Climate Transition: Subsidies v. Carbon Tax
Discussion of Fries and Aghion et al.

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SUMMARY

Fries paper:
- Question: What is the macroeconomic rationale for sequencing clean energy subsidies before a carbon tax?
- Insight: Clean energy becomes more substitutable for fossil energy as clean energy capital stock grows
- Implication: Microeconomic and macroeconomic factors favor subsidies

Aghion et al. paper:
- Question: Was shale boom beneficial for the clean energy transition?
- Insight: Directed technical change results in excessive innovation in fossil technologies
- Implication: Both subsidies and carbon tax needed to implement transition
MACROECONOMIC FRAMEWORK

SETUP (BMW 2023)

Household/utilities investment problem:

\[
\max \sum_{t=0}^{\infty} \beta^t u(C_t)
\]

subject to

\[
C_t + p^c_t I_t^c + p^f_t I_t^f = p^e_t E_t + \tau_c K_t^c - \tau_f K_t^f - T_t + W_t \bar{N}
\]

\[
E_t = G \left( K_t^c, K_t^f \right)
\]

\[
K_t^i = I_t^i + (1 - \delta_i) K_t^i \quad i \in \{c, f\}
\]

Output and electricity demand:

\[
Y_t = F \left( E_t, \bar{N} \right)
\]

\[
p^e_t = F_e \left( E_t, \bar{N} \right)
\]
Clean energy subsidy is a supply-side policy: lower energy prices, higher output, productivity and wages.
Optimal climate policy

Setup

\begin{align*}
\max & \sum_{t=0}^{\infty} \beta^t [u(C_t) - d(S_t)] \\
C_t + p_t^c I_t^c + p_t^f I_t^f &= F(E_t, \bar{N}) \\
E_t &= G(K_t^c, K_t^f) \\
K_{t+1}^i &= I_t^i + (1 - \delta_i) K_t^i \quad i \in \{c, f\} \\
S_{t+1} &= S_t + \kappa K_t^f
\end{align*}

- Planner internalizes the environmental damage externalities from the fossil fuel capital

- Planner’s resource constraint depends only on underlying technologies: \( p_t^c, p_t^f, G(\cdot, \cdot) \)
OPTIMAL POLICY LEAVES CLEAN ENERGY MARGIN UNDISTORTED

Utilities capital choice under subsidies/tax:

\[
p_c^t = \frac{1}{1 + r_t} \left[ (p_{t+1}^e + \tau_{t+1}^c) G_c (K_{t+1}^c, K_{t+1}^f) + p_{t+1}^c (1 - \delta_c) \right]
\]

\[
p_f^t = \frac{1}{1 + r_t} \left[ (p_{t+1}^e - \tau_{t+1}^f) G_f (K_{t+1}^c, K_{t+1}^f) + p_{t+1}^f (1 - \delta_f) \right]
\]

Planner’s allocation:

\[
p_c^t = \frac{1}{1 + r_t} \left[ p_{t+1}^e G_c (K_{t+1}^c, K_{t+1}^f) + p_{t+1}^c (1 - \delta_c) \right]
\]

\[
p_f^t = \frac{1}{1 + r_t} \left[ p_{t+1}^e G_f (K_{t+1}^c, K_{t+1}^f) + p_{t+1}^f (1 - \delta_f) \right] - \mu_{t+1} \kappa
\]

- The electricity production function \( G \left( K_t^c, K_t^f \right) \) could be variable elasticity of substitution, but implies zero subsidy
Tax v. Subsidy under Innovation

Setup

\[
\max \sum_{t=0}^{\infty} \beta^t [u(C_t) - d(S_t)]
\]

\[
C_t + p_t^c I_t^c + p_t^f I_t^f = F(E_t, \bar{N})
\]

\[
E_t = G(K_t^c, K_t^f)
\]

\[
K_{t+1}^i = I_t^i + (1 - \delta_i) K_t^i \quad i \in \{c, f\}
\]

\[
S_{t+1} = S_t + \kappa K_t^f
\]

\[
p_{t+1}^i = p_t^i \left(1 - \eta_i s_t^i\right) \quad i \in \{c, f\}
\]

\[
1 = s_t^c + s_t^f
\]

- Adaption of Acemoglu, Aghion, Bursztyn, and Hemous (2012)

- How does the planner allocate innovation effort between clean and fossil fuel energy?
IS THE PRIVATE ALLOCATION OF INNOVATION SUB-OPTIMAL?

Optimal allocation of innovation:

\[ v^i_i = \frac{1}{1 + r_t} \left[ I^i_{t+1} + v^i_{t+1} \left(1 - \eta^i_{i} s^i_{t+1}\right) \right] \quad i \in \{c, f\} \]

\[ v^c_i \eta^c p^c_t = v^f_i \eta^f p^f_t \]

Discussion:

- The planner’s allocation decision is undistorted relative to private sector allocation and optimal subsidy is zero

- Why does AABH (2012) and AABH (2023) find otherwise?

- Private sector innovation decisions is insufficiently forward-looking (static in AABH (2023))
INNOVATION AND PRICE MECHANISM

Role for research subsidies in AABH (2012) and successors:

▶ Innovation is generically undersupplied due to investment horizon and market structure

▶ Innovation in clean energy is disproportionately impacted due to low scale and low initial productivity

Inflation Reduction Act subsidies rely on price mechanism:

▶ IRA investment and production incentives induce upstream innovation only indirectly

▶ Justification for IRA incentives reliant on scale effects in manufacturing ("learning-by-doing") or financial frictions
SHALE BOOM AND CLEAN ENERGY INNOVATION

- AABH (2023) model shale boom as productivity shock to natural gas energy production and extraction

- Fracking innovation has no applications for clean energy energy production in their model

- Fracking and, more generally, fossil fuel technologies may have important applications for clean energy
  - Enhanced geothermal requires fracturing hot rock formations and achieving greater drilling depths
  - Existing carbon capture used for enhanced oil recovery; techniques may be used for sequestration