"Directed Technical Change as a Response to Natural Resource Scarcity" by Hassler et al. (2021)

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Env Reading Group

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Introduction

- What is the income share of scarce resource under technical change? The case of fossil fuel-based energy as an input into production.
- On the one hand, scarcity $\rightarrow$ price rises $\rightarrow$ curbed use $\rightarrow$ income share increases (elasticity of substitution is smaller than 1)
- On the other hand, price rises $\rightarrow$ endogeneous technical change $\rightarrow$ save on scarce inputs $\rightarrow$ income share decreases;
- With endogenous energy saving, a long-run fossil income share strictly between zero and one. The share depends on the "technology menu".
- The long-run income share for fossil fuel is 8%. $\rightarrow$ Only a small reduction in long-run consumption growth due to the finiteness of fossil energy.

Fuel Price and Income Shares

- Co-movements of fossil fuel and its income share → Low substitution between energy and other inputs

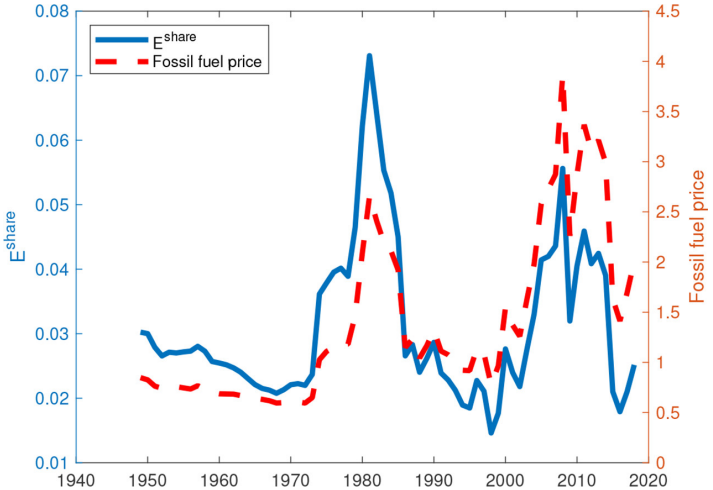

Figure 1: Fossil Fuel Prices and Its Income Share

Fuel Price and Input-saving Technology

- Production function

$$y_t = \left[(1-\gamma)\left(A_t k_t^{\alpha} l_t^{1-\alpha}\right)^{(\epsilon-1)/\epsilon} + \gamma\left(A_{et} e_t\right)^{(\epsilon-1)/\epsilon}\right]^{\epsilon/(\epsilon-1)} \tag{1}$$

where

  - A_t,A_{et}: input-saving technology levels for composite and energy;
  - ϵ: elasticity of substitution between capital/labor composite and energy;

- Perfectly competitive input market $\rightarrow$ marginal product is equal to price

$$A_t = \frac{y_t}{k_t^{\alpha} l_t^{1-\alpha}}\left[\frac{l_t^{share}}{(1-\alpha)(1-\gamma)}\right]^{\epsilon/(\epsilon-1)}, \quad A_{et} = \frac{y_t}{e_t}\left[\frac{e_t^{share}}{\gamma}\right]^{\epsilon/(\epsilon-1)} \tag{2}$$

- $\epsilon = 0.02$

Fuel Price and Input-saving Technology

- Fossil-energy saving technology series co-moves with fuel prices;
- Input-saving technology series co-move negatively;

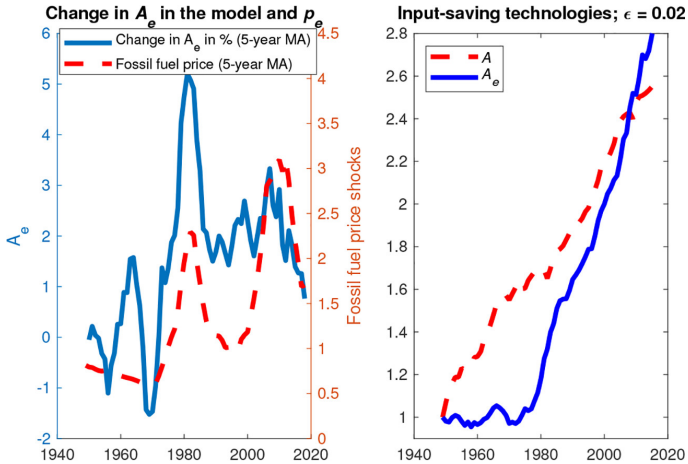

Figure 2: Fuel price and input-saving technology

Recap up

- Empirical results show that
  - **It is hard to substitute fossil fuel energy by increasing capital or labor;**
  - **Technical change directs itself toward the input on which it is profitable to save;**
- Need quantitatively measurement: the evolution of fossil fuel's income share with the increase of scarcity.

Setup

- Social planner problem:

$$\max_{\{c_t, k_{t+1}, e_t, A_{t+1}, A_{e,t+1}\}} \sum_{t=0}^{\infty} \frac{c_t^{1-\sigma} - 1}{1-\sigma} \tag{3}$$

$$\text{subject to} \quad c_t + k_{t+1} = F(A_t k_t^{\alpha}, A_{et} e_t) + (1-\delta) k_t \tag{4}$$

$$G\left(\frac{A_{t+1}}{A_t}, \frac{A_{e,t+1}}{A_{et}}\right) = 0 \tag{5}$$

$$\sum_{t=0}^{\infty} e_t \leq R_0 \tag{6}$$

- The CES production function:

$$F(A_t k_t^{\alpha}, A_{et} e_t) = \left[(1-\gamma)\left(A_t k_t^{\alpha}\right)^{(\epsilon-1)/\epsilon} + \gamma\left(A_{et} e_t\right)^{(\epsilon-1)/\epsilon}\right]^{\epsilon/(\epsilon-1)} \tag{7}$$

Technology Menu

- Technology menu: G is increasing in both arguments $\rightarrow$ The tradeoff between two input saving.
- Restate $G(\cdot)$ as

$$g_{A,t} = f(n_t) \tag{8}$$

$$g_{A_e,t} = f_e(1 - n_t) \tag{9}$$

- n_t is the share of a fixed amount of R&D resources that is allocated to enhancing the efficiency of the capital/labor composite

Balanced Growth Path (BGP)

- The two arguments of the aggregate production function, $A_t k_t^{\alpha}$ and $A_{et} e_t$, both grow at the rate of output g;
- Energy use falls at a constant rate: $e_{t+1}/e_t = \beta g^{1-\sigma}$;
- Technology effort n and the consumption growth factor g are determined by $f_e(1-n)\beta = f(n)^{\sigma/(1-\alpha)} = g^{\sigma}$;
- Energy's share of income is determined by how costly it is to enhance energy efficiency in terms of lost capital/labor efficiency.

$$\frac{1 - e^{share}}{e^{share}} = -\frac{d \ln(g_{A_e})}{d \ln(g_A)} \tag{10}$$

Conclusion

- Strong evidence that the economy actively directs its efforts at input saving so as to economize on scarce inputs;
- With endogeneous technical change, the fossil income share will be 8% in the long run.

References

Hassler, J., Krusell, P., and Olovsson, C. (2021). Directed technical change as a response to natural resource scarcity. *Journal of Political Economy*, 129(11):3039–3072.