The Effects of Restricting Coal Consumption on Coal Exports and Greenhouse Gas Emissions

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Motivation

• Reducing coal consumption is a frequent policy goal
  – Climate change
  – Health

• However, restricting coal consumption has unintended consequences
  – Fuel switching
  – Carbon leakage

• These spillovers could change the sign of the effect of the policy on world emissions
Summary of this Paper

• Research question
  – What happens if the U.S. restricts coal consumption?

• My contribution
  – Estimate policy impact using a model that includes aforementioned spillovers
  – Modify GTAP-E to allow for binding constraints on cost function

• Results
  – A U.S. restriction reduces world emissions
  – Foreign carbon leakage is negligible
  – Restrictions greater than 30% do not reduce emissions much more than the 30% restriction does
Agenda

• Background
  – Coal policies
  – Spillovers
  – Literature

• Methodology
  – GTAP
  – Policy shocks

• Results
BACKGROUND
Coal Emissions and Policy

• Coal and greenhouse gas emissions
  – 95% of U.S. coal CO₂ emissions are from power generation
  – Coal produces 75% more CO₂ per kWh than natural gas
  – Coal power plants are 21% of all U.S. greenhouse gas emissions

• Policies to phase out coal power plants
  – 2014: Ontario
  – 2030: Canada, France, UK
  – 2035: Oregon

• Clean Power Plan in United States would have required
generators to reduce their coal intensity
Unintended Consequences

• Restricting coal consumption has spillover effects
  – Domestic fuel switching
    • Increased domestic natural gas emissions
  – Foreign carbon leakage
    • Increased coal exports
    • Energy-intensive industries move abroad

• When you include spillovers, what is the effect of restricting coal consumption?
METHODS
Overview of GTAP-E

• GTAP-E is a computable general equilibrium model of world economy
  – 8 sectors and 9 regions
  – Can describe how trade, consumption, and production of different goods respond to policy changes

• Model specializes in energy and international trade
  – Fuel switching
  – Foreign carbon leakage
Description of the Policy

• Policy: U.S. government mandates that coal intensity in power generation sector falls by X%  
  – Coal intensity = use of coal / use of all fuels  
  – 4 scenarios where X ranges from 10% to 40%

• Calculate impact of policy by comparing  
  – Baseline business as usual  
  – Scenarios were various coal policies are implemented
My Modifications to GTAP-E

• Policy adds a binding constraint to the firm cost minimization problem

• However, GTAP-E does not allow for such constraints

• I modify the firm cost equation to allow for binding constraints
Policy’s Effects on U.S. Electricity Generation

<table>
<thead>
<tr>
<th>Change in Economic Variable (%)</th>
<th>Coal Intensity Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>Demand for Gas for Generation</td>
<td>13</td>
</tr>
<tr>
<td>Demand for Coal for Generation</td>
<td>-11</td>
</tr>
</tbody>
</table>

- Policy leads to substantial fuel switching

- Large changes lead to uncertainty
  - Results driven by model parameters
  - GTAP’s parameter values are intended to reflect actual 2011
  - 30% and 40% policies look very different from actual 2011
  - Parameter values might be different in such a world
  - So the estimated effects of those policies have large error bars
Policy’s Effects on Coal Trade

<table>
<thead>
<tr>
<th>Change in Economic Variable (%)</th>
<th>Coal Intensity Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>U.S. Coal Production</td>
<td>-8</td>
</tr>
<tr>
<td>U.S. Coal Imports</td>
<td>-5</td>
</tr>
<tr>
<td>U.S. Coal Exports</td>
<td>3</td>
</tr>
<tr>
<td>World Coal Production</td>
<td>-1</td>
</tr>
</tbody>
</table>

- U.S. coal production, consumption, and imports decrease
- U.S. coal exports increase
- World coal production decreases
### Policy’s Effects on Carbon Emissions

<table>
<thead>
<tr>
<th>Change in Emissions (million MT)</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Coal</td>
<td>-181</td>
<td>-396</td>
<td>-667</td>
<td>-1,061</td>
</tr>
<tr>
<td>U.S. Gas</td>
<td>60</td>
<td>148</td>
<td>298</td>
<td>634</td>
</tr>
<tr>
<td>Non-U.S. Total</td>
<td>-1</td>
<td>-3</td>
<td>-6</td>
<td>-13</td>
</tr>
<tr>
<td>World Total</td>
<td>-119</td>
<td>-239</td>
<td>-350</td>
<td>-377</td>
</tr>
</tbody>
</table>

- Domestic fuel switch (to gas) offsets much of the coal emissions reduction
- International carbon leakage is negligible
- World emissions decrease
- 30% policy reduces emissions by about as much as 40% does
CONCLUSIONS
Summary

• Some countries are phasing out coal

• But coal restrictions may have spillover effects
  – Fuel switching
  – Foreign carbon leakage

• This paper analyzes the effect of coal restrictions
  – Include these spillovers
  – Modify GTAP-E to allow for constrained optimization
Conclusions

• Restricting U.S. coal consumption reduces world carbon emissions

• There is little carbon leakage to foreign countries

• Domestic fuel switching to gas is substantial and offsets almost all of the incremental reduction for restrictions greater than 30%
APPENDIX
Contact Information

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Future Work

• Use a partial equilibrium model focused on the choice of generation technology
Comprehensive carbon policies have small spillovers

• “Comprehensive” means it applies to all emissions
  – Cap and trade
  – Carbon tax

• Böhringer, Balistreri, and Rutherford (2012)
  – Foreign carbon leakage offsets 5-20% of domestic emissions reduction

• Arlinghaus (2015)
  – Competitive losses and distributional impact not significant
Spillovers in Coal vs. Comprehensive

• Policies focused on a particular input can have much larger spillovers
  – Biofuel mandates may increase global emissions

• Coal
  – If policy restricts coal consumption, increased exports could offset 47% of restriction (Riker, 2012)
  – Australian coal export tax could reduce Australian welfare and increase world emissions (Richter, Mendelevitch, and Jotzo, 2015)
Figure 16  GTAP-E Production Structure

Output

Value-added-Energy
(Including energy inputs)

All other inputs
(Excluding energy inputs but including energy feedstock)

\( \sigma_{\Delta x} \)

Natural Resource

Labor

Capital-Energy Composite

Skilled

Unskilled

Domestic

Foreign

Region 1 ... Region \( r \)

Figure 17  GTAP-E Capital-Energy Composite Structure

Capital-Energy Composite

Capital

Energy Composite

Non-Electric

Electric

Coal

Non-Coal

Petroleum products

Domestic

Foreign

Region 1 ... Region \( r \)