Modeling Climate, Monetary and Fiscal Policy Interactions

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16 March 2022

Presentation to Banque de France Workshop on Advances in Macro and Finance Modelling of Climate Change
16 March 2022
Overview

• The G-Cubed model
• The interaction of climate and fiscal policy
  • Achieving Global Net Zero Emissions
• The interaction of climate and monetary policy
  • Monetary and Climate Policy in the Euro Area

• Conclusion
Key references


G-Cubed Model

G-Cubed Model

- Hybrid of dynamic stochastic general equilibrium (DSGE) models (used by central banks) and computable general equilibrium (CGE) models.

- Models Inter-industry linkages, international trade, capital flows, consumption, and investment.

- Annual macroeconomic and sectoral dynamics

- Captures frictions in labor market and capital accumulation
  - Full employment in the long run but unemployment in the short run
  - Labor mobile across sectors but not regions
  - Sector specific quadratic adjustment cost to physical capital
G-Cubed Model

• Each country has a fiscal rule for government spending and taxation policy

• Each country has a monetary rule which shows how interest rates are adjusted to trade off various policy target (inflation, output, exchange rates, nominal income)
Summary of Key Features

- **Intertemporal optimization** by households and firms
  - Forward-looking savings and investment
  - Financial arbitrage
  - But also rule of thumb for many households and firms

- Extensive **econometric parameterization**
  - Behavior consistent with historical demands and supplies
  - Technical change based on a catchup model of growth

- Distinguishes between **financial and physical capital**
  - Financial capital can move easily between regions and sectors
  - Physical capital does not move once installed
10 countries/regions

United States
Japan
Australia
Europe
Rest of Advanced Economies
China
India
Russian Federation
Oil-exporting and the Middle East
Rest of World
## 20 Sectors

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Code</th>
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<tbody>
<tr>
<td>1</td>
<td>Electricity delivery</td>
<td>ElecU</td>
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<td>2</td>
<td>Gas Extraction and utilities</td>
<td>GasU</td>
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<tr>
<td>3</td>
<td>Petroleum refining</td>
<td>Ref</td>
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<td>4</td>
<td>Coal mining</td>
<td>CoalEx</td>
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<td>5</td>
<td>Crude oil extraction</td>
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<td>6</td>
<td>Construction</td>
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<td>7</td>
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<tr>
<td>8</td>
<td>Agriculture and forestry</td>
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<td>Durable goods</td>
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<td>12</td>
<td>Services</td>
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<td>16</td>
<td>Nuclear generation</td>
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<td>17</td>
<td>Wind generation</td>
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<td>18</td>
<td>Solar generation</td>
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<tr>
<td>19</td>
<td>Hydroelectric generation</td>
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</tr>
<tr>
<td>20</td>
<td>Other generation</td>
<td>Other</td>
</tr>
</tbody>
</table>
Production structure in G-Cubed model

Output

Energy Composite

Capital

Labour

Material Composite

CES Aggregator

Electricity

Gas

Petroleum

Coal

Oil Extraction

CES Aggregator

Coal generation

Natural gas generation

Petroleum generation

Nuclear generation

Wind generation

Solar generation

Hydro generation

Other generation

CES Aggregator

Construction

Mining

Agriculture

Durable manufacturing

Non-durable manufacturing

Transportation

Services

CO2 emissions from fossil fuels
Variables Modelled

• Macro variables (by country):
  • Real and nominal GDP
  • Real GNP
  • Real private Consumption – aggregate and by sector
  • Real private Investment – aggregate and by sector
  • Private Employment – aggregate and by sector
  • Government spending on goods and services
  • Government spending on labor
  • Real Imports – aggregate and by sector by country of origin
  • Real Exports – aggregate and by sector
  • Trade balance
  • Current Account balance
  • Housing Stock (proxied by household durable capital stock)
  • Households stock of human capital
  • Stock of government debt.
Variables Modelled

- Financial Variables (by country):
  - Policy interest rate (nominal and real)
  - Bond rates 2, 5, 10 year (nominal), 10 year (real)
  - Nominal and real effective exchange rates
  - Nominal and real exchange rate relative to $US
  - Equity prices by sector
  - Money Supply
Variables Modelled

• Prices (by country):
  • Aggregate price index
  • Consumer price index
  • Consumer price inflation (actual and expected)
  • Produce price inflation (actual and expected)
  • Producer price by sector
    • Commodity prices where sector is a commodity
  • Consumer price by sector
  • Energy price
  • Materials price
  • Nominal wage
  • Housing price (proxied by price of household’s purchases of durable goods)
Generating the Baseline
Baseline without significant climate policy

- Solve the model from 2018 to 2100 under assumptions about:
  - population growth by country;
  - productivity growth by sector and country;
  - technological assumptions,
  - policy rules etc
2018 is not the steady state

• We assume that the base year for projections (2018) is on a stable transition path adjusting towards a steady state in the long distant future

• We adjust the model so that the database for 2018 is a solution of the model

• We calculate intertemporal constants (risk premia) in the financial arbitrage conditions that cause the model outcome for forward looking variables (equity prices, interest rates, exchange rates) to be equal to the database values.
The Interaction of fiscal and climate policy
Based On


• Also based on IMF(2020) Mitigating Climate Change: Growth- and Distribution-Friendly Strategies, October 2020 WEO Chapter 3
Baseline without significant climate policy

- Assume historical Autonomous Energy Efficiency Improvements (1%)
- The productivity assumptions and labor force growth assumptions are exogenous to the core model
- Capital accumulation and the sectoral and national output growth rates are endogenous
Implementation of climate policies

• Surprise climate agreement in 2021
• Agents know the future path of the climate policies in 2021.
• 30% of firms and households have rational expectations
• 70% follow a rule of thumb
Global temperature and CO2 emissions

Temperature
*(Degrees Celsius above preindustrial average)*

- BAU, low to high climate sensitivity
- Mitigation policies, low to high climate sensitivity
- BAU, medium climate sensitivity
- Mitigation policies, medium climate sensitivity
- Mitigation policies and CCS, medium climate sensitivity

Annual Global Emissions of CO2
*(Gigatons of CO2)*

- Business as usual
- Mitigation policies
- Mitigation policies and CCS

Source: IMF staff calculations.
Business-as-usual emissions

Business-as-Usual Baseline CO2 Emissions
(Gigatons of CO2)

Source: G-Cubed model simulations version GGG20Jv154

Decomposition of the Change in Global CO2 Emissions
(Percent change)
Policy Package

Green supply policies:
- 80% subsidy rate on renewables production,
- a 10-year green public investment program

Pricing Carbon:
- $6 to $20 a ton of CO₂
- Growth rate of 7% per year
Infrastructure Investment

• When a government undertakes infrastructure investment, the government purchases goods and services from the private sector through a change in Government spending. This is a change in demand which is funded through issuing debt.

• The sectors that use the public infrastructure experience a boost to the level of total factor productivity

• We base our analysis on the results from Calderon, Moral-Benito and Serven (2015) who find that for every 10 percent increase in the aggregate stock of infrastructure capital assets, productivity in private sector output rises by 0.8%.
Global Results
Policy package: CO2 emissions and output effects

Global CO2 Emissions
(Gigatons of CO2)

Impacts on real GDP
(deviation from baseline, percent)

Source: G-Cubed model simulations version GGG20Jv154
Figure 8: Global Fiscal Impact

Ratio of the global fiscal balance to real GDP (percentage point deviation from baseline)

Debt to real GDP (percentage point deviation from baseline)

Source: G-Cubed model simulations version GGG20Jv154
Additional material in the paper

- Individual country impacts
- Co benefits
- Avoided damages
- Different degrees of participation
Regional GDP and Co-Benefits, 3 year average

(percent deviation from baseline)

Source: G-Cubed model simulations version GGG20Jv154
Figure 17: GDP and Investment: Policy Package vs. Carbon Tax Only

Global real GDP (percent deviation from baseline)

Global investment (percent deviation from baseline)

Source: G-Cubed model simulations version GGG20Jv154
Climate Policies and Monetary Policies in the Euro Area

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Presentation to Sintra Forum, 29 September 2021
Summary

• Overview of the paper
• Empirical results on Carbon taxes and inflation and output in Europe
• A global model for climate policy and monetary policy interactions
• Model Simulations of climate issue under different monetary rules
  • Global climate shocks (physical risk)
  • Climate policy changes in the Euro Area (transition risk)
  • Global climate policy changes (transition risk)
• Conclusion
Overview of the paper

• Use two different approaches to explore the impact of climate change on monetary policy in Europe

  • Historical exploration of the impact of carbon taxes on inflation and growth in European economies from 1985 to 2020

  • Apply a global model to explore physical climate risk (both underlying climate change and extreme climate events), transitional climate risk (through changes in climate policies), and climate policies applied only in the Euro area compared to a global policy response.

  • Explore the interaction of the climate shocks and the ECB monetary policy rule, focusing on the degree of forward-lookingness of the monetary policy rule.
Two Alternative ECB policy Rules

\[
i_t = i_{t-1} + 0.34 \times (\pi_{t,t+1} - \bar{\pi}_{t+1}) + 0.4 \times (g_{t,t+1} - \bar{g}_{t+1}) \quad \text{HS} \quad (1)
\]

\[
i_t = i_{t-1} + 0.5 \times (0.34 \times (\pi_t - \bar{\pi}_t) + 0.4 \times (g_t - \bar{g}_t))
\]

\[
+ 0.5 \times (0.34 \times (\pi_{t,t+1} - \bar{\pi}_{t+1}) + 0.4 \times (g_{t,t+1} - \bar{g}_{t+1}) \quad \text{MHS} \quad (2)
\]

Where \( i_t \) is the policy interest rate, \( \pi_{t,t+1} \) is the expectation in period \( t \) of inflation in period \( t+1 \) (rationally expected from the model) and \( g_{t,t+1} \) is the growth rate in output in period \( t+1 \) expected in period
Climate Shocks

• Following Fernando, Liu, and McKibbin (2021) we consider a physical climate risk scenario that incorporates both
  » Chronic climate change
  » Extreme climate Events

• Based on (Representative Concentration Pathway) RCP 4.5
  » CO2 Concentrations stabilize at 650ppm by 2100
Climate Policy in Europe

• Euro countries implement a carbon tax in 2021 that starts at $50 euro per ton of CO2 and rising by 3% per year
Climate Policy in Euro Area (under MHS)

Source G-Cubed Model Version GGG20N_v161
Climate Policy in Euro Area

Source G-Cubed Model Version GGG20N_v161
Climate Policy Globally

• All countries (except oil exporting Middle East) implement a carbon tax in 2021 that starts at $50 euro per ton of CO2 and rising by 3% per year
Global Climate Policy

Europe GDP

% Deviation

Europe Inflation

% Deviation

Source G-Cubed Model Version GGG20N_v161
Global Climate Policy

Europe Real Effective Exchange Rate

% Deviation

Europe Trade Balance

% GDP Deviation

Source G-Cubed Model Version GGG20N_v161
Global Climate Policy

Source G-Cubed Model Version GGG20N_v161
Conclusion 1/

- **Historically, carbon taxes in Euro area** have tended to have a short positive effect headline inflation, which is contained after 3 years.

- The impact on core inflation tended to be negative indicating that carbon taxes operated mostly by changing relative prices rather than affecting the overall price level, for a given monetary policy.
Conclusion 2/

- The short run outcome from the various climate shocks depend significantly on the policy rule followed by the ECB.
- Depending on the monetary policy response implementing a carbon tax could result in inflation or deflation.
- Incorporating current and future information into the policy rule leads to better inflation and output outcomes than a purely forward-looking rule.
- Inflation in the Euro area is contained in all shocks and the magnitude of the inflationary response is in line with our finding of the historical responses in the Euro area.
Further information on G-Cubed

www.gcubed.com
Additional Slides
Climate Shocks

Source: G-Cubed Model Version GGG20N_v161
Climate Shocks

Source G-Cubed Model Version GGG20N_v161