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The objective of this study is the comparison of CO₂ emission reduction potentials in the high energy intensive U.S. industries (such as iron-steel and cement) through national scale efficiency measures and/or emissions trading with China.

- To offset CO₂ emissions with national scale efficiency measures, investments are realized in the U.S. industries.
- To offset CO₂ emissions with carbon trading from China, U.S. invests on efficiency measures in Chinese industries, then imports the commodities.

The purpose of this analysis is to find the minimum cost of reducing CO₂ emission in the U.S. iron-steel and cement industries.

- Should the U.S. invest on efficiency measures domestically or in China and then imports from there (i.e. shrink the size of the industry in the U.S.)? Which one is cost effective?
Literature

- To date, the majority of existing bottom-up models have been based on the theoretical representation of an ideal closed market, e.g., MESSAGE, EFOM, MARKAL.

- In reality, however, few economies can be described adequately using closed market assumptions. Most of the time, trade policies are excluded from the model, as well as their likely effects on sector production, energy consumption, and emissions.

- Meanwhile, existing models used for trade policy analysis generally employ top-down approaches and lack of technological detail, e.g., EPPA, SGM, GTAP.

- ISEEM is a new type of modeling approach combining technological representations of the bottom-up models with the trading representations of the top-down models.
ISEEM Modeling Framework

- Bottom-up, optimization modeling framework, developed specifically for industry sector, and trading of industrial products.

- Captures the effects of various trading characteristics such as tariffs, transportation costs, or emissions due to commodity trading.

- Enables international scenario analysis such as cross-country carbon trading.

- Emulates energy carrier, raw material and commodity flow in production systems, and trading of final products between countries.

- Captures technological change to include energy efficiency improvement.
### U.S. Iron-Steel and cement sectors in base year ‘2010’

#### Iron-steel:

<table>
<thead>
<tr>
<th>Production</th>
<th>Import</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOF</td>
<td>EAF</td>
</tr>
<tr>
<td>31.2</td>
<td>49.3</td>
</tr>
</tbody>
</table>

- **Total Production**: 80.5 Mtonnes
- **Total Import**: 22 Mtonnes

#### Cement:

<table>
<thead>
<tr>
<th>Production</th>
<th>Import</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td>Wet</td>
</tr>
<tr>
<td>60.7</td>
<td>5.8</td>
</tr>
</tbody>
</table>

- **Total Production**: 66.5 Mtonnes
- **Total Import**: 6 Mtonnes

**NOTE:** There is almost no steel import from China in the Base year because of the U.S. quotas.

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**Total Final Energy Consumption**

- **Iron-steel**: 878.9PJ
- **Cement**: 296.5PJ

![Diagram showing energy consumption and production for iron-steel and cement sectors]
Annual projections of the U.S. steel and cement demands exogenously inputted in the ISEEM Model (Mtonnes):

Data-source for historical data: USGS
Data-source for exogenous demand projections: COBRA energy modeling analysis (Wagner and Sathaye, 2006)
## Scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Symbol</th>
<th>Trading</th>
<th>Efficiency Measures</th>
<th>Emission Restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Scenario</td>
<td>Base</td>
<td>★</td>
<td>✓</td>
<td>NO</td>
</tr>
<tr>
<td>Emission Restriction without Trading Scenario</td>
<td>‘ER w/o CO₂ T’</td>
<td>!</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Emission Restriction with CO₂ Emission Trading Scenario</td>
<td>‘ER w CO₂ T’</td>
<td>✓★</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**Emission Restriction:** Emissions are restricted 20% below of those in the Base scenario, starting from 2020.

**Import limitation is applied only for steel sector (no limitation on cement sector)!**

- ★ : In the Base scenario, steel import is limited to the maximum import share in the last 15 years (i.e., 1995-2010) through the planning horizon (i.e., 30%).
- ! : In ‘ER w/o CO₂ T’ scenario, import is limited to the levels in the Base scenario.
- ✓★ : Limitation on steel import in the Base scenario is extended 50% (i.e., 45% instead of 30% in the Base scenario).
In the ‘ER w/o CO2T’ Scenario, annual steel and cement production and import levels are the same as that of the Base scenario because no trading instrument is imposed.

Production cost of steel is higher compared to import cost from China, in each scenario per year. Thus, steel import from China increases from year to year, until the allowed limits are achieved.

Production cost of cement is lower compared to import cost from China, in the Base scenario per year. Only in the ‘ER w CO2T’ scenario cement import from China increases.
Scenario results: primary energy consumption and intensity

Iron-steel Sector Primary Energy Consumption

Iron-steel Sector: Average Primary Energy Intensity

Cement Sector Primary Energy Consumption

Cement Sector: Average Primary Energy Intensity
to mention axis does not start from 0.
abrush, 6/10/2014

Explanations are on the Note section.
abrush, 6/11/2014
Scenario results: \( CO_2 \) emission intensity and abatement cost

- **Iron-steel Sector: Average \( CO_2 \) Emission Intensity**
  - 20% emission reduction is achieved with an increase of $7-10/tonne steel (2-2.5% increase in unit cost) and $4-9/tonne cement (5-10% increase in unit cost) between the periods 2020 and 2050 with national scale efficiency measures (i.e., in ‘ER w/o CO2T’).

- **Cement Sector: Average \( CO_2 \) Emission Intensity**
  - 20% emission reduction is achieved with an increase of $7-10/tonne steel (2-2.5% increase in unit cost) and $4-9/tonne cement (5-10% increase in unit cost) between the periods 2020 and 2050 with national scale efficiency measures (i.e., in ‘ER w/o CO2T’).

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a5  to mention axis does not start from 0.
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a6  Explanations are on the Note section.
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Conclusion

- The ISEEM framework enables us to analyze emission reduction potentials in industry sectors with or without carbon trading from China.

- **Iron-steel:**
  - The cost of Chinese steel import in the model is much lower than that of the U.S. Even with additional costs associated with carbon trading, the unit cost of imported steel still remains lower than that of the U.S. domestic cost. As a result, the optimization process prefers importing from China up to the allowable quota. Thus, raising steel quotas in CO$_2$ emission trading (i.e., ‘ER w CO2T’) scenario favors imports from China.
  - However, the ‘ER w/o CO2T’ scenario shows that a 20% emission reduction can be achieved with an increase of $7-10/tonne steel (i.e., 2-2.5% increase on unit production cost) with national scale efficiency measures. If there are no subsidies on the China side, investments in national scale efficiency measures in the U.S. may be cost-effective.

- **Cement:**
  - The cost of Chinese cement imports in the model is higher than that of the U.S. Thus, the optimization process favors cement production in the U.S., and phases out cement imports in the Base and ‘ER w/o CO2T’ scenarios.
  - In the ‘ER w CO2T’ scenario, there are some cement imports. However, reduction in energy consumption in the cement sector in this scenario is the result of both the declining domestic production in the U.S. (i.e., increasing import from China) and improvement in energy efficiency, not solely reduction in production.
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Unit cost of imported steel from China is lower than the unit production cost in the U.S. in each scenario.

In the ‘ER w/o CO2T’ Scenario, steel production cost is higher than that of the Base and ‘ER w CO2T’ scenarios.

Unit cost of imported steel from China is higher than the unit production cost in the U.S. in each scenario.

In the ‘ER w/o CO2T’ Scenario, steel production cost is higher than that of the Base and ‘ER w CO2T’ scenarios.