# The General Equilibrium Impacts of Carbon Tax Policy in China: A Multi-model Assessment

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# Introduction

- The purpose of this modeling exercise is to conduct a multi-model comparison of carbon tax policy in China using CGE model, to examine the potential impacts in medium-term 2030 and distant future 2050.
  - Multi-sector CGE model – inter-sectoral linkages, economywide general equilibrium impacts of carbon pricing on energy sectors
  - Different Models vary greatly across models: economic model structure, model assumption and projections, model functions and parameters, multi-model comparison help to understand the simulation results across models
  - Multi-model comparison: providing model consensus or plausible range of impacts for policy decision

# Exercise: Carbon Pricing to Reach NDC target

- **Research Goal**: Assess how likely a future carbon pricing regime would mitigate carbon emissions, as well as general equilibrium effects at economy-wide for China.
- CEMF group: focus on **8 Chinese CGE models**
- Modeling comparison: use common assumptions on main drivers and key projections: population/labor input projections, calibrating **a common trend of GDP growth till 2050**, **world oil price**, and a **common set of carbon tax** policy scenarios (low, medium and high scenarios) with carbon tax rate set for each year.
- Contributing to EMF literature: Sugiyama et. al, 2019; Huntington, 2013; Stanford EMF Projects on the Energy Journal Special issue of volume 32 and other EMF reports

## Summary of eight Chinese CGE Models

- **C-GEM** (Tsinghua Zhang Xiliang group), 2010s – now, GTAP 9 and Chinese CSY data (2011)
- **CHEER|CGE Model** (Tsinghua Cai Wenjia, Wang Can), 2001-now, Model 2012
- **CHINAGEM** (ISD, CAS, Liu Yu) GEMPACK, 2006-now, Model 2012
- **DRC CGE** (DRC, Li Shantong, He Jianwu), 90s-now, Model 2015
- **DREAM** (Fudan Wu Libo, Qian Haoqi), 2011-now, Model 2011
- **HTCGE** (Harvard & Tsinghua, Cao Jing, Mun Ho, Dale Jorgenson), 90s-now, Model 2014
- **IMED|CGE** (Peking, Dai Hancheng), 2009-now, Global 2002, National 2012 provincial data
- **SICGE** (State Information Center, Li Jifeng), GEMPACK, 2007-now, Model 2012

# Data requests to all modeling groups

| Tab | Notes/Instructions |
|---|---|
| meta | Please fill in your name, your institution's name, your model's name, and the date and time of the submission. |
| model description | Model characteristics, publication and etc |
| comments | On this tab, you should fill in any information you think is necessary for understanding your scenario and simulation results. We are particularly interested in assumptions made about policy simulations. If your model deviates from our common model assumptions and scenarios, you should note there including your definitions. Please describe your method of converting to the specified monetary units as this often introduces non-comparable values. For example, in 2012 yuan or 2015 yuan |
| assumption | On this sheet, we provide some common trend to eliminate assumption differences in each model, that is, we will provide a basic trend and carbon pricing trajectory that you can use to put into your own model |
| carbon tax rate | we will adopt a common pathway of increasing carbon tax in China, all models should implement the same level of carbon tax rate |
| world energy price projection | we will adopt a common projection of world energy prices (especially oil price) |
| benchmark economic path | We decide to use Li Shantong & He Jianwu CGE model Population and macro economic projection as a common trend for all models |
| data | On this tab you should fill out model results. Please fill in all required fields, which are highlighted in blue. There may be categories of data that are not available in your model, please mark these rows with N/A. Please fill in data for any historical years included in your model. For example, if the base year is 2004, you should add a column for 2004. |
| variable definitions | This tab provides definitions and reporting conventions for each variable in the worksheet. |

# Model Assumptions on BAU Scenario:

- DRC CGE is used as the benchmark projection of GDP growth for other models to calibrate (most models calibrate TFP to target the GDP growth, some also calibrate population)
- DRC CGE's major social-economic drivers: population growth, urbanization rate, and labor input participations are given in the following tables:

| | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| Population(mil.) | 1375 | 1411 | 1426 | 1428 | 1418 | 1395 | 1366 | 1331 |
| Urban | 771 | 869 | 943 | 998 | 1032 | 1045 | 1042 | 1033 |
| Rural | 603 | 542 | 483 | 430 | 386 | 351 | 323 | 298 |
| Urbanization Rate （%） | 56.1 | 61.6 | 66.1 | 69.9 | 72.8 | 74.9 | 76.3 | 77.6 |
| Labor input （mil.） | 775 | 768 | 764 | 731 | 702 | 673 | 654 | 632 |

# Model Assumptions

- DRC-CGE's GDP growth rate projection and decomposition on labor input, capital formation and TFP

| | 2015~2020 | 2020~2025 | 2025~2030 | 2030~2035 | 2035~2040 | 2040~2045 | 2045~2050 |
|---|---|---|---|---|---|---|---|
| GDP growth rate | 6.5 | 5.5 | 4.5 | 4.0 | 3.4 | 3.4 | 2.9 |
| Decomposed into: | | | | | | | |
| Labor input growth rate | -0.2 | -0.1 | -0.9 | -0.8 | -0.8 | -0.5 | -0.7 |
| Capital formation growth rate | 9.7 | 7.2 | 5.7 | 4.5 | 3.5 | 3.2 | 2.9 |
| TFP | 1.7 | 2.0 | 2.1 | 2.2 | 2.1 | 2.1 | 1.8 |

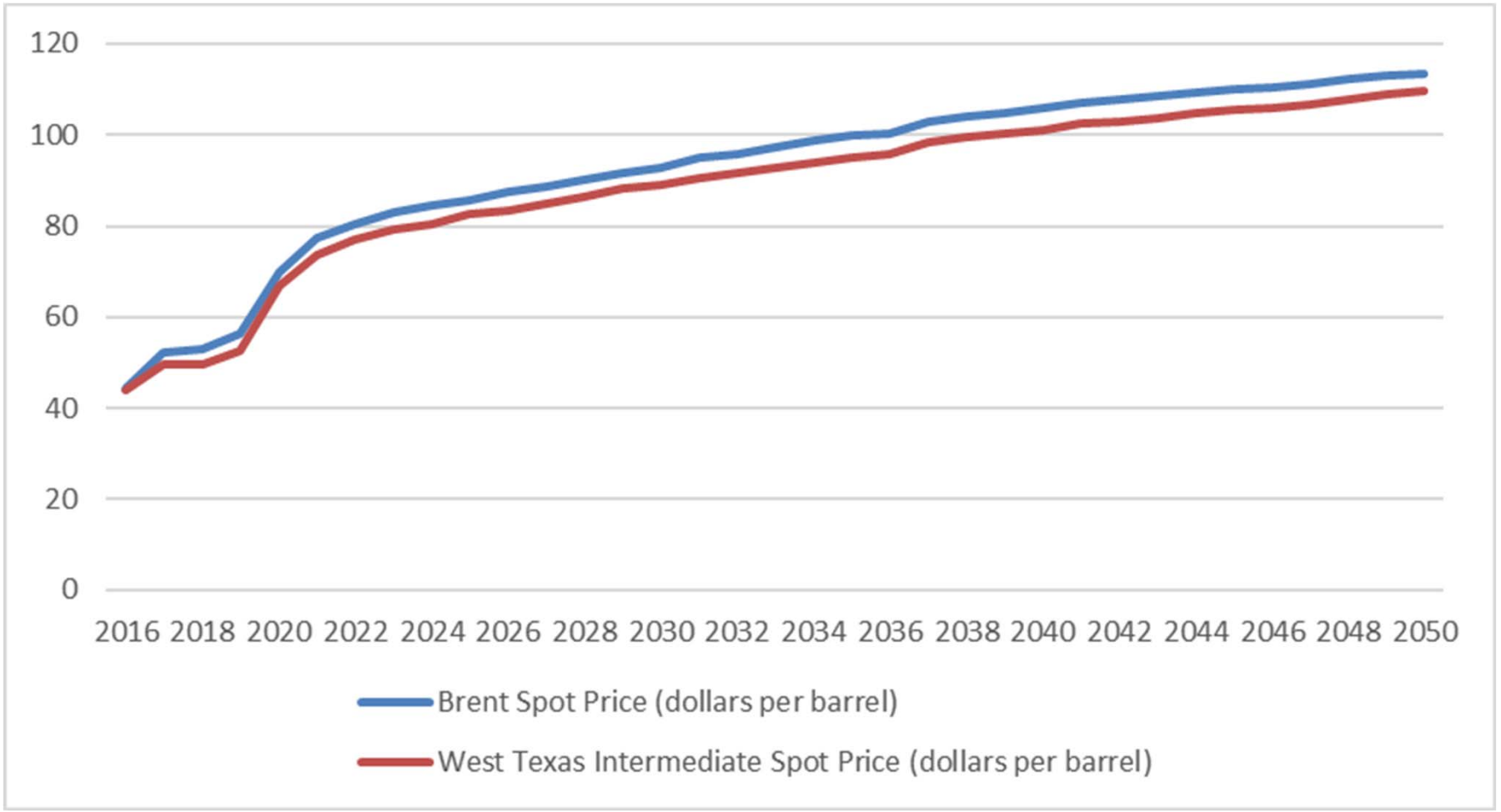
# Model Assumptions (continued)

| | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| Primary Sector | 8.8 | 6.7 | 5.8 | 4.5 | 3.7 | 2.8 | 2.3 | 1.8 |
| Secondary Sector | 40.9 | 35.6 | 31.3 | 29.1 | 26.2 | 24.4 | 22.6 | 21.0 |
| Tertiary Sector | 50.2 | 57.5 | 62.8 | 66.2 | 70.0 | 72.7 | 75.0 | 77.1 |

| | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| GDP: | | | | | | | | |
| Household Consumption | 38.0 | 45.5 | 49.9 | 50.8 | 55.0 | 56.1 | 57.1 | 58.2 |
| Government Consumption | 13.8 | 14.7 | 15.5 | 16.1 | 16.6 | 17.1 | 17.7 | 18.3 |
| Capital Formation | 44.7 | 39.8 | 34.5 | 33.1 | 28.3 | 26.7 | 25.2 | 23.6 |
| Net Export | 3.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

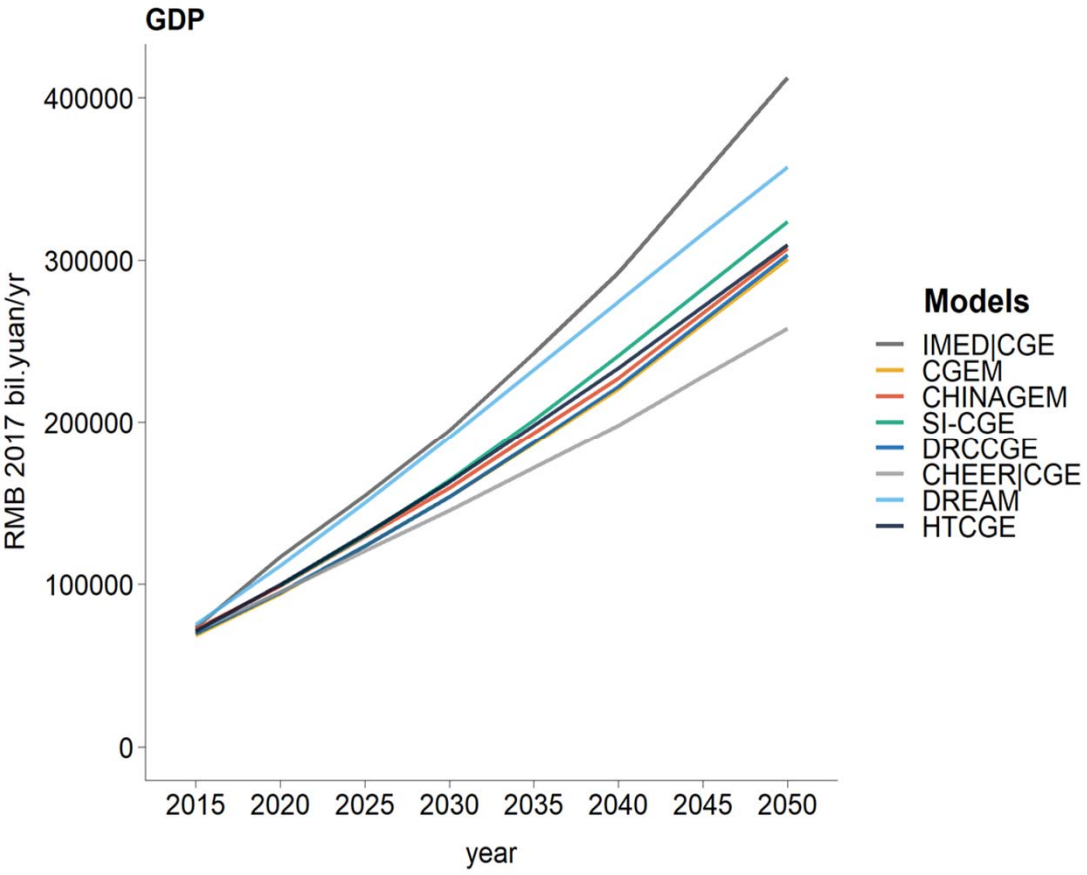
# Model Assumptions

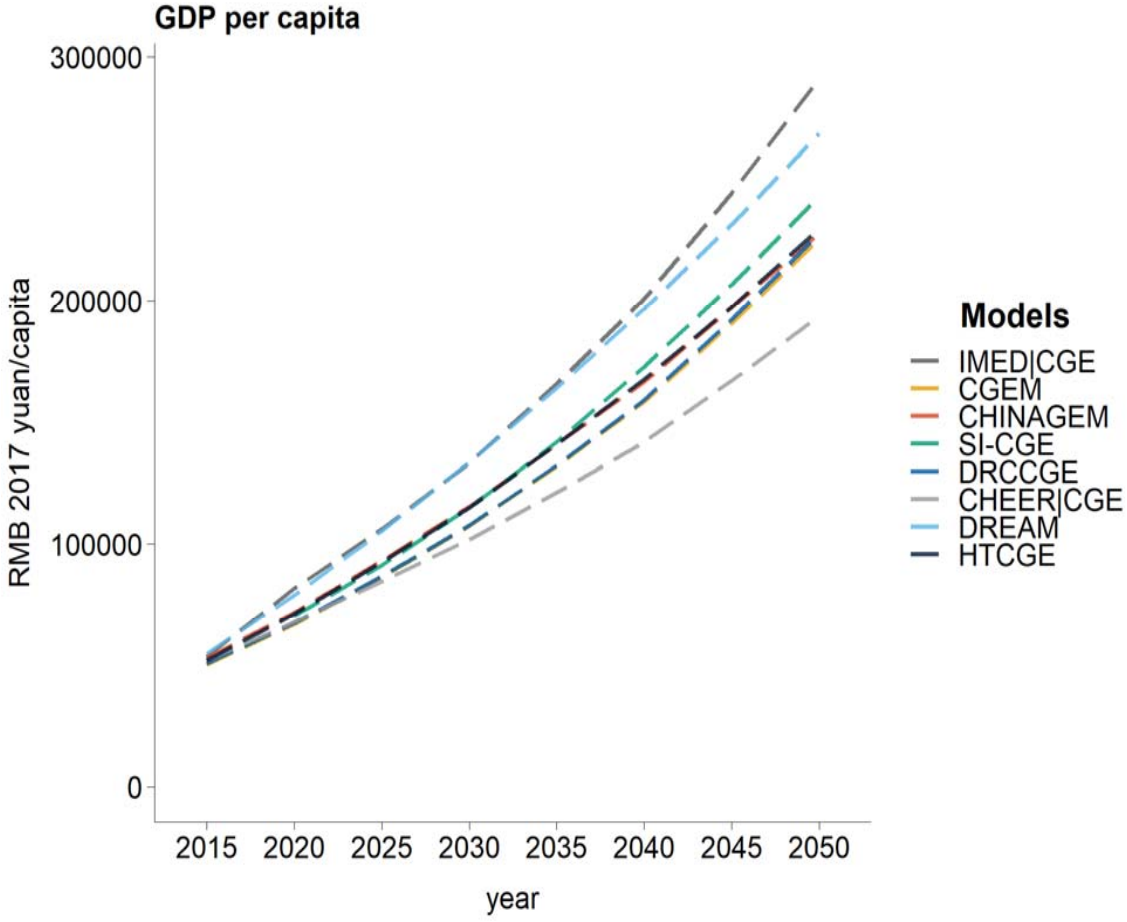
Projected Oil Price Forecast (EIA)



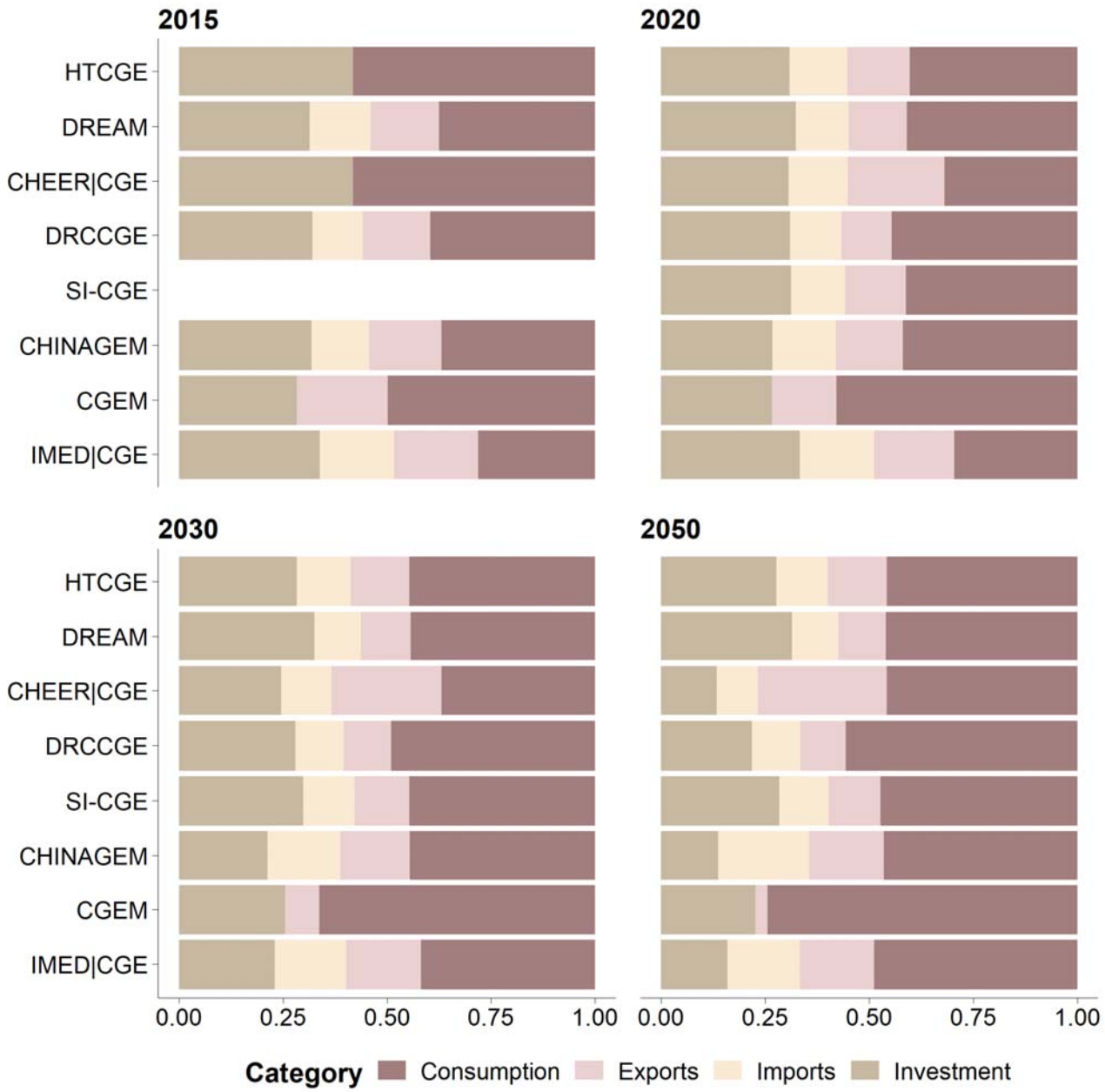

Source: https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-aeo2017&cases=ref2017~ref_no_cpp&sourcekey=0; collected on January 19, 2019

# Model Results – Base Case

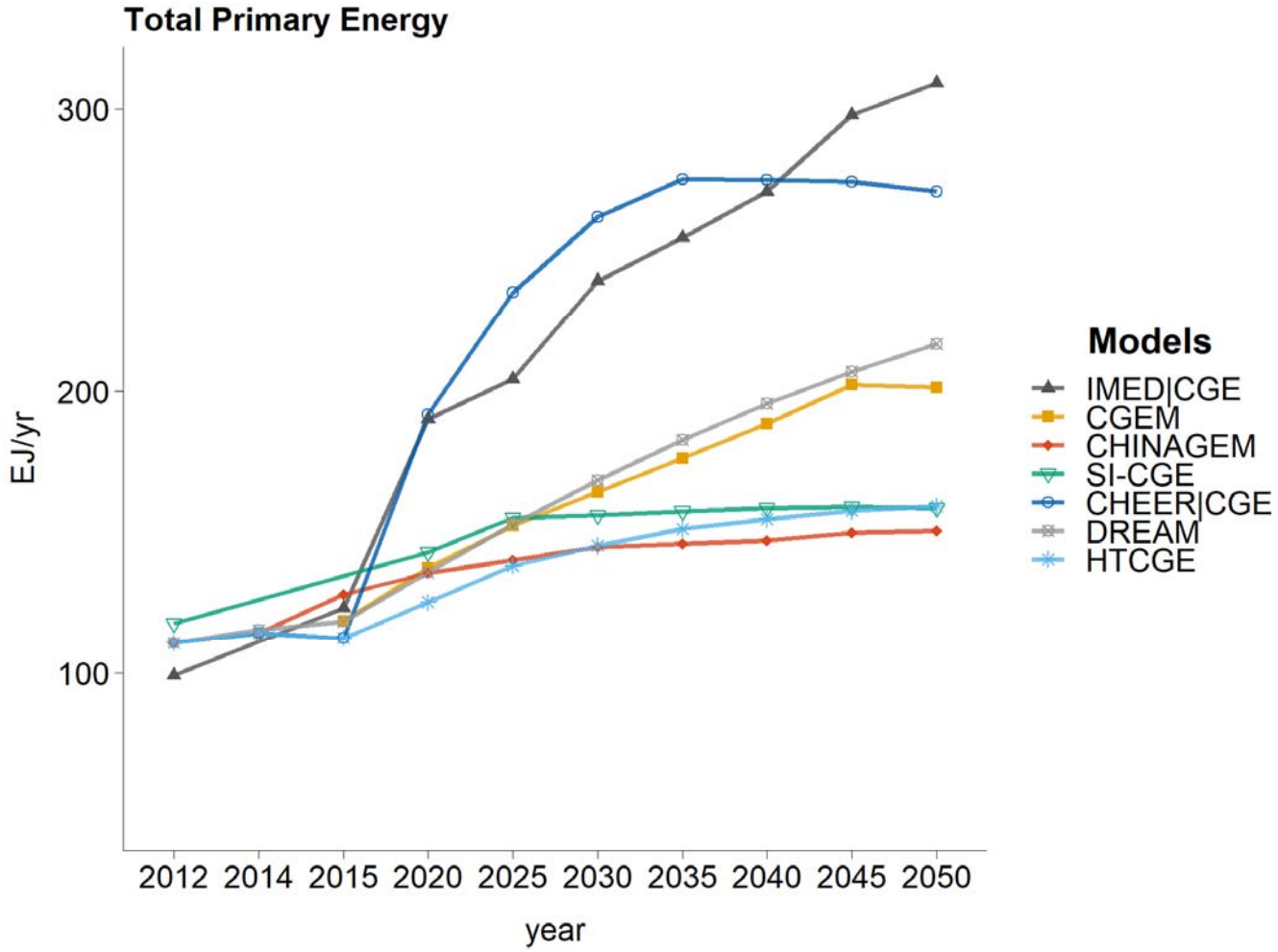


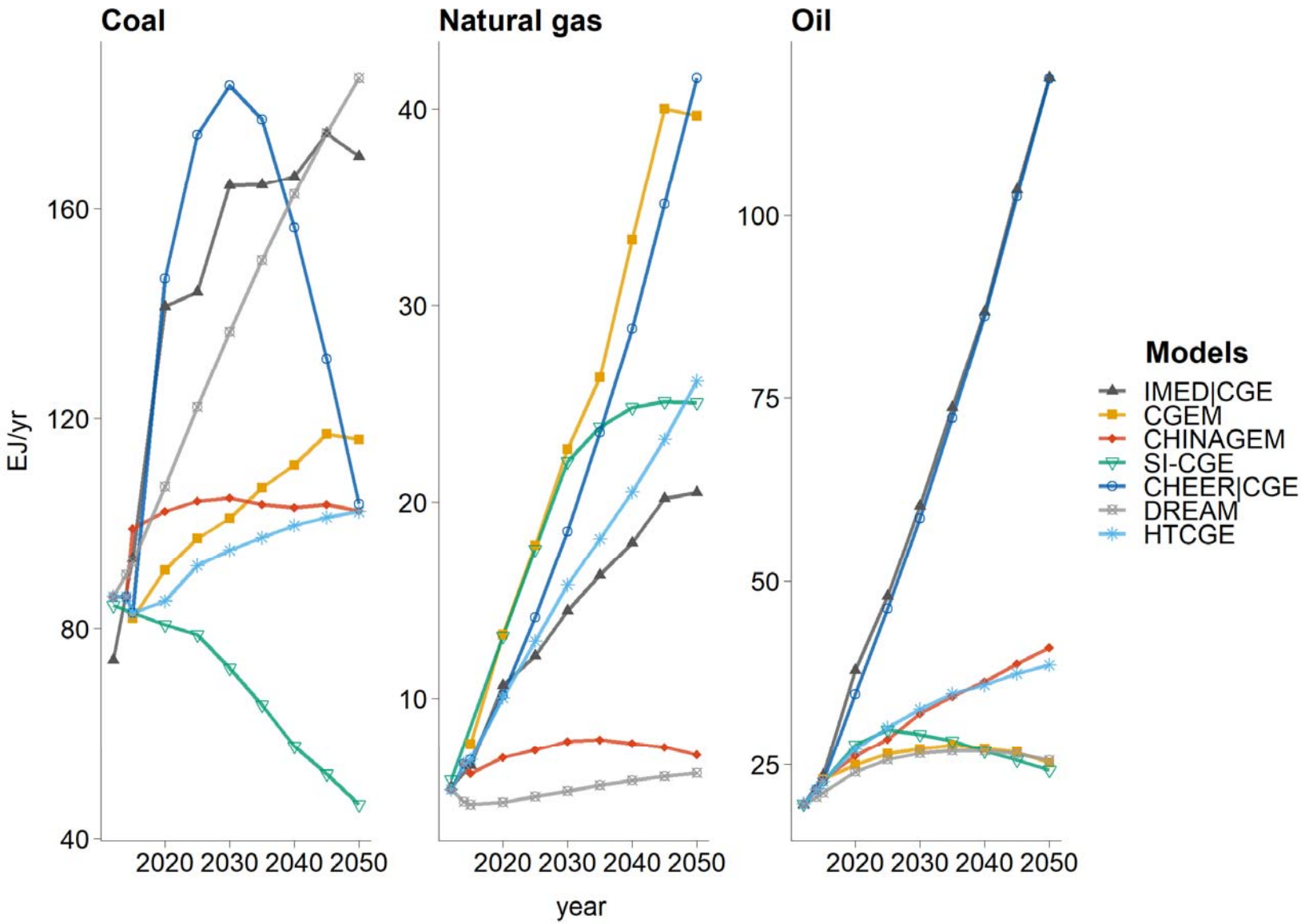
# Model Results – Base Case



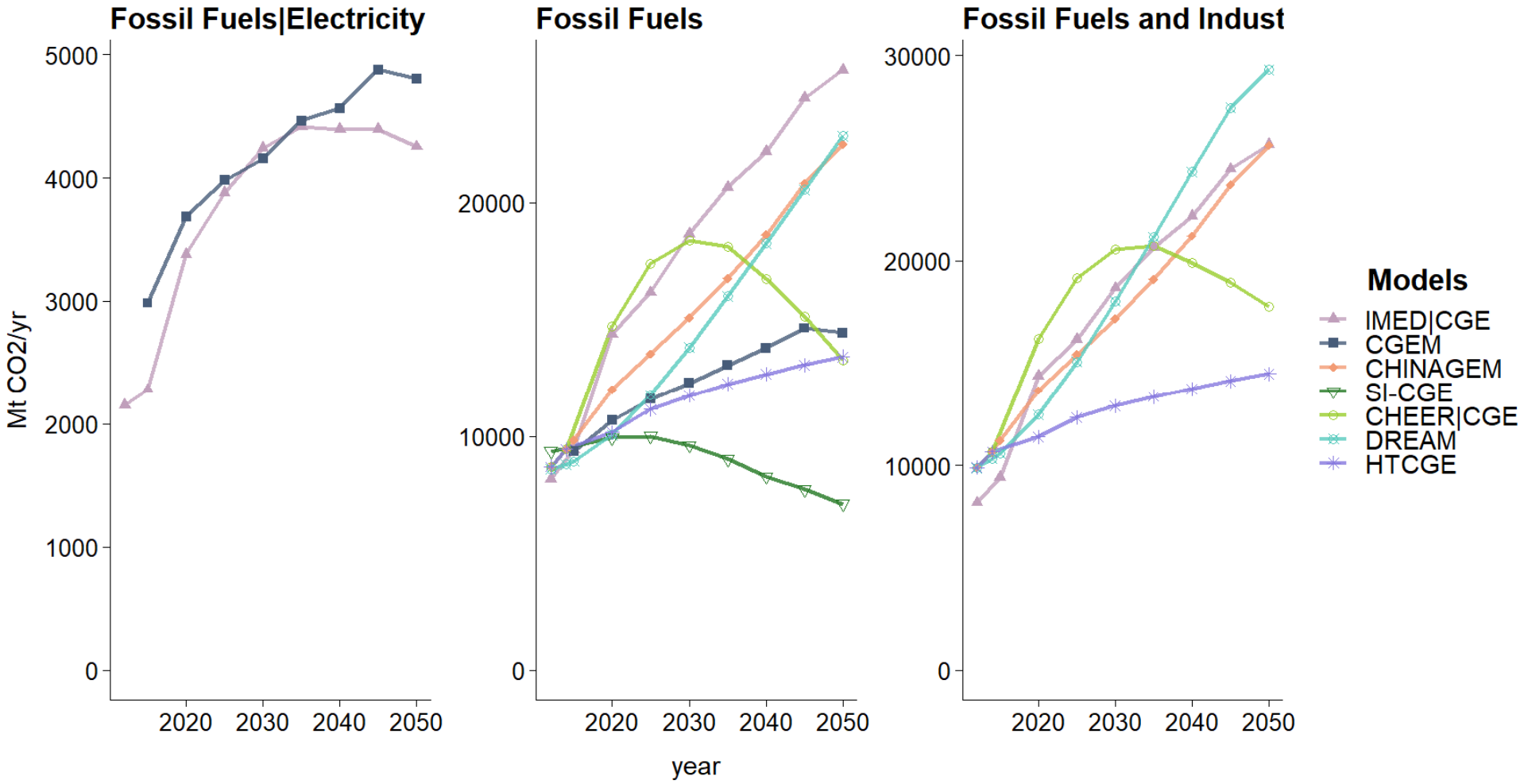
# Model Results – Base Case



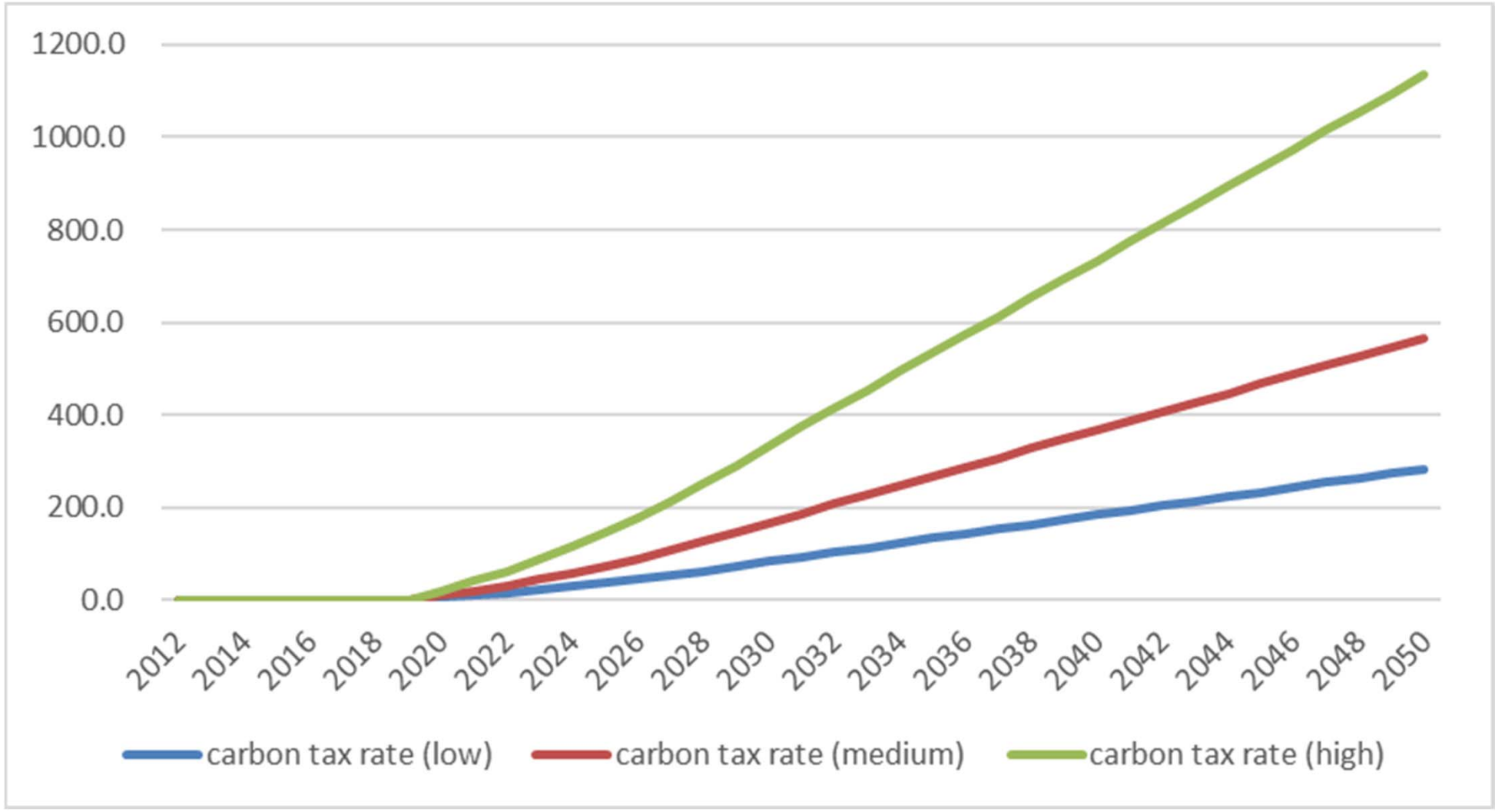
# Model Results – Base Case



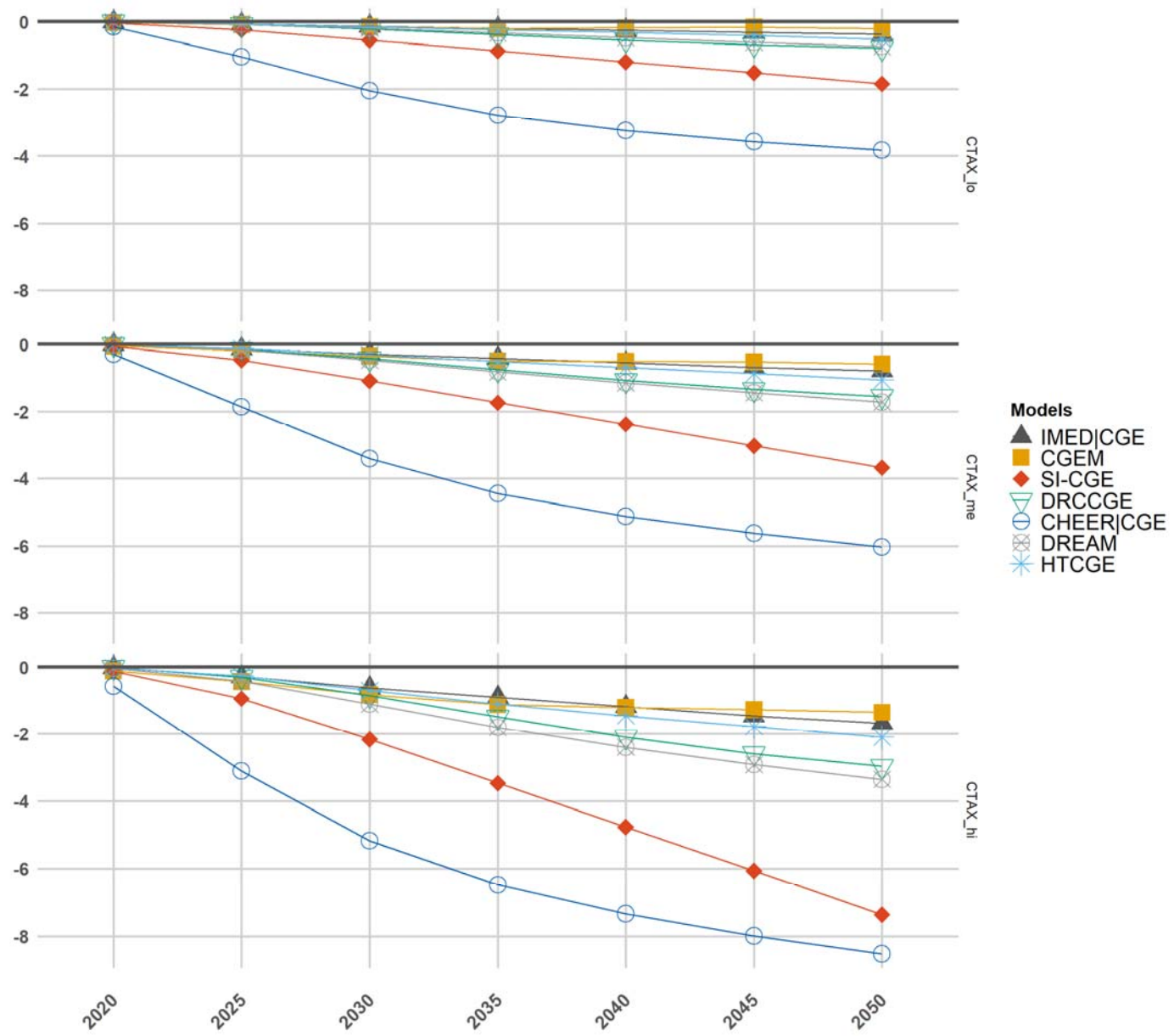
# Model Results – Base Case



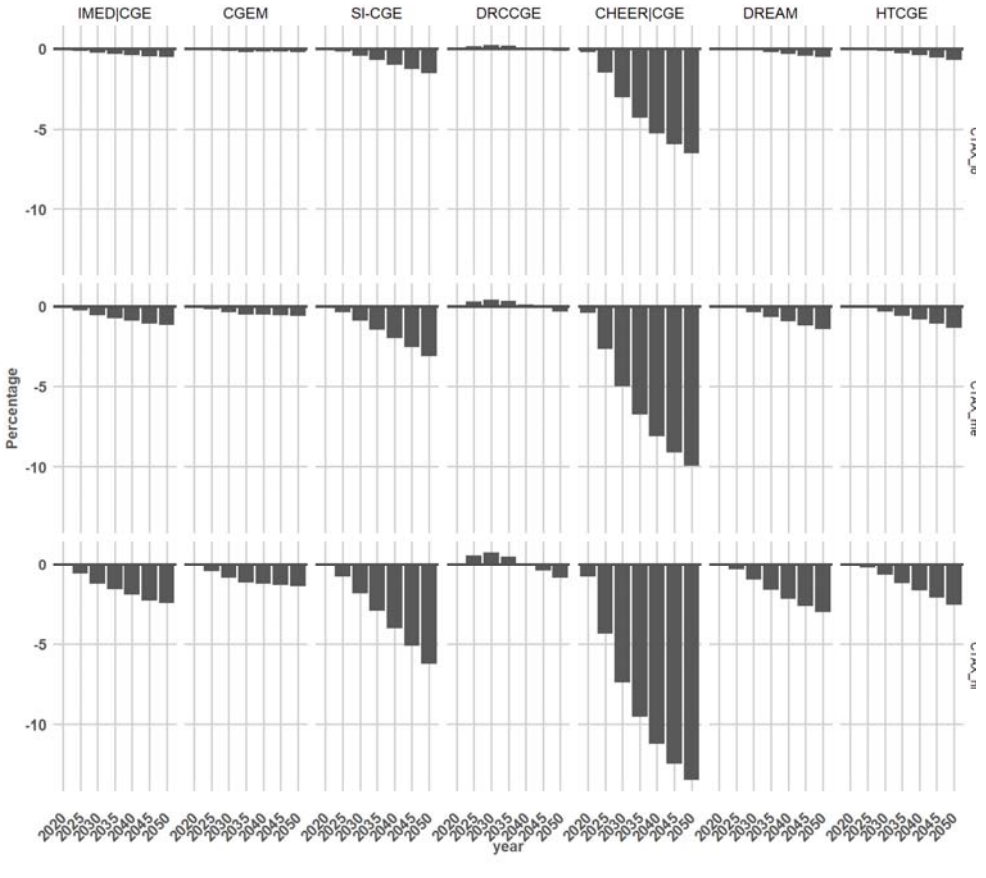
# Policy Scenarios – Carbon Tax



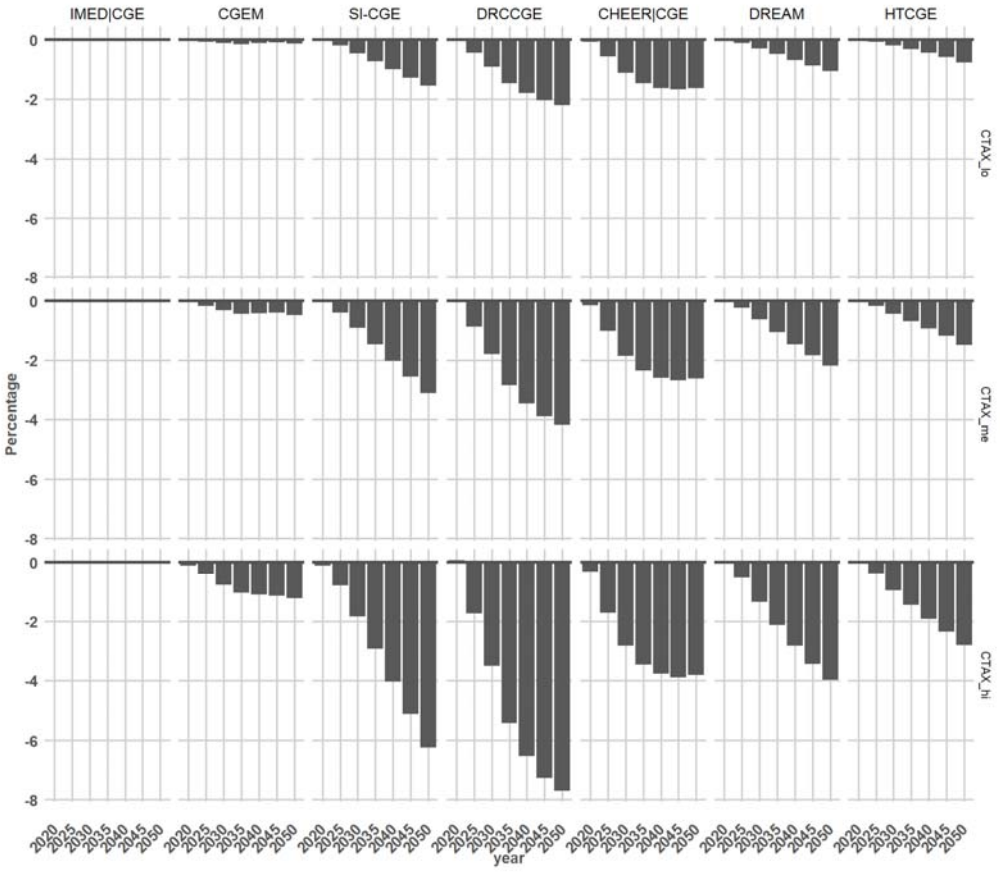
# Model Results – Policy Impacts on GDP



# Model Results – Policy Impacts on Consumption and Investment

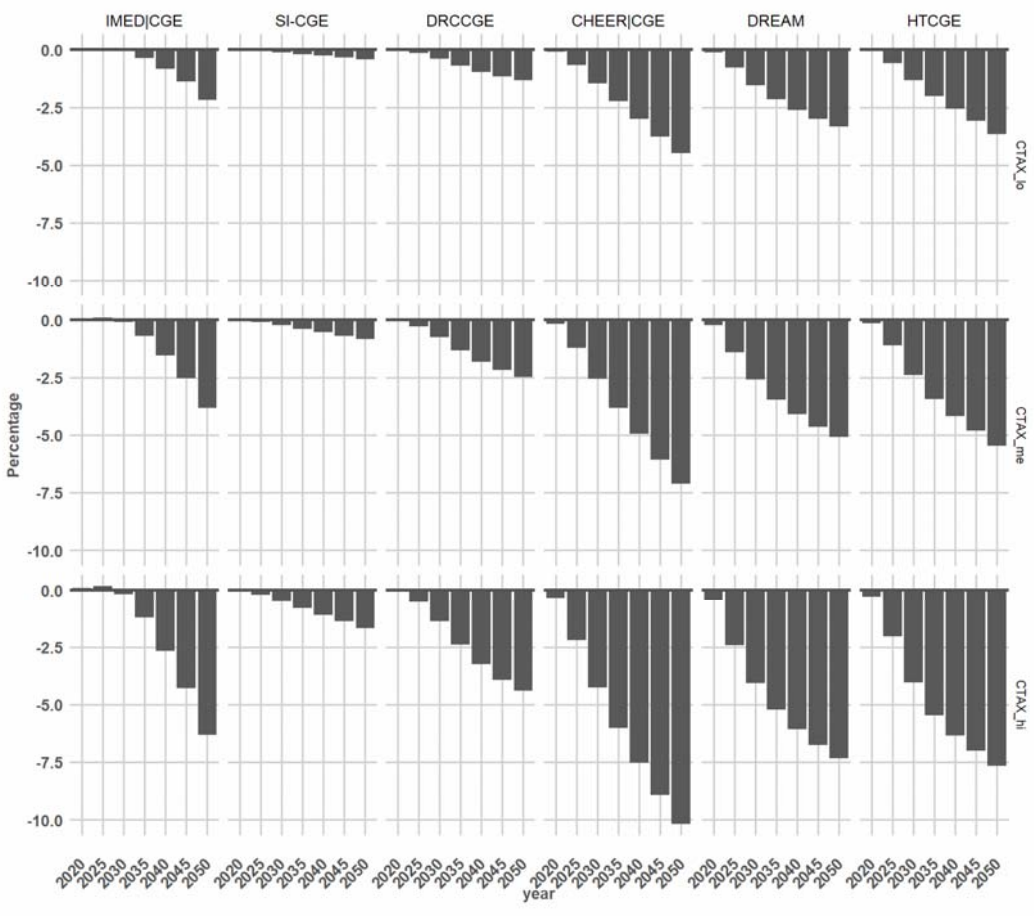



Consumption

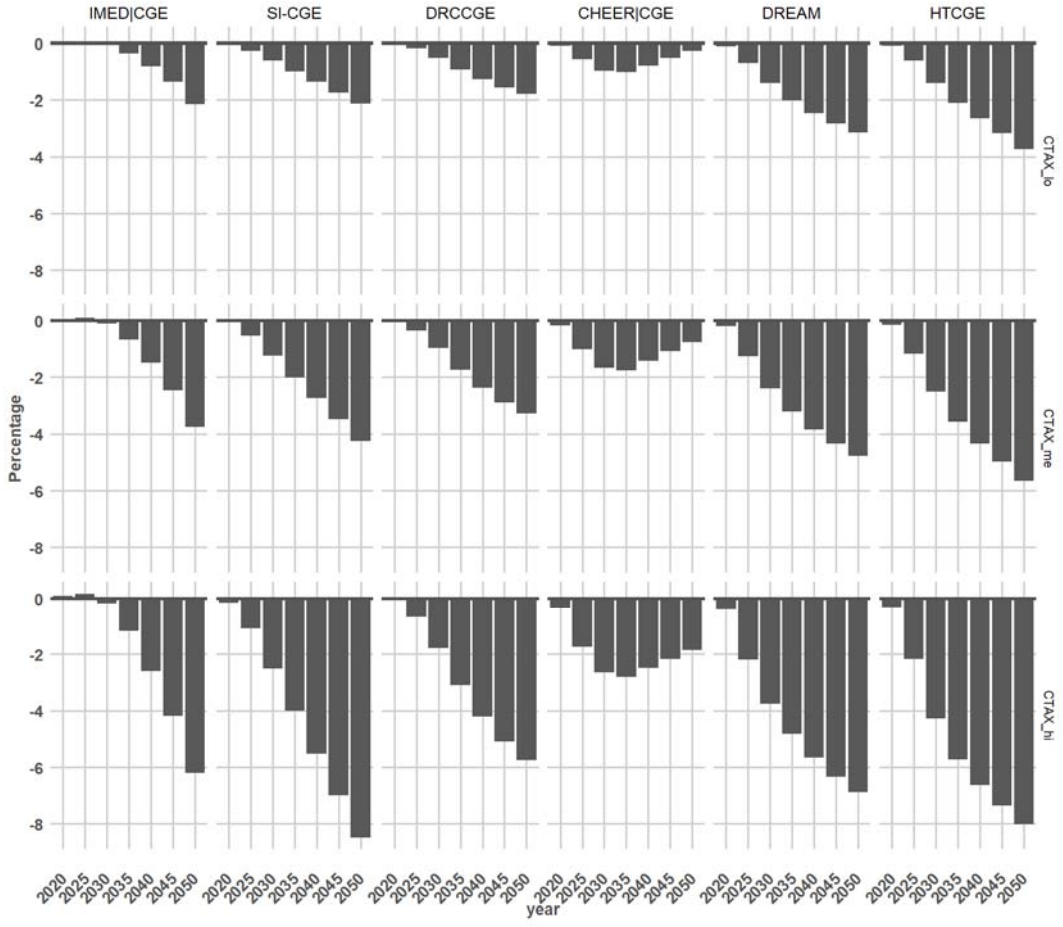



Investment

# Model Results – Policy Impacts on Import and Export

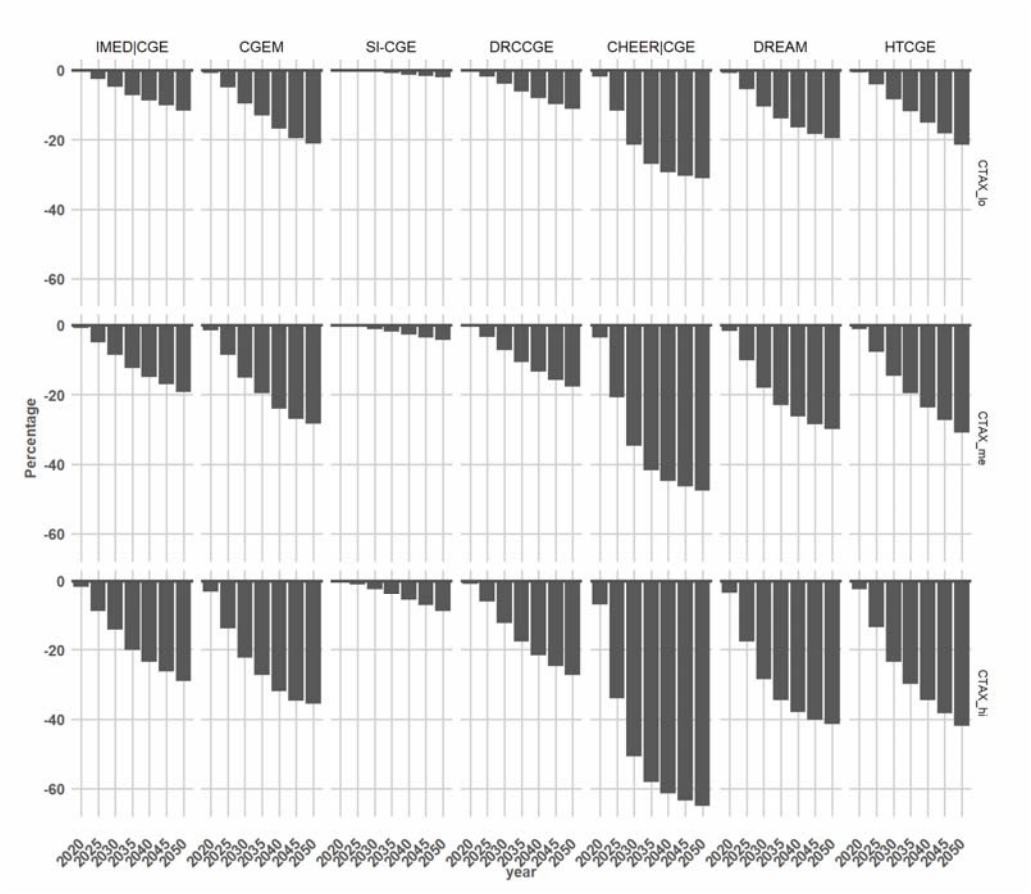



Import

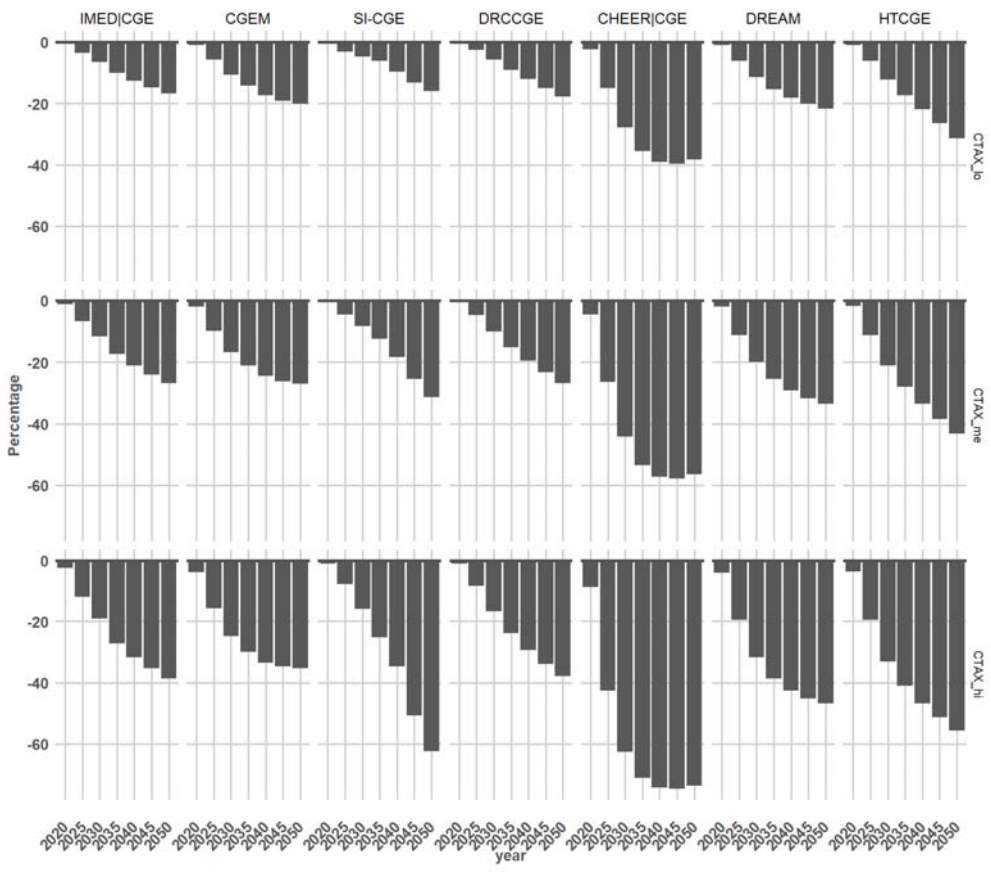



Export

# Model Results –Total Primary Energy and coal use

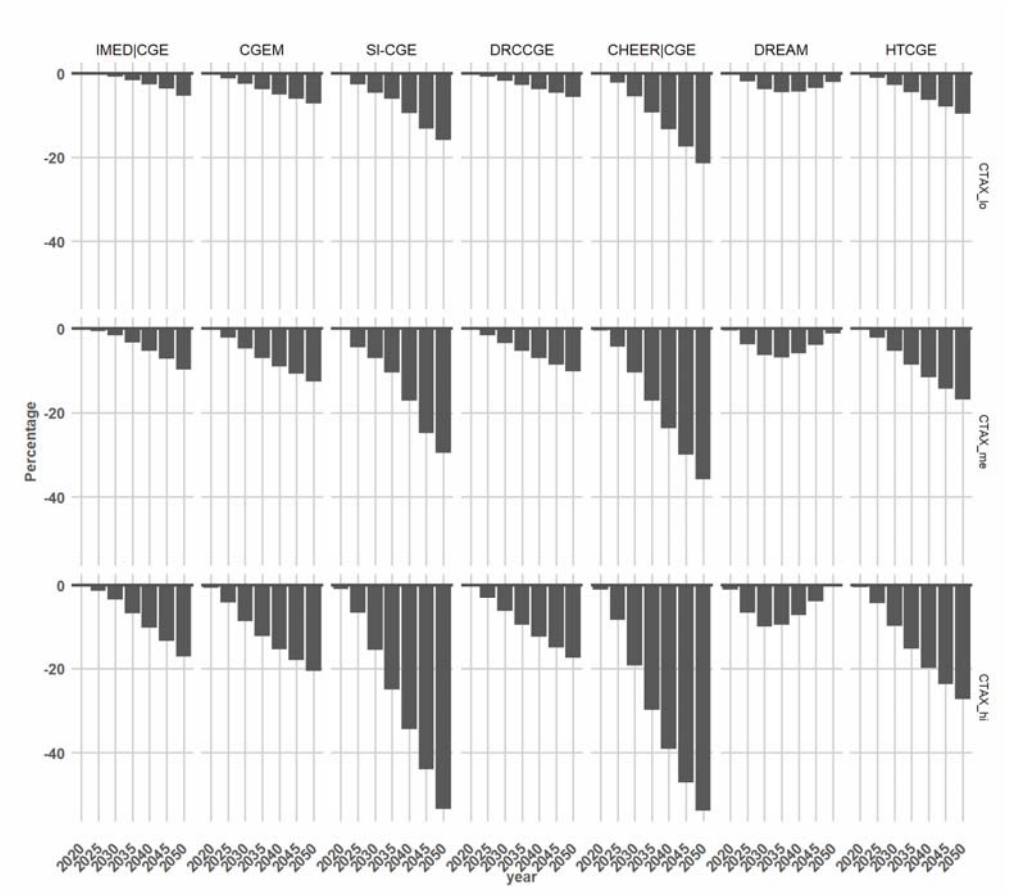



Impacts on Total Primary Energy

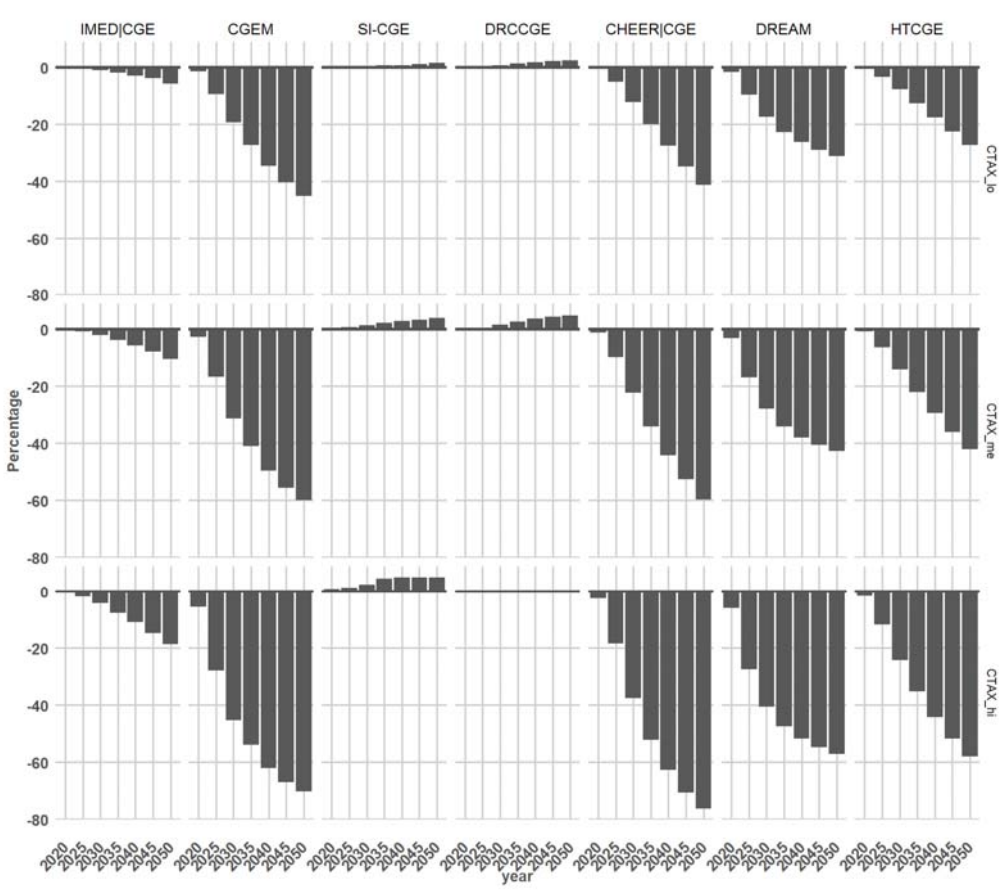



Impacts on Total Coal Use

# Model Results – Impacts on Total oil and natural gas use

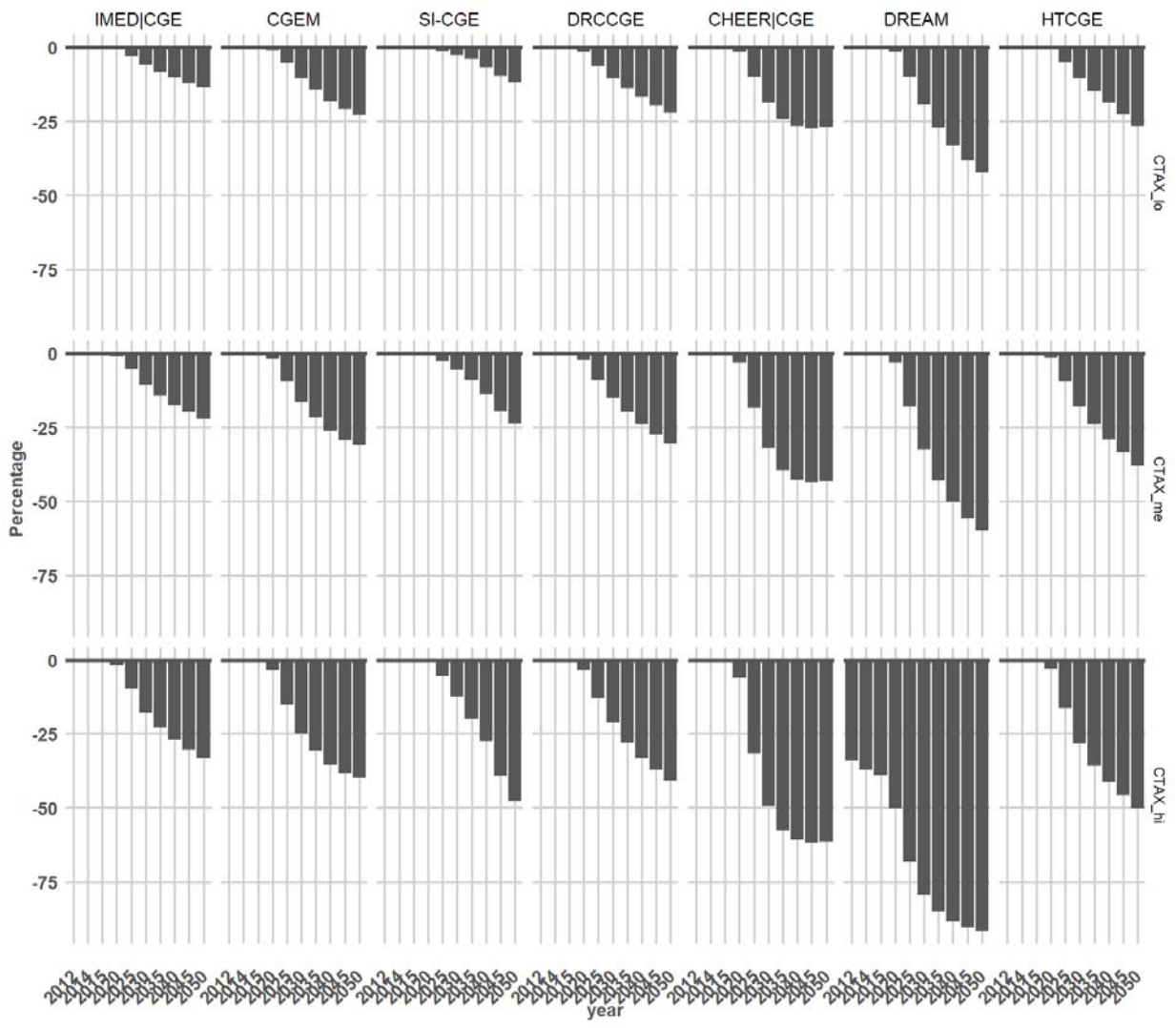



Impacts on Total Oil Use

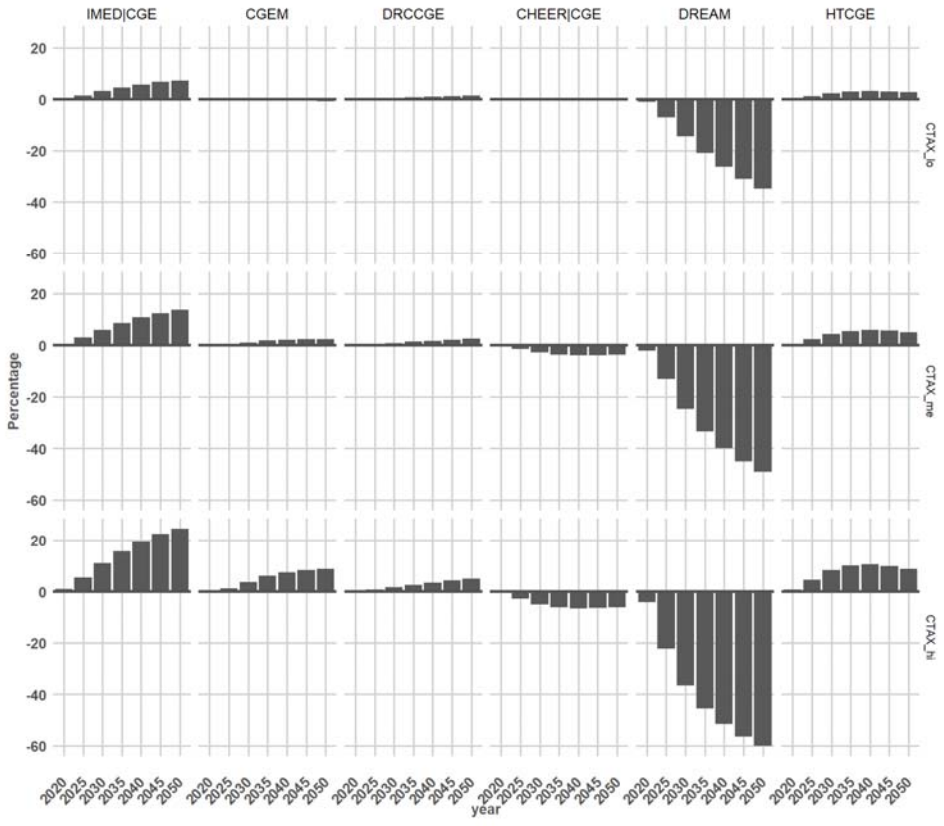



Impacts on Total Natural Gas Use

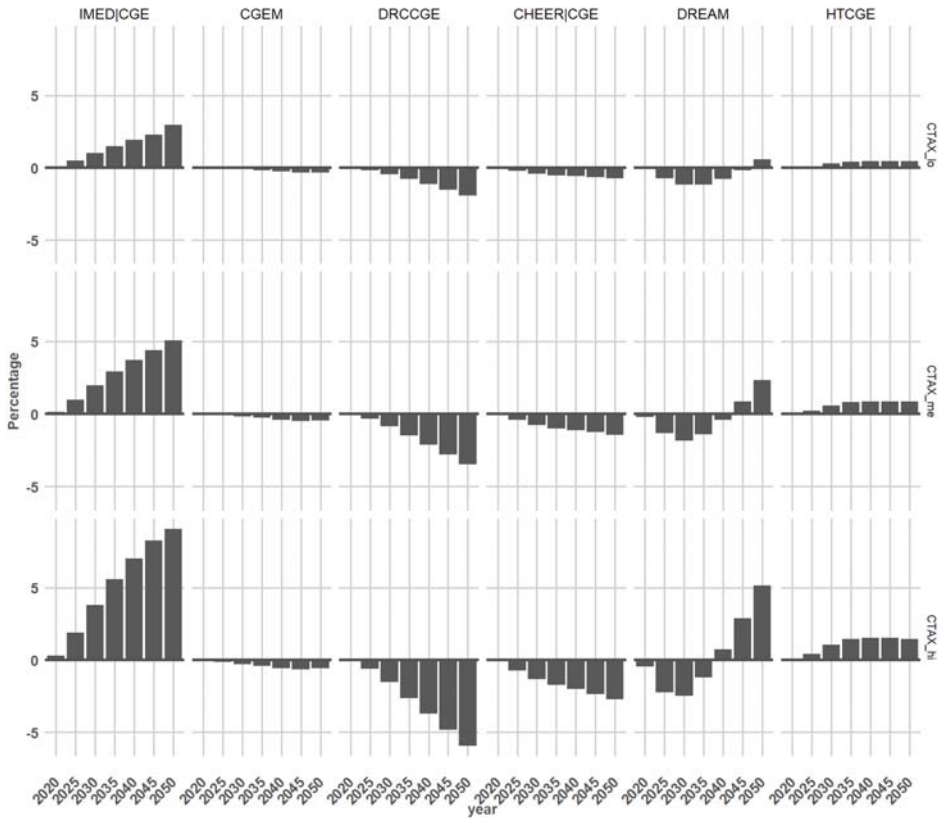
# Model Results – Policy Impacts on total carbon emissions



# Model Results – Impacts on coal and oil price

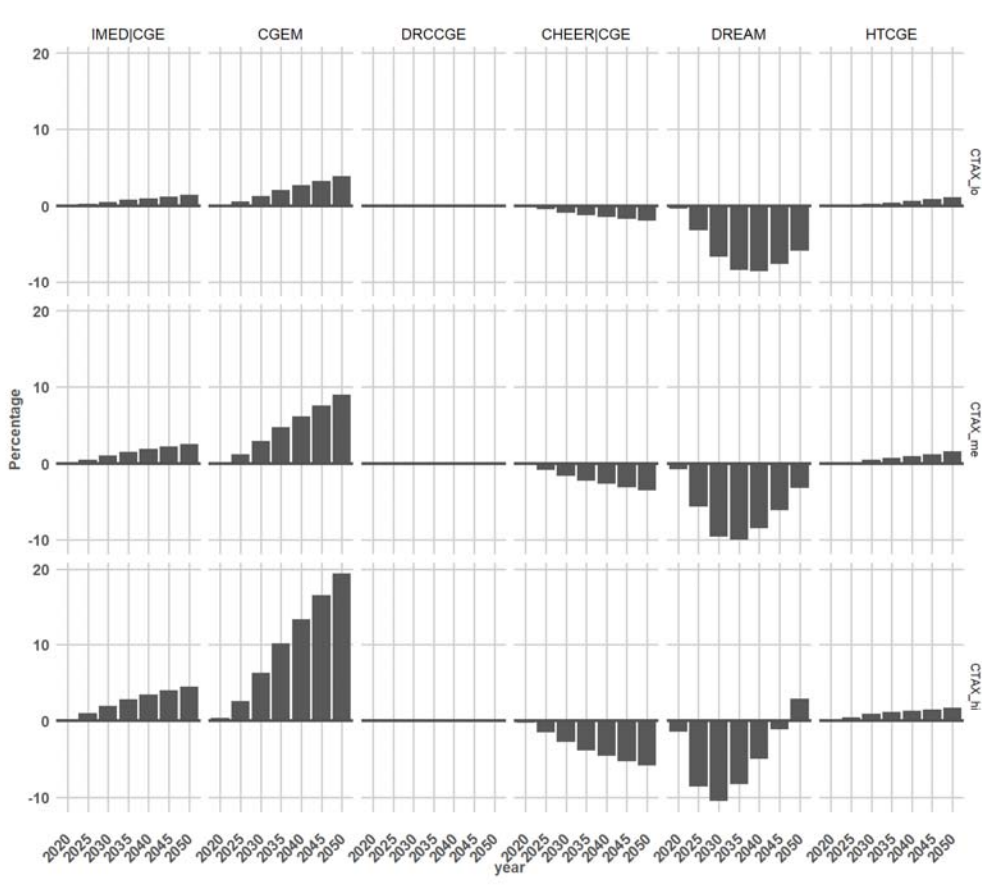



Impacts on coal price

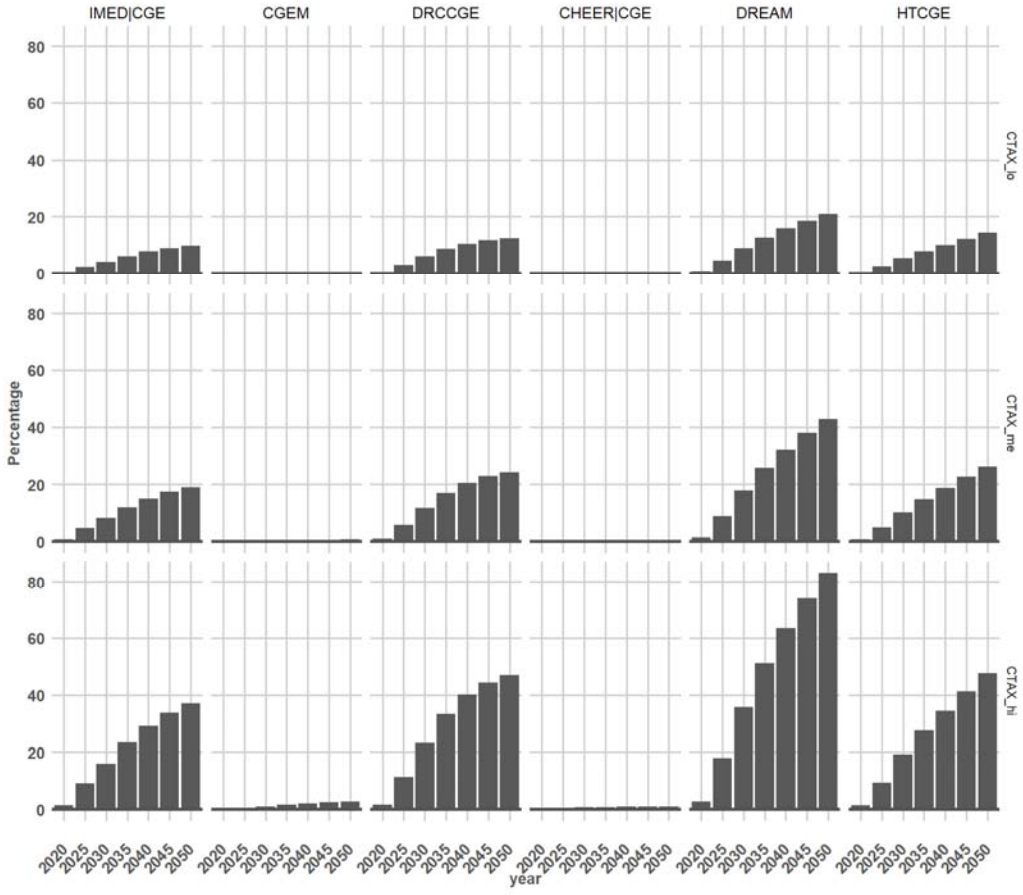



Impacts on oil price

# Model Results – Impacts on natural gas and electricity price

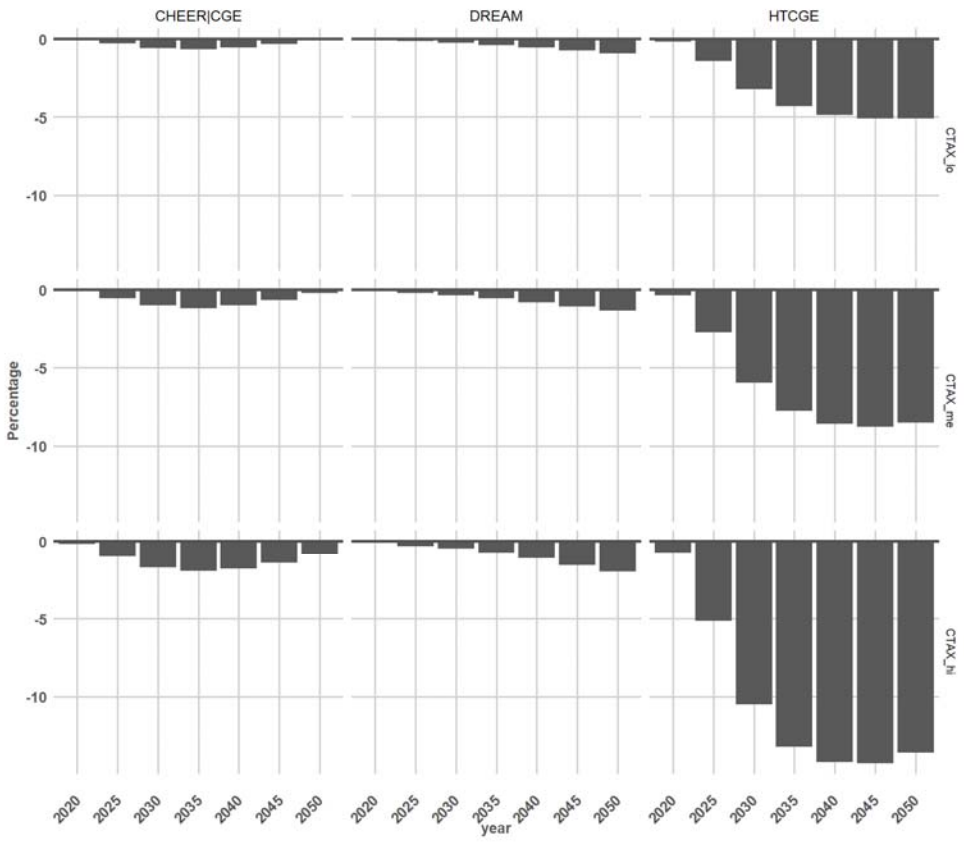



Impacts on natural gas price

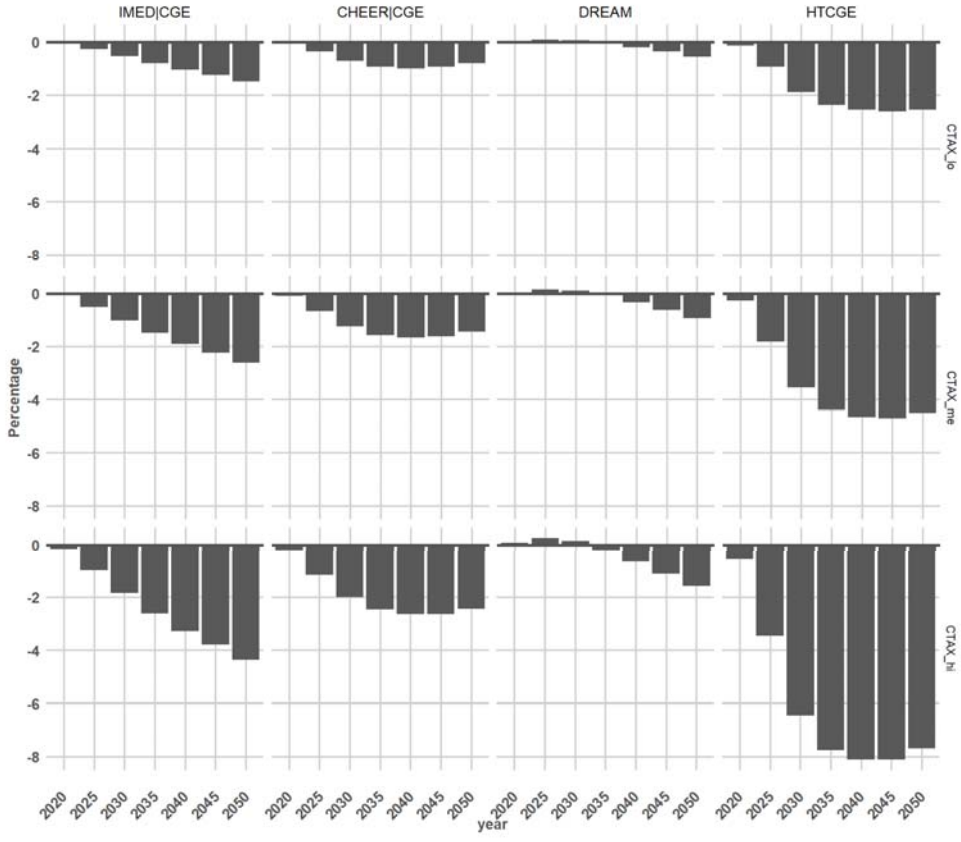



Impacts on electricity price

# Model Results – Impacts on steel and cement output

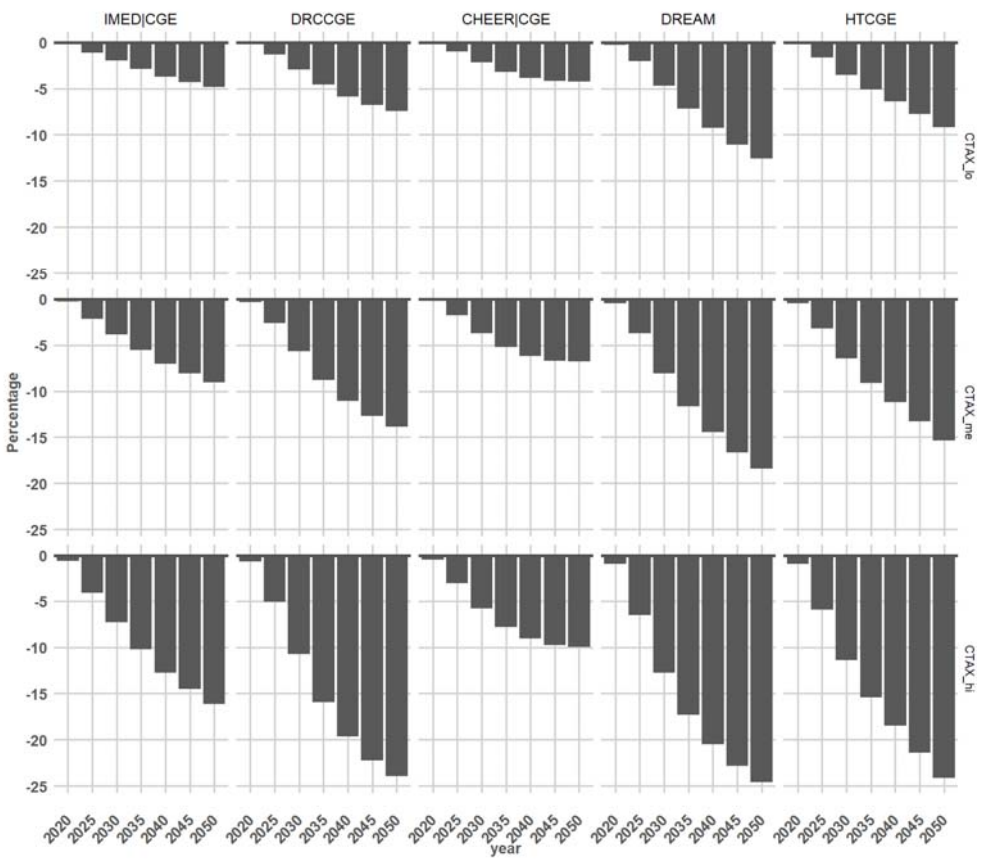



Impacts on steel output

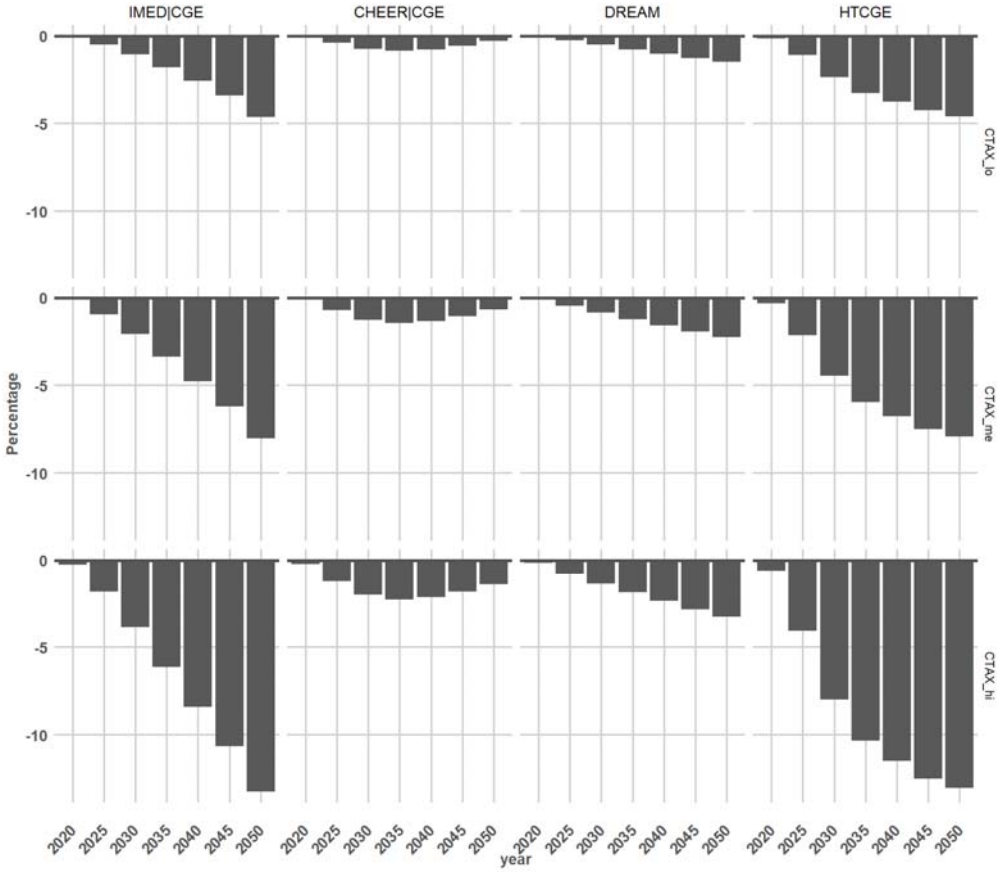



Impacts on cement output

# Model Results – Impacts on electricity and EITE output




Impacts on electricity output




Impacts on EITE output

# Model Results – Impacts on Carbon Intensity (NDC targets)

# Model Simulation Variations and Possible Channels

- Though different assumptions on labor, TFP, investment and capital formation, we all keep GDP trajectory similar across modeling teams, as well as external shocks (world oil prices)
- All models are recursive dynamics, so no perfect foresight, saving rates are all exogenous;
- Different future energy paths; different revenue recycling or revenue using channels;
- Different induced technology change assumptions;
- Except DREAM, all models show similar carbon and energy use reductions after imposing same carbon tax rates; impacts of specific energy sectors are different

# Model Simulation Variations and Possible Channels

- **Revenue Recycling:**
  - HTCGE: tax revenue were used to reduce all other taxes proportionally to keep tax neutral; *(explaining the impacts on investments are less than other groups)*
  - DRC-CGE, Dream, IMED|CGE recycle tax revenue via lump-sum transfer; (*less impacts on consumption, DRC-CGE in later years are positive impacts on consumption*)
  - CHEER: no recycling, so government size increases (*macro-impacts are very large, most results*
    *very different from all other models*)

- **Different Energy Structure change in the BAU or strong induced technology change**
  - **SI-CGE:** Assume China adopts aggressive cleaner energy path according to China's future energy strategy plan; (*less impacts on coal and total energy reductions*)
  - **CHEER, C-GEM:** consider BAU with huge subsidies on wind and solar and continuing lower learning costs on renewables and big induced technology change from carbon tax (*may explain why there is no or very little impacts on electricity prices*)

# Conclusion and Policy Implications

- We conduct a multi-CGE-model comparison to assess carbon pricing in China, we find a low to medium carbon tax can help to achieve China's 2020 and 2030 target, while carbon neutral in 2050 cannot be achieved with even very high carbon tax, but can achieve around 80-90% off 2005 benchmark level with high carbon tax rate
- No double dividend for most models, but macroeconomic costs are also mild
- Caveats and future work