Abatement Performance Evaluation of Climate Policies in China - A Study based on Integrated Assessment Model

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Introduction

• Countries need to adopt domestic climate policies to control greenhouse gas (GHG) emission in response to global climate change

• The implementation of climate policies has two sides

Cost

- Social output limit
  - Increasing energy cost
  - Externality internalization

Benefit

- Climate damage offset
  - Climate damage definition
Introduction

- In general, climate policies evaluation has two components

  **Cost-Effectiveness Analysis (CEA)**
  - GDP loss
  - Consumption loss
  - Energy cost increase
  - Energy investment increase

  **Cost-Benefit Analysis (CBA)**
  - Cost
  - Benefit: damage reduction

- The relative cost advantage between different energy technologies may be adjusted
- Increasing energy cost in the short term
- Social output will be limited because of the shortage of energy supply
- Substantial energy investment for promoting non-fossil energy technologies
- Consumption of final goods limits (van der Zwaan et al., 2002; Gerlagh et al., 2004, 2006; Duan et al., 2014; Zhu et al., 2014)

(Source: Manne et al., 1995)
Introduction

- The global response to climate change has been influenced to a great extent by particular regions with large CO₂ emissions (e.g. the USA, the EU and China).
- China, the world’s largest developing country, is the nation with the greatest CO₂ emission; approximately 92 million tons in 2012, which is around 26.72% of total global emission (BP, 2013).

Therefore, the implementation of China’s climate policies can not only impact on domestic sustainable development, but can also have a direct effect on the performance of global actions on climate change.

Source: BP, wind
Introduction

Several difficulties exist in policy evaluation based on IAM in single region:

- Difficult to clearly consider and describe the characteristics of specific regional economic development, as well as energy use
- In addition to the global temperature target, countries can adopt different types of domestic emission reduction policies, or policy mix
- Due to the global greenhouse effect, climate damage in a specific region is directly influenced by the global CO2 emission, not by the region itself (Nordhaus and Boyer, 2000)

Our Work

- To better analyze and evaluate abatement performance of a specific region in the medium- and long-term, we establish a modified single-region version of DEMETER model (DEMETER-R), to evaluate China’s climate policies
Model

- **Model**: DEMETER-R
- **Subject**: social welfare maximization
- **Agent**: consumer, fossil energy sector and non-fossil energy sector
- **Technological change**: AEEI, LBD, LBS curve
- **Climate module**: multi-stratum carbon recycle system (Nordhaus and Boyer, 2000)
- **Term**: 2010-2150
- **Policies**: fixed carbon tax, dynamic carbon tax, and mixed policy
## Model

- **Definition of Regional Climate Loss**
  - Regional and Global Emission Ratio Setting
  - Multi-stratum carbon recycle system (Nordhaus and Boyer, 2000)
  - Market and Non-Market Climate Loss (Manne et al., 1995)

<table>
<thead>
<tr>
<th>Definition</th>
<th>Equation</th>
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</thead>
<tbody>
<tr>
<td>Emission ratio</td>
<td>( \hat{E}m_{t}^{ROW} = \Theta_t \hat{E}m_{t}^{domestic} )</td>
</tr>
<tr>
<td>Market damage factor</td>
<td>( D_t = d_1 \cdot TEMP_t^{d_2} )</td>
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<tr>
<td>Non-market damage factor</td>
<td>( WTP_t = d_3 \cdot TEMP_t^{d_4} / (1 + 100 \cdot \exp(-0.23 \cdot GDP_t / L_t)) )</td>
</tr>
<tr>
<td>Regional climate damage</td>
<td>( Damage_t = (MD_t + WTP_t) \cdot GDP_t )</td>
</tr>
<tr>
<td>Output distribution</td>
<td>( Y_t^C = GDP_t + Damage_t + \sum_k M_t^k )</td>
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- **‘Burden’ scenario**
  - The abatement ratio of China compared to the world will increase when its CO2 emission share decreases compared to the world.

- **Free-riding’ scenario**
  - Conversely, the abatement ratio of China will decrease compared to the world when its CO2 emission share increases compared to the world.
Model

- Abatement Performance Measure

  - Cost-Effectiveness Performance
    - Consumption Loss (CL)
    - GDP Loss (GL)
    - Energy Cost Increase (EC)
    - Energy Investment Increase (EI)

  - Cost-Benefit Performance
    - Consumption loss Cost Benefit Ratio (CBR)
    - GDP Loss CBR
    - Energy Cost Increase CBR
    - Energy Investment Increase CBR

Equations:

<table>
<thead>
<tr>
<th>Performance</th>
<th>Indicators</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption Loss</td>
<td>$CL_i = \sum_{t=0}^{T} (1+\rho)^{-t} (C_{num,t} - C_{oji})$</td>
<td></td>
</tr>
<tr>
<td>GDP Loss</td>
<td>$GL_i = \sum_{t=0}^{T} (1+\rho)^{-t} (GDP_{num,t} - GDP_{oji})$</td>
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</tr>
<tr>
<td>Energy Cost Increase</td>
<td>$ECI_i = \sum_{t=0}^{T} \left[ (1+\rho)^{-t} (p_{i,t} Y_{i,t} - p_{num,t} Y_{num,t}) \right]$</td>
<td></td>
</tr>
<tr>
<td>Energy Investment Increase</td>
<td>$EII_i = \sum_{t=0}^{T} \left[ (1+\rho)^{-t} (I_{i,t} + ARD_{i,t} - I_{num,t} - ARD_{num,t}) \right]$</td>
<td></td>
</tr>
<tr>
<td>Consumption loss Cost Benefit Ratio (CBR)</td>
<td>$CCBR_{i} = \frac{\sum_{t=0}^{T} (1+\rho)^{-t} (C_{num,t} - C_{oji})}{\sum_{t=0}^{T} (1+\rho)^{-t} \text{Benefit}_{t,i}}$</td>
<td></td>
</tr>
<tr>
<td>GDP loss Cost Benefit Ratio (CBR)</td>
<td>$GCBR_{i} = \frac{\sum_{t=0}^{T} (1+\rho)^{-t} (GDP_{num,t} - GDP_{oji})}{\sum_{t=0}^{T} (1+\rho)^{-t} \text{Benefit}_{t,i}}$</td>
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</tr>
<tr>
<td>Energy cost increase Cost Benefit Ratio (CBR)</td>
<td>$ECBR_{i} = \frac{\sum_{t=0}^{T} (1+\rho)^{-t} (p_{i,t} Y_{i,t} - p_{num,t} Y_{num,t})}{\sum_{t=0}^{T} (1+\rho)^{-t} \text{Benefit}_{t,i}}$</td>
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<td>Energy Investment increase Cost Benefit Ratio (CBR)</td>
<td>$EICBR_{i} = \frac{\sum_{t=0}^{T} (1+\rho)^{-t} (I_{i,t} + ARD_{i,t} - I_{num,t} - ARD_{num,t})}{\sum_{t=0}^{T} (1+\rho)^{-t} \text{Benefit}_{t,i}}$</td>
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<tr>
<td>CAS_{i,j} Abatement contribution Share</td>
<td>$CAS_{i,j} = \left( \frac{\sum_{t=0}^{T} Y_{i,t}^P}{\sum_{t=0}^{T} Y_{num,t}^P} \right) \left( \frac{Y_{num,t}^P - Y_{i,t}^P}{Y_{num,t}^P - Y_{i,t}^P} \right)$</td>
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<tr>
<td>TAS_{i,j} Abatement contribution Share</td>
<td>$TAS_{i,j} = \left( \frac{\sum_{t=0}^{T} Y_{i,t}^P}{\sum_{t=0}^{T} Y_{num,t}^P} \right) \left( \frac{Y_{num,t}^P - Y_{i,t}^P}{Y_{num,t}^P - Y_{i,t}^P} \right)$</td>
<td></td>
</tr>
<tr>
<td>Annual Technology-switching Change Ratio</td>
<td>$ATCR_{i,j} = \sqrt{TAS_{i,j} / \sum_{t=0}^{T} TAS_{i,j}^t}$</td>
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<tr>
<td>Technology Relative Price</td>
<td>$TRP_{i,j} = \frac{P_{i,j}}{P_{num,j}}$</td>
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In the BAU scenario, the emission share between the world and China was calculated by the estimate of CO$_2$ emission of global DEMETER and DEMETER-R under the BAU scenario.
Result and analysis

- Group 1 (Case 1-6)

The results show that the performance of dynamic carbon tax from the perspective of cost-effectiveness is clearly better than that of fixed carbon tax.

But the implementation of fixed carbon tax will lead to a lower GL and EC cost-benefit ratio, which are interpreted as better cost-benefit efficiency of fixed carbon tax.
Result and analysis

• Group 2 (Case 7-10)

• For these two policies, the four cost effectiveness factors declined with ‘burden’ and increased with ‘free-riding’

• However, the EC and EI cost-benefit efficiency factors increased with ‘burden’ and decreased with ‘free-riding’

Figure 3. Four types of cost effectiveness factor under 450 ppmv

Figure 4. Four types of cost benefit efficiency factor under 450 ppmv
Thanks for your attention

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