Structural Change in the Long Run
a case for constant, but time-varying elasticity of substitution

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1 Introduction

2 Implementation

3 Results and discussion

4 Conclusion remarks/next step
Production functions, “deep parameters”, structural change

Constant elasticity of substitution (CES) production function

\[ F(K_t, L_t) = A_t \left[ \alpha K_t^{\frac{\sigma-1}{\sigma}} + (1 - \alpha) L_t^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \]  \hspace{1cm} (1)

\[ \sigma \in [0, +\infty] = \frac{d \log(K/L)}{d \log(F_N/F_L)} \]  \hspace{1cm} (2)
Production functions, “deep parameters”, structural change

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(2)

Some speculation at the birth of CES function:

Arrow, Chenery, Minhas, and Solow (1961)

“the process of economic development itself might shift the over-all elasticity of substitution.”

Is this what have happened in the past, and will happen in the future?
Economic literature:

- Klump and Grandville (2000, AER): $\sigma < 1$ implies ever-increasing labor income share/ ES can be an increasing function of capital/ increasing efficiency build in.
- Duffy and Papageorgiou (2000, JoEG): capital and labor are more substitutable in wealthier countries.
- La Grandville (1989, AER): ES is a powerful engine of growth (the case of East Asia).

Potential questions

- little known third derivatives of the production function.
Introduction - evidence of time-varying ES

For energy transition modeling

\[ f(t) = \frac{1}{1 + \exp(-\alpha(t - t_0) - \beta)} \]

Figure 1: Source: Kaya et al. (2015), Fouquet (2010), Grubler (2012), Marcotullio and Schulz (2007)

- S shape transitions curve.
- Factor share preservation property of the CES function (Kaya et al. 2015).
- Mariesse et al (2015): comparing the modeled energy system change to historical rates of change - insights from history.
Purpose of this study:

- Model the long-run energy transitions by implementing time-varying ES in WITCH.
- We focus on the substitution between renewable energies and fossil fuels, and also explore further substitutions.
- We evaluate the optimal energy composition and transition path under this new specifications.
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\[ \text{ELFFREN} = \left[ \alpha \cdot \text{ELFF}^\rho + (1 - \alpha) \cdot \text{REN}^\rho \right]^{1/\rho}, \sigma = 1/(1 - \rho) \]

Figure 2: linear varying $\rho$

$\rho_0 = 0.8, \rho_1 = [0.5, 0.9, 0.99]$  
Correspondingly  
$\sigma_0 = 5, \sigma_1 = [2, 10, 100]$
Implementation

\[ ELFFREN = [\alpha \cdot ELFF^\rho + (1 - \alpha) \cdot REN^\rho]^{1/\rho}, \sigma = 1/(1 - \rho) \]

- **Figure 2:** linear varying \( \rho \)
  \( \rho_0 = 0.8, \rho_1 = [0.5, 0.9, 0.99] \)
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- **Figure 3:** linear varying \( \sigma \)
  \( \sigma_0 = 5, \sigma_1 = [2, 10, 100] \)
  Correspondingly
  \( \rho_0 = 0.8, \rho_1 = [0.5, 0.9, 0.99] \)

- Scenarios
  - No policy
  - 1.5 degree policy
Outline

1. Introduction
2. Implementation
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4. Conclusion remarks/next step
Emissions and Temperature

Emissions (bau & 1.5 policy)

![Graph showing emissions over time for baseline and policy scenarios.](image-url)
Emissions and Temperature

Emissions (bau & 1.5 policy)

Temperature (bau & 1.5 policy)
Primary Energy Supply

Energy supply (bau & 1.5 policy)

![Graph showing energy supply trends for bau and policy scenarios.](chart)

*TPES [EJ]*

*Year*

- *tpesbau*
- *tpespolicy*
Primary Energy Supply

Energy supply (bau & 1.5 policy)

RD investment (bau & 1.5 policy)
Primary Energy Mix

Energy Mix (bau, $\sigma_1 = 5,100$)
Primary Energy Mix

Energy Mix (bau, $\sigma_1 = 5, 100$)

Energy Mix (1.5 policy, $\sigma_1 = 5, 100$)
Electricity Mix (bau, $\sigma_1 = 5, 100$)
Electricity Mix (bau, $\sigma_1 = 5, 100$)  

Electricity Mix (1.5 policy, $\sigma_1 = 5, 100$)
Renewable shares (bau & 1.5 policy)

[Graphs showing renewable shares under different policies.]
The economic cost of transitions (preliminary)

Carbon price

Policy cost
The economic cost of transitions (preliminary)
Sensitivity analysis

Production function

Legend:
- **EL**: Electricity
- **NEL**: Non-electric Energy
Figure 4: Emissions at different ES, bau
Time-varying ES better models the renewable transitions.

The process of adopting the renewables reflected from RD investment.

Further explorations to be done by matching the historical transitions path.

Better indicators for the economic cost and look for the nonlinear effect.