Monetary Policy for the Energy Transition

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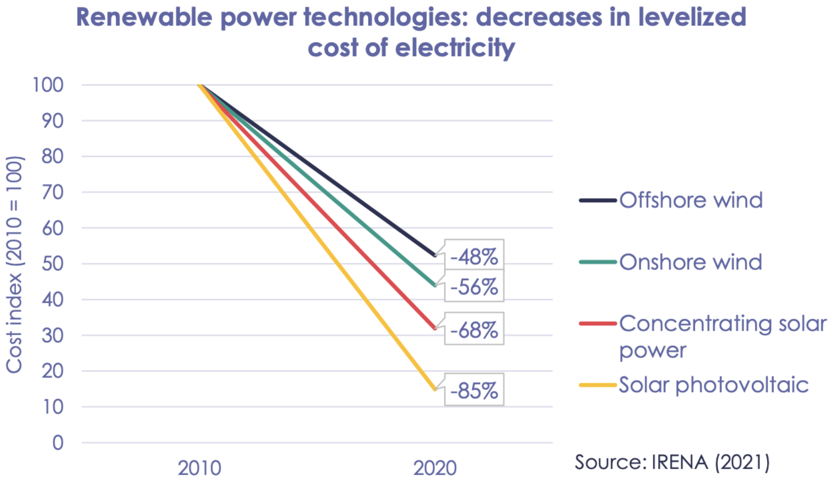
Motivation

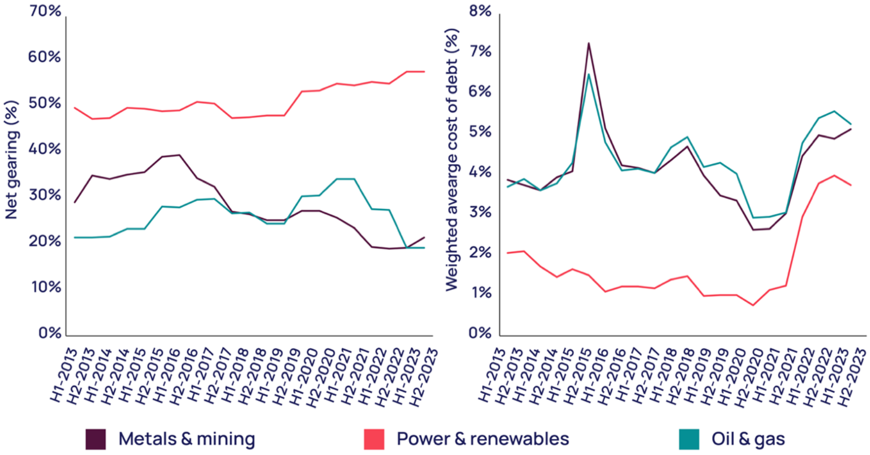
- Climate change is one of the biggest challenges of our societies
- Energy transition requires a massive sectoral reallocation of investment and economic activity
  - Policy-driven phasing out of fossil fuels (carbon taxes, ETS,...)
  - Fast development of green technologies


Renewable power technologies: decreases in levelized cost of electricity
Cost index (2010 = 100)
100
90
80
70
60
50
40
30
20
10
0
2010
2020
-48%
-56%
-68%
-85%
Offshore wind
Onshore wind
Concentrating solar power
Solar photovoltaic
Source: IRENA (2021)

Motivation

- Climate change is one of the biggest challenges of our societies
- Energy transition requires a massive sectoral reallocation of investment and economic activity
  - Policy-driven phasing out of fossil fuels (carbon taxes, ETS,...)
  - Fast development of green technologies
- Implications of energy transition for monetary policy are little understood
  - Inflation/economic activity trade-off during the transition?
  - How does monetary policy affect the speed of the transition?
- Monetary/financial channel for green investment likely to be powerful

Gearing in renewable sector



Source: Martin, P., Whiteside, J., McKay, F. and Santhakumar, S. The cost of investing in the energy transition in a high interest-rate era, Wood MacKenzie, April 2024

This paper

- Macroeconomic model of the energy transition
  - Supply constraints in the dirty sector
  - Endogenous technological change in the clean sector
- Transitory inflation is a natural symptom of the energy transition
  - Higher price of dirty goods fosters reallocation toward clean ones
  - Containing inflation requires sharp drop in economic activity
- Tight monetary stance discourages investment in green technologies
  - Consistent with preliminary empirical evidence
  - Intertemporal trade-off: lower inflation in the short run, but higher inflationary pressures in the medium run

Outline of the talk

1. Sketch of the model
2. Macroeconomic impact of dirty energy shortages
3. Endogenous green innovation
4. Some empirical evidence

Households and monetary policy

- Aggregate demand decreasing in real interest rate

$$C_t = \frac{C_{t+1}\pi_{t+1}}{\beta(1+i_t)} \quad \text{where} \quad \frac{1+i_t}{\pi_{t+1}} \equiv 1 + r_t$$

- Nominal wage rigidities

$$\frac{W_t}{W_{t-1}} = \left(\frac{L_t}{\bar{L}}\right)^{\xi} \pi_{t-1}^{\lambda}$$

- By setting policy rate i_t, monetary policy controls cost of credit r_t and aggregate demand C_t

Firms - final good production

- Large number of competitive firms producing according to

$$Y_t = L_t^{1-\alpha} \int_0^1 A_{j,t}^{1-\alpha} x_{jt}^{\alpha} dj$$

- x_j is an intermediate input of productivity A_j
- Price of the final good equal to marginal cost

$$P_t = \left(\frac{W_t}{\int_0^1 \frac{A_{j,t}}{P_{j,t}^{\frac{\alpha}{1-\alpha}}} dj} \right)^{1-\alpha} \frac{1}{(1-\alpha)^{1-\alpha} \alpha^{\alpha}}.$$

Firms - intermediate sectors

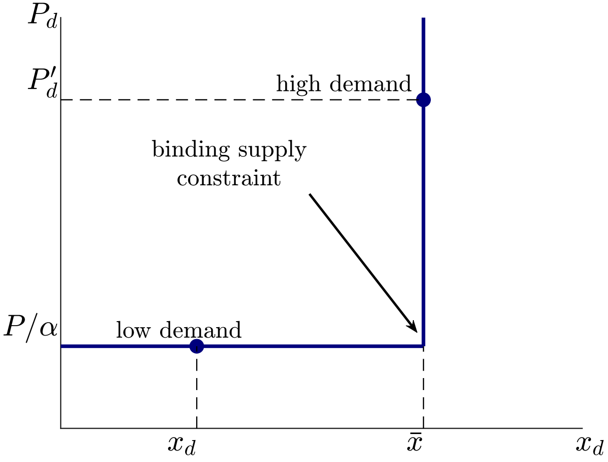
- Every good j is produced by a single firm
- Clean intermediate goods
  - Produced one-for-one with final good

$$P_{c,t} = \frac{P_t}{\alpha}$$

- Dirty intermediate goods
  - Produced one-for-one with final good
  - Face supply constraint $\bar{x}_t$ (green regulations, geopolitical shocks,...)

$$x_{d,t} \leq \bar{x}_t$$

Convex supply curves in dirty sector



- Price increases steeply with output when supply constraint binds, as documented empirically by Boehm and Pandalai-Nayar (AER 2022)

A non-linear Phillips curve

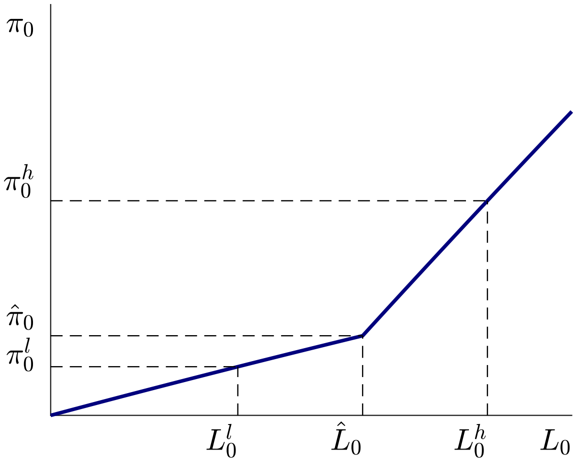
- Inflation given by

$$1 + \pi_t = \frac{W_t}{W_{t-1}} \frac{\chi A^c_{t-1} + (1-\chi) A^d \left(\alpha p^d_{t-1}\right)^{-\frac{\alpha}{1-\alpha}}}{\chi A^c_t + (1-\chi) A^d \left(\alpha p^d_t\right)^{-\frac{\alpha}{1-\alpha}}}$$

$$p^d_t = \max\left(\frac{1}{\alpha}, \alpha\left(\frac{L_t A^d}{\bar{x}_t}\right)^{1-\alpha}\right)$$

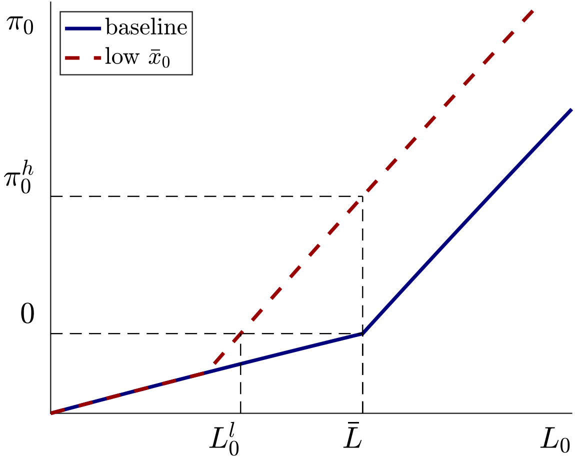
- Constraint on supply of dirty goods creates inflationary pressures
  - High inflation volatility in response to demand shocks
  - Tighter supply constraints worsen inflation/employment trade-off

High volatility of inflation under demand shocks



- High demand pushes up price of dirty goods creating strong inflationary pressures

Supply shocks worsen inflation/employment trade-off



- High employment cost from containing inflation in response to negative supply shocks

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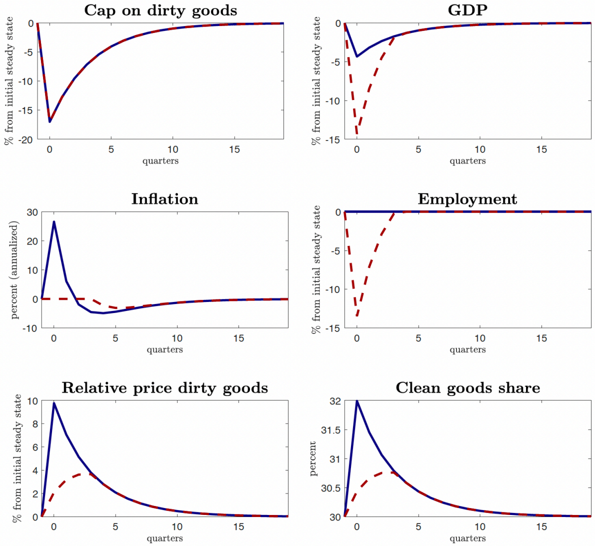
Macroeconomic impact of dirty energy shortages

- Temporary dirty-energy shortages
  - Cost-push shock: higher inflation and lower economic activity, consistent with empirical evidence (Kanzig and Konrandt, 2023)
  - Inflation fosters reallocation toward clean goods

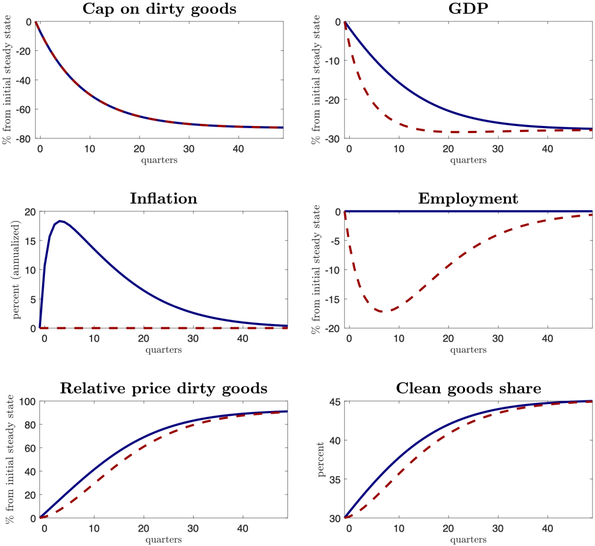
Temporary dirty energy shortage



Macroeconomic impact of dirty energy shortages

- Temporary dirty-energy shortages
  - Cost-push shock: higher inflation and lower economic activity, consistent with empirical evidence (Kanzig and Konrandt, 2023)
  - Inflation fosters reallocation toward clean goods
- Gradual phasing out of dirty energy sources
  - Temporary inflationary pressures
  - Contractionary monetary stance slows down reallocation, and amplifies economic cost of transition
- Transitory inflation is a natural symptom of the reallocation of production out of dirty goods, and toward clean ones

Phasing out of dirty energy sources



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Endogenous green innovation

- Clean firms invest to increase productivity

$$A^c_{j,t+1} = (1-\delta)A^c_{j,t} + \frac{\psi_t}{\phi}\left(I^c_{j,t}\right)^{\phi}$$

- Optimal investment maximizes profits

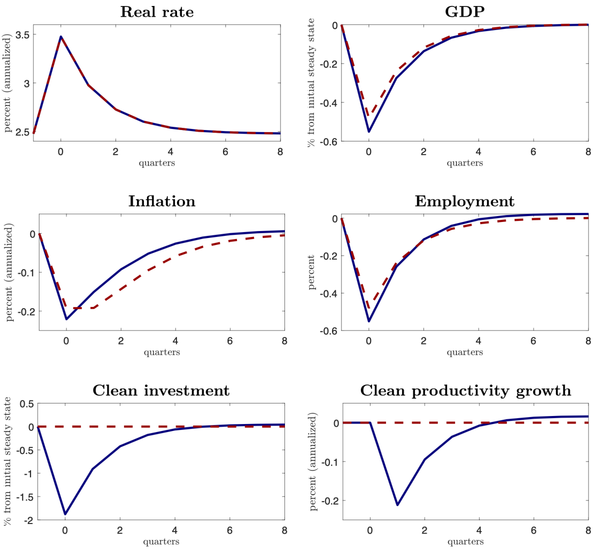
$$\left(I^c_{j,t}\right)^{1-\phi} = \psi_t \sum_{\tau=t}^{\infty}\left(\prod_{\hat{\tau}=t}^{\tau}\frac{1}{1+r_{\hat{\tau}}+\eta}\right)\left((1-\delta)^{\tau-t}\varpi L_{\tau+1}\right)$$

- Monetary contraction depresses green investment
  - Higher cost of capital ($\uparrow r, \downarrow I$)
  - Lower demand and profits ($\downarrow L, \downarrow I$)

An intertemporal inflation trade-off

- Central bank increases policy rate to lower inflation
  - Short run: slack on labor market depresses inflation
  - Medium run: lower investment, lower productive capacity, higher inflationary pressures

Monetary contraction



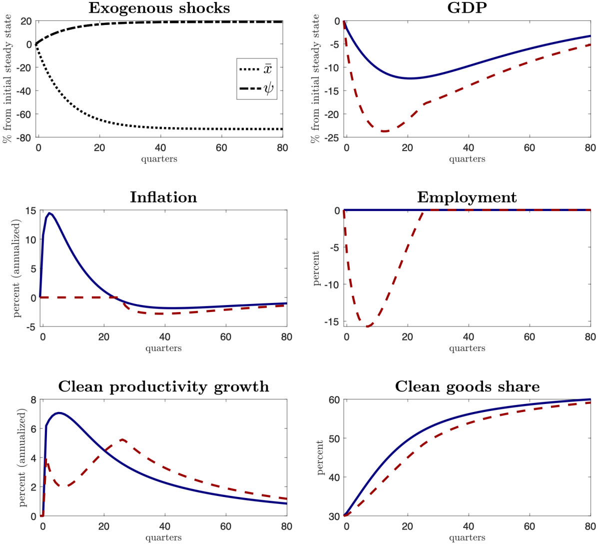
An intertemporal inflation trade-off

- Suppose that central bank increases policy rate to lower inflation
  - Short run: slack on labor market depresses inflation
  - Medium run: lower investment, lower productivity, higher inflationary pressures
- Trade-off may be particularly important during the green transition
  - Large investments needed to hit climate goals
  - Green investments are particularly responsive to changes in the cost of capital (Gormsen et al. 2023)

Transition toward a clean economy

- Two forces driving the transition
  - Tighter supply constraints on dirty goods
  - Investment boom in clean technologies
- Monetary policy shapes the transition
  - Dovish: temporary inflation, fast transition
  - Hawkish: larger output losses, lower investment and slower transition

Transition toward a clean economy



Transition toward a clean economy

- Two forces driving the transition
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- Monetary policy shapes the transition
  - Dovish: temporary inflation, fast transition
  - Hawkish: larger output losses, slower investment and transition
- Fiscal subsidies to green investment can reconcile a fast transition with mild inflationary pressures (Fornaro and Wolf, 2023)

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Impact of financial shocks on green investment

- Local projections - Compustat data on US quoted companies, sample 1986q1-2023q4
- Dependent variable: investment rate and R&D intensity
- Study dynamic response of financial shocks using Chicago Fed index of financial conditions and sub-components (Choleski identification) on investment and R&D
- Estimate average companies' responses and then distinguish between green and non green innovators using patent data for classification

Average effect

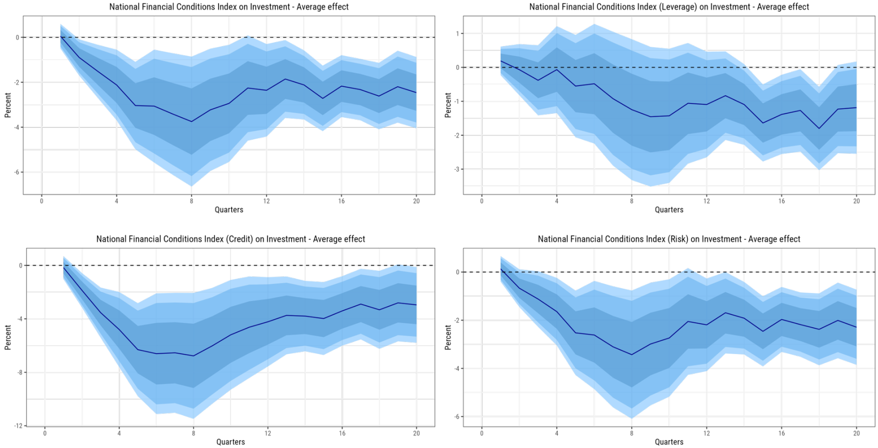
For each firm i we estimate a LP constraining the response of the dependent variable to a tightness of financial condition to be the same across firms:

$$\Delta^h Y_{i,t+h} = \gamma_i + \beta^h X_t + \Gamma^h \mathbf{Z}_t + \epsilon_{i,t+h}, \qquad \forall h \in 0, \cdots, H$$

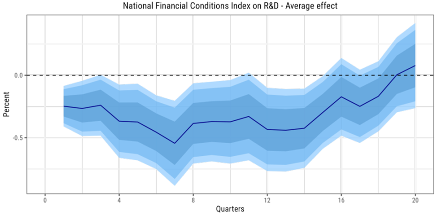
- Y_{it} is investment rate or R&D intensity
- $\Delta^h Y_{i,t+h} = Y_{i,t+h} - Y_{i,t-1}$
- X_t Chicago Fed's index of financial conditions (NCFI) (and sub-components)
- $\mathbf{Z}_t$ various controls: four lags and contemporaneous values of GDP growth and one-year interest rate
- γ_i firm fixed effect

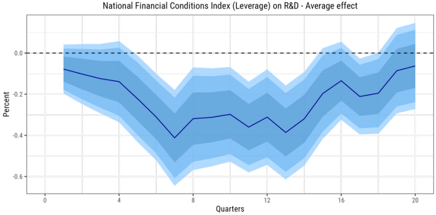
We obtain cumulative IRFs for $h = 0, \cdots, 19$ and the corresponding 68%, 90% and 95% confidence intervals calculated using Driscoll and Kraay, 1998 standard errors clustered by firm. As the NFCI it is constructed to have unit standard deviation over the entire sample, coefficients are response to 1sd increase in NFCI.

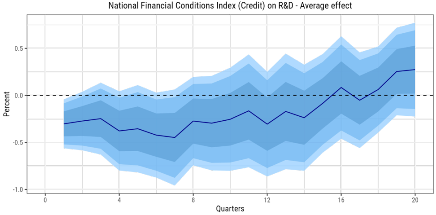
Effect of tighter financial conditions on investment

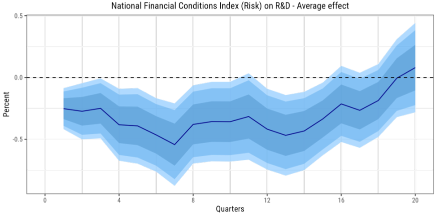


Effect of tighter financial conditions on R&D









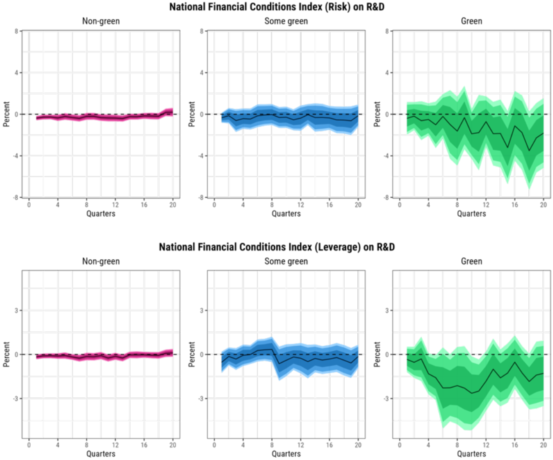
Stratified local projection - green dummies

$$\Delta^h Y_{i,t+h} = \gamma_i^h + \sum_{g=1}^{G} \beta_g^h \mathbb{1}[\text{Green}_i \in g] \times X_t + \Gamma^h \mathbf{Z}_t + \epsilon_{i,t+h}, \qquad \forall h \in 0, \cdots, H$$

where:

$$\text{Green}_{i,t} = \begin{cases} \text{Green} & \text{if } \text{ patent mix}_{i,t} > 25\% \\ \text{Some Green} & \text{if } \; 0 < \text{patent mix}_{i,t} < 25\% \\ \text{Non} - \text{green} & \text{if } \text{ patent mix}_{i,t} = 0\% \end{cases}$$

Risk and leverage on R&D - AABH classification



Conclusions

- Transitory inflation may be needed for a smooth energy transition
- Important to take into account impact of monetary policy on green investment
- Difficult trade-off for central banks: sustaining economic activity and green transition, while keeping inflation expectations anchored
- Monetary policy is not the only game in town
  - Fiscal subsidies to green investment
  - Green macroprudential regulation

Details on design

1. Extract the entire universe of patents granted by the US patent and Trademark Office (USPTO) from 1976 to 2023 with information on patentś filing date, grant date and cooperative patent classification (CPC) code.
2. Classify a patent as green in two alternative ways:
   - AABH: if contains one of the following CPC codes: Y02E10, Y02E30, Y02E50 (as in Acemoglu et al. 2023)
   - Y02: if contains Y02 CPC code
   - The patent data are then matched to firms using the patent to firm matching of Arora et al. (2021). With this method, the green status of a firm is updated each time new patents information is received.
3. Define a stratified local projection model to estimate the dynamic response. For each firm, the patent mix at time t is the number of green patents granted at t divided by the total patents granted.

More details

- Y02 classification uses the entire CPC class defined as "Technologies or applications for mitigation or adaptation against climate change", selects 104 green companies
- AABH classifies a subset of the Y02E CPC Subclass defined as "Reduction of greenhouse gas emissions, related to energy generation, transmission olimitedr distribution", specifically the codes:
  - Y02E10: Energy generation through renewable energy sources
  - Y02E30: Energy generation of nuclear origin
  - Y02E50: Technologies for the production of fuel of non-fossil origin

  it selects 80 companies

Risk and leverage on R&D - Y02 classification