton, 2012)
Cost depletion would replace percentage

Cost Depletion: taxpayer deducts a percent of lease cost equal to percent of resource extracted

Percentage Depletion:
- Taxpayer deducts a constant percentage of property’s gross income
- Percentage varies from 5-22% depending on resource
- Not allowed for integrated oil companies

Budget Proposal:
Coal, oil, and gas extraction must use cost depletion
Percentage depletion is not first-best but may be second

Non-neutral in a first best world:
- Percentages based on resource extracted
- Eligibility based on organizational form
- Deduction not based on actual cost of capital invested

Offset other distortionary features:
- Severance taxes
- Excise taxes
US taxes foreign source income but credits taxes paid

Territorial tax system:
- Does not tax foreign source income

Worldwide tax system:
- Does tax foreign source income
- Credit for certain foreign taxes

Dual capacity:
- A foreign tax is creditable if it is not payment for a specific economic benefit
- A dual-capacity taxpayer has some non-creditable taxes
Firms could only credit income tax

What foreign taxes are creditable?

- Facts and circumstances method: tax creditable if not for specific economic benefit
- Safe harbor method: credit an amount equal to host country’s generally imposed income tax rate

Budget Proposal:

Firms must credit an amount equal to host country’s income tax rate for other industries
No consensus on taxation of foreign source income

Is budget method more accurate than facts and circumstances method?

Should foreign source income be taxed at all?
- Kleinbard (2007) and Gravelle (2012) say yes
- Desai and Hines (2004) say no
Taxes excluded from METR are significant

Figure 1: Taxes paid by Fossil Fuel Producers in 1998-2009

Source: Author’s calculation from Bureau of Economic Analysis (BEA) US Input-Output Accounts and NIPA Table 6.18D.
**Corporate prevalence by industry**

**Table 5 :** Business Receipts in 2007 by Industry and Type of Entity (Percent)

<table>
<thead>
<tr>
<th>Sector</th>
<th>C Corporation</th>
<th>Pass-through</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining</td>
<td>66</td>
<td>34</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>All sectors</td>
<td>62</td>
<td>38</td>
</tr>
</tbody>
</table>

Source: Table 3 of the Internal Revenue Service’s Integrated Business Dataset
Calculating average effective tax rates

Average effective tax rate $= \frac{\text{tax payments}}{\text{tax base}}$

What payments?
- All corporate income and firm production taxes
- Includes federal, state, and local taxes

What base?
- Total value of output base
  - Forward shifting (tax borne by consumers)
- Factor income base
  - Backward shifting (tax borne by capital or labor)
Average of all taxes are higher on fossil fuels

Table 6: Average Effective Tax Rates of All Firm Taxes by Sector, 1998-2009

<table>
<thead>
<tr>
<th>Sector</th>
<th>AETR (%)</th>
<th>Factor Income</th>
<th>Value of Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil and gas extraction</td>
<td>19.3</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
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<td>20.4</td>
<td>5.1</td>
<td></td>
</tr>
<tr>
<td>Pipeline transportation</td>
<td>16.5</td>
<td>7.2</td>
<td></td>
</tr>
<tr>
<td>All fossil fuel</td>
<td>19.6</td>
<td>7.3</td>
<td></td>
</tr>
<tr>
<td>All sectors</td>
<td>10.8</td>
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</tbody>
</table>
But the AETR is incomplete too

Limitations:

- Firm taxes excludes those paid under the personal income tax
- Marginal rates can differ greatly from average rates

Non-uniform rates may be efficiency enhancing:

- Externalities
Previous models did not include all 3 issues

<table>
<thead>
<tr>
<th>Substitution</th>
<th>Partial Equilibrium</th>
<th>General Equilibrium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy resource supply</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Externalities</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Partial equilibrium (PE) models:
- Dasgupta, Heal, and Stiglitz (1981)
- Hotelling (1931)

General equilibrium (GE) models:
- Babiker et al. (2008)
- Jorgenson and Yun (2001)
Most of my model is conventional

1 representative household and 22 firms

Industries are perfectly competitive with constant returns to scale

Capital, labor, and energy resource are perfectly mobile between sectors

Consumer expenditure function and producer cost function determine their purchases
Regression

Use regression to find credible parameter values for the cost function

Cost share of input $i$ for industry $x$ at time $t$:

$$\text{share}_{xit} = \sum_{j=1}^{N} \beta_{xij} \ln(price_{xit}) + \beta_{xi}^{\text{trend}} \text{year} + \beta_{xi}^{\text{constant}}$$

Problems with estimating this equation:

- Cost shares are endogenous to input prices
- Cost share error terms are correlated

Iterated 3-stage least-squares solves both of these problems
Data sources for regression

Regression needs data on prices and cost shares for each industry and input.

Data sources for regression describe the US economy from 1960-2010:
- Jorgenson (2007)
- BEA
  - NIPA (National Income and Product Accounts)
  - Gross output price index
Translog has good traits but needs a large number of parameters.

The cost $c$ of output $o$ for industry $x$ at time $t$ is given by:

$$\ln(c_{xot}) = \frac{1}{2} \sum_{i=1}^{N} \sum_{j=1}^{N} \beta_{xij} \text{substitution} \ln(p_{xit}) \ln(p_{xjt})$$

$$+ \sum_{i=1}^{N} \ln(p_{xit}) \left( \beta_{xi} \text{share trend} t + \beta_{xi} \text{share constant} \right)$$

$$+ \beta_{xo} \text{cost trend} t + \beta_{xo} \text{cost constant}$$

The $p$'s are prices and the $\beta$’s are the parameters to be estimated.

Notable features:
- Allows for both Hicks-neutral and biased technological change.
- Large number of parameters dealt with by nesting.
Translog has good traits but needs a large number of parameters

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+ \sum_{i=1}^{N} \ln(p_{xit}) \left( \beta_{xit} \text{trend} + \beta_{xit} \text{constant} \right) \\
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$$

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Notable features

- Allows for both Hicks-neutral and biased technological change
- Large number of parameters dealt with by nesting
Nesting functions means putting cost functions inside other cost functions in order to group the most similar products together.

Nesting increases the number of equations but reduces the number of parameters in each equation.

I follow the nesting structure of Jorgenson and Yun and have 9 nests.

The model has 23 sets (22 industries and 1 household) of regressions for each nest.
CES Nesting

\[
\begin{align*}
O_i & \quad K_i \\
& \quad L_i \\
& \quad E_i \quad M_i
\end{align*}
\]
Cost functions nesting in my model

Final domestic output of industry $x$

$K_x$, $L_x$, $E_x$, $M_x$

$211$, $22$, $324$, $486$

$MM_x$, $MP_x$, $MS_x$, $MO_x$

$11$, $21$, $31$, N 61, 62, 71, 72, 51, 55, 56

$MSS_x$, $MOT_x$

$52$, $54$, $81$, $42$, $44$, $48$
Cost functions nesting in my model

Final domestic output of industry $x$

$K_x \quad L_x \quad E_x \quad M_x$

$MM_x \quad MP_x \quad MS_x \quad MO_x$

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211 \quad 22 \quad 324 \quad 486 \\
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Cost functions nesting in my model

Final domestic output of industry $x$

$K_x, L_x, E_x, M_x$

$MM_x, MP_x, MS_x, MO_x$

$MSS_x, MOT_x$

Barbé
A New Model of Energy Taxation
Predictive power of my model is high

Do not look at individual parameters for significance

Predictions of the model as a whole are what matter

Table 7: $R^2$ of Cost Function Regressions for All Industries

<table>
<thead>
<tr>
<th></th>
<th>Min</th>
<th>Mean</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R^2$</td>
<td>0.971</td>
<td>0.993</td>
<td>0.999</td>
</tr>
</tbody>
</table>
Remove tax preferences in a base-broadening reform

Compare long-run equilibrium of US economy under current law and budget proposal

Tax reform
- Increase tax rates on fossil fuel producing sectors as given in budget proposal
- Simultaneously lower overall capital tax rate on all sectors
- Revenue neutral

Results express the effects of the budget proposal

Externalities are included by calculating the social cost of carbon for which the proposal has no net effect on welfare
Capital and labor are a small fraction of costs

Table 8: Selected Industry Cost Shares (Percent)

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<tr>
<th>Industry</th>
<th>Cost share of:</th>
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<td>Capital and</td>
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<td></td>
<td>Labor</td>
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<td></td>
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<td>Materials</td>
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<td></td>
<td>89</td>
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<td></td>
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Output decreases very little because capital and labor are only a small fraction of costs
Including the energy resource matters but exactly how does not.

Table 9: The Effects of Budget Proposal Under Various Resource Supply Assumptions

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<td>Inelastic resource</td>
<td>-0.04</td>
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</tr>
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<td>No energy resource</td>
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<td>-0.02</td>
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Including an energy resource changes results but exactly how it is modeled matters little.
Including the energy resource matters but exactly how does not

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</tr>
<tr>
<td>Inelastic resource</td>
<td>-0.04</td>
<td>-0.01</td>
</tr>
<tr>
<td>No energy resource</td>
<td>-0.09</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

Including an energy resource changes results but exactly how it is modeled matters little.
Including the energy resource matters but exactly how does not not

Table 9: The Effects of Budget Proposal Under Various Resource Supply Assumptions

<table>
<thead>
<tr>
<th>Specification</th>
<th>Percent Change in:</th>
<th>Social Cost of Carbon ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capital Stock</td>
<td>Employment</td>
</tr>
<tr>
<td>Baseline</td>
<td>-0.04</td>
<td>-0.01</td>
</tr>
<tr>
<td>Elastic resource</td>
<td>-0.05</td>
<td>-0.01</td>
</tr>
<tr>
<td>Inelastic resource</td>
<td>-0.04</td>
<td>-0.01</td>
</tr>
<tr>
<td>No energy resource</td>
<td>-0.09</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

Including an energy resource changes results but exactly how it is modeled matters little
Instruments are weak

Weak instruments can harm inference

Test instruments by testing for underidentification (Anderson, 1951) and weak instruments (Stock and Yogo, 2002)

Table 10 : Summary of Instrumental Variable Tests

<table>
<thead>
<tr>
<th></th>
<th>Regressions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reject underidentification (5% level)</td>
<td>57</td>
</tr>
<tr>
<td>Reject weak instruments (0.30 maximal bias)</td>
<td>13</td>
</tr>
</tbody>
</table>

My instruments are weak
Results are not sensitive to weak instruments

Table 11: Effects of Budget Proposal under Different Instrumental Variables

<table>
<thead>
<tr>
<th>Specification</th>
<th>Percent Change in:</th>
<th>Social Cost of Carbon ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capital Stock</td>
<td>Employment</td>
</tr>
<tr>
<td>Baseline</td>
<td>-0.04</td>
<td>-0.01</td>
</tr>
<tr>
<td>2 period lags for IV</td>
<td>-0.03</td>
<td>-0.01</td>
</tr>
<tr>
<td>No instruments</td>
<td>-0.05</td>
<td>-0.01</td>
</tr>
</tbody>
</table>
Results are not sensitive to cost function values

Table 12: Effects of Reform in Monte Carlo Simulations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percentile of Percent Change in Variable</th>
<th>5%</th>
<th>50%</th>
<th>95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Stock</td>
<td></td>
<td>-0.05</td>
<td>-0.04</td>
<td>-0.04</td>
</tr>
<tr>
<td>Employment</td>
<td></td>
<td>-0.01</td>
<td>-0.01</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percentile of Variable</th>
<th>5%</th>
<th>50%</th>
<th>95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social Cost of Carbon</td>
<td></td>
<td>19</td>
<td>15</td>
<td>12</td>
</tr>
</tbody>
</table>

Even at the 95% level, no variable changes sign
Results are not sensitive to cost function values

Table 12: Effects of Reform in Monte Carlo Simulations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Percentile of Percent Change in Variable</th>
<th>Percentile of Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5%</td>
<td>50%</td>
</tr>
<tr>
<td>Capital Stock</td>
<td>-0.05</td>
<td>-0.04</td>
</tr>
<tr>
<td>Employment</td>
<td>-0.01</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

Even at the 95% level, no variable changes sign.
Elasticity parameters do not affect efficiency costs

Table 13: The Effects of Budget Proposal Under Various Capital and Labor Elasticities

<table>
<thead>
<tr>
<th>Specification</th>
<th>Percent Change in:</th>
<th>Social Cost of Carbon ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capital Stock</td>
<td>Employment</td>
</tr>
<tr>
<td>Baseline</td>
<td>-0.04</td>
<td>-0.01</td>
</tr>
<tr>
<td>Elastic capital</td>
<td>-0.09</td>
<td>-0.01</td>
</tr>
<tr>
<td>Inelastic capital</td>
<td>-0.02</td>
<td>-0.01</td>
</tr>
<tr>
<td>Elastic labor</td>
<td>-0.05</td>
<td>-0.02</td>
</tr>
<tr>
<td>Inelastic labor</td>
<td>-0.04</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

The social cost of carbon is very stable because greater tax distortion increases both its numerator and denominator.
Substitution is important for the efficiency costs of the budget proposal

Table 14: Effects of Tax Reform Under Various Import Assumptions

<table>
<thead>
<tr>
<th>Specification</th>
<th>Percent Change in:</th>
<th>Social Cost of Carbon ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Capital Stock</td>
<td>Employment</td>
</tr>
<tr>
<td>Baseline</td>
<td>-0.04</td>
<td>-0.01</td>
</tr>
<tr>
<td>No world market for fossil fuels</td>
<td>0.00</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

Removing the world market assumption reduces the costs of the budget proposal