Climate Change Mitigation: How Effective is Green Quantitative Easing?

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Research Question

- How much can Green QE contribute to climate change mitigation?
- Comparison of Green QE to Carbon Tax with respect to emission/temperature reduction
- Green QE understood as ...
  - ... shift in central banks’ private sector securities portfolio ...
  - ... towards green assets
- Rationale for QE itself not modeled
Approach

- Integrated Assessment Model (IAM)
  - World economy
  - General equilibrium
  - Two production sectors: **Clean** (green) and **Dirty**
  - Dirty energy sector emits CO2
  - Climate module
  - Portfolio choice: clean and dirty capital
    - Idiosyncratic return-risk
    - Imperfect correlation $\rightarrow$ partial crowding out

Policy Experiments:
- Carbon tax
- Green quantitative easing (QE)
- Carbon tax + green QE
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Green Quantitative Easing

- **Investigate maximum effect of (stylised) QE**
  - Immediate and complete shift towards green assets of central banks’ portfolio of privately issued securities (held constant to total capital stock)
  - Perfect taxonomy
  - High elasticity of substitution between clean and dirty goods
  - Zero correlation of asset returns
Green Quantitative Easing

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- Modest Carbon Tax
  - Carbon tax of 50 USD/tC ($\approx 13.6 \text{USD}/t\text{CO}_2$), tax rate constant
Green QE can contribute to climate change mitigating

But less effective than a carbon tax

Green QE complementary, if insufficient carbon pricing through taxes or other fiscal policies
Related Literature

- IAMs along the **transition**: Golosov et al. (2014), Kotlikoff et al. (2019, 2021), Nordhaus and Boyer (2000), Van Der Ploeg and Rezai (2021), etc.

- **DSGEs** with climate module and green monetary policy: Heutel (2012), Giovanardi, Kaldorf, Radke, and Wicknig (2021), Ferrari and Landi (2020), Benmir and Roman (2020)
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- Papoutsi, Piazzesi and Schneider (2021): Carbon bias in Eurosystem’s corporate bond portfolio
Model Overview

Components

Climate Module → Final Good Sector

Dirty Intermediate Sector → Households

Clean Intermediate Sector → Households

Dirty Energy Production → Households

Monetary Authority → Households

Fiscal Authority → Households

Clean Energy Production → Households
Model Overview

Energy Production

\[ E^D = A^D L^D \]

\[ E^C = A^C L^C \]

at \( p^D \) and \( p^C \)

Dirty Intermediate Sector

Clean Intermediate Sector

Dirty Energy Production

Monetary Authority

Fiscal Authority

Clean Energy Production

Households
Model Overview

Intermediate Sectors

Climate Module

Final Good Sector

Dirty Intermediate Sector

Clean Intermediate Sector

Households

Dirty Energy Production

Monetary Authority

Fiscal Authority

Clean Energy Production

\[ Y^D = \psi[(K^D)^\alpha (L^D)^{1-\alpha}]^\gamma (E^D)^{1-\gamma} \]

at \( p^D \)

\[ Y = (1-D_t) \cdot A_t^Y \cdot \left( \kappa^C (Y^C)^{\epsilon-1 \over \epsilon} + \kappa^D (Y^D)^{\epsilon-1 \over \epsilon} \right)^{\epsilon \over \epsilon-1} \]

\[ Y^C = \psi[(K^C)^\alpha (L^C)^{1-\alpha}]^\gamma (E^C)^{1-\gamma} \]

at \( p^C \)
Model Overview

Households

\[ K_{t+1}^C,HH + K_{t+1}^D,HH + \left(1 + \tau_t^C\right) C_t = \left(1 + r_t^K^C\right) K_{t}^C,HH + \left(1 + r_t^K^D\right) K_{t}^D,HH + r_t^L L \]
Model Overview

Climate Module

Climate Module

Final Good Sector

Dirty Intermediate Sector

Clean Intermediate Sector

Households

Dirty Energy Production

Monetary Authority

Fiscal Authority

Clean Energy Production

\[ E_t^D \rightarrow S_t(S_{t-1}, E_t^D) \rightarrow T_t(S_t) \rightarrow D_t(T_t) \]

S - Carbon Stock
T - Temperature
D - Damage

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CBP = r^K_C K^{C,QE} + r^K_D K^{D,QE} - \Delta K^{C,QE} - \Delta K^{D,QE}

\( \tau^E \cdot E^D + \tau^C \cdot C + CBP = 0 \)
Model Overview
All Together
Results - Baseline
Exogenous Driving Forces

**L - Labor supply**

**Energy productivity**

- $A^C$ - clean energy
- $A^D$ - dirty energy

**$A^Y$ - Final good productivity**

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Results - Baseline

Intermediate Production Inputs

Energy prices (USD)

Energy input

Capital input

Labor input
Results - Baseline

Final Production Inputs

\[ p^D/p^C \] - Intermediate good price ratio

\[ Y^D/Y^C \] - Intermediate good input ratio
Results - Baseline
Climate Variables

$E^D$ - CO2 emissions (GtC/year)

$T$ - Temp. increase compared to pre-industrial (°C)
1. **Carbon tax:** $\tau_t^E = 50$ USD/tC = **13.6** USD/tCO2, growing with dirty energy price ($\approx 0.4\%$)

2. **Green QE:** **full shift** to $K^C$, growing with capital ($\approx 2.0\%$)
Results - Scenarios
Dirty Energy Price & Capital Return

\[ p^D \] - Dirty energy price (USD)

\[ r^D \] - Dirty rate

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Carbon Tax: 2 mechanisms of a dirty energy price increase $p^{ED} \uparrow$

1. **Final** production: Shift *away* from dirty intermediate good:
   \[ p^{ED} \uparrow \rightarrow p^D \uparrow \rightarrow Y^D \downarrow \rightarrow E^D \downarrow \]

2. **Intermediate** production: Shift *away* from dirty energy:
   \[ p^{ED} \uparrow \rightarrow E^D \downarrow \]
Results - Scenarios
Mechanisms

- **Carbon Tax:** 2 mechanisms of a dirty energy price increase $p^E_D \uparrow$
  1. **Final** production: Shift away from dirty intermediate good:
     
     $p^E_D \uparrow \rightarrow p^D \uparrow \rightarrow Y^D \downarrow \rightarrow E^D \downarrow$
  2. **Intermediate** production: Shift away from dirty energy:
     
     $p^E_D \uparrow \rightarrow E^D \downarrow$

- **Green QE:** 2 mechanisms of a dirty cost of capital increase $r^K_D \uparrow$
  1. **Final** production: Shift away from dirty intermediate good:
     
     $r^K_D \uparrow \rightarrow p^D \uparrow \rightarrow Y^D \downarrow \rightarrow E^D \downarrow$
  2. **Intermediate** production: Shift towards dirty energy: $r^K_D \uparrow \rightarrow E^D \uparrow$
Results - Scenarios
Climate Variables - Reductions

Year 2100 temperature reduction of **Green QE equivalent** to
≈ 11 USD/tC ≈ 3 USD/tCO2 carbon tax
Green QE on top of carbon tax (somewhat) less effective than standalone.
Imperfect crowding out of private held capital $K^{C,HH}$ through quantitative easing $K^{D,HH}$ due to imperfect correlation of clean and dirty capital.
Sensitivity analysis

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<td>$T$ in 2100</td>
<td>3.505</td>
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<td>$\Delta T$</td>
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<td>-0.170</td>
<td>-0.155</td>
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<td>$\Delta T - QE$</td>
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<td>-0.011</td>
<td>-0.056</td>
<td>-0.032</td>
<td>-0.005</td>
<td>-0.036</td>
<td>-0.029</td>
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Notes: Different calibrations for sensitivity analyses. “Flat QE”: Size of monetary authority’s balance sheet held constant over time. “CO2 Bias”: Size of dirty assets on monetary authority’s balance sheet 43% larger, i.e. $K_{0a-df}^m = 12770$. “Pos. Corr.”: Correlation between clean and dirty returns set to $\rho_{cl,dt} = 0.4$. “Low SE”: Low substitution elasticity $\varepsilon = 2.25$ such that energy elasticity is $\eta_{K_{a-dt}}^{\frac{r^m}{K_{a-dt}}, \frac{F_{a-dt}}{P_{a-dt}}} = 1.05$. “WAPR”: time varying working age population ratio $\omega_t$. “CO2 Re.”: strong CO2 reduction in baseline such that share of CO2 in GDP decreases at $-1.5\%$ annually.
Summary

- Lower CO2 emissions  
- Higher CO2 emissions

Carbon tax leads to ...

1. Final sector: **Lower demand** for dirty interm. good
2. Interm. sector: **Lower demand** for dirty energy

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3. Partial crowding out of private capital
Summary

- Lower CO2 emissions  
  - Carbon tax leads to ...
    1. Final sector: **Lower demand** for dirty interm. good
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  - Green QE leads to ...
    1. Final sector: **Lower demand** for dirty interm. good
    2. Interm. sector: **Higher demand** for dirty energy
    3. Partial crowding out of private capital
  - Carbon tax stronger (\(-0.167{\degree}C\) vs. \(-0.039{\degree}C\) for green QE) ...
    - Green QE equivalent to carbon tax \(\approx 3 \text{ USD/tCO2}\)
- Higher CO2 emissions

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Thank you for your attention!