Industrial Revolutions and Global Imbalances

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1The views expressed here are those of the authors and do not necessarily reflect the opinion of the Federal Reserve Bank of St. Louis or the Federal Reserve System.
Introduction

- **Global Imbalances:** Major Countries: Large CA & NFPs

- **Literature:**
  - SOE or Two Country Models.
  - Stationary Business Cycle Fluctuations.
  - Frictions and Policies.

- **This paper:**
  - Global Capital Markets with Many countries.
  - Industrial Revolutions: Changing World Income Distribution.
  - Alternative contractual environments.
Industrial Revolutions and the World Income Distribution.

Figure: Per Capita Incomes, Maddison Data
Global Imbalances

Figure: The Long History of Global Imbalances

- **Gold**
  - U.K.
  - France
  - Germany
  - U.S.A.
  - Japan

- **NFAs**

The graph shows the country holdings of world gold and NFA/world assets for selected countries over the years 1850 to 2000.
This Paper:

How Should Countries Finance Their Industrial Revolutions?

Theoretical Benchmarks: Global Balances and \( \{K_t, Y_t, C_t\} \).

- **Model of Industrial Revolutions:**
  - **Diffusion:** Time and geography.

- **Contractual Environments:**
  - **Participation:** Universal vs Sequential.
  - **Other Frictions:**
    - Incomplete Markets.
    - Limited Commitment (default temptation).

- **Computational Challenges:**
  - Non-stationary: non-recursive, infinite horizon.
  - Global Markets: Many heterogeneous countries.
The Economic Environment

- Production, Open Economies Extension of Lucas’ (2001)
  - A continuum, ex-ante identical people in \( S \) countries.
  - Calendar time: \( t = 0, 1, 2, \ldots \)
  - Countries’ Ascension times to I.R. \( s: \)
    - \( s < t: \) Country started I.R. before \( t \)
    - \( s = t: \) Country started I.R. at \( t \)
    - \( s > t: \) Countries still in pre-modern age at \( t \).

- Mass of Countries Ascending \( \pi(t) \):
  \[
  \pi(t) = \lambda(t) \times \left[ 1 - \sum_{s < t} \pi(s) \right].
  \]
  - **Lucas:** \( \lambda(t) \): Increasing in Modern-to-Pre-Modern gap.
The Economic Environment

- Preferences: For all $s$

$$U_0 = E \left[ \sum_{t=0}^{\infty} \beta^t \frac{c(s,t)^{1-\sigma}}{1-\sigma} \right].$$

- Output: year $t = 1, 2, ...$, countries $s \leq t$:

$$y(s,t) = [k(s,t)]^\nu [z(s,t)]^{1-\nu}.$$

- TFP: $z(s,t)$:

$$z(s,t) = \begin{cases} 
  z_0 (1+\alpha)^t, & s = 1: \text{Leader;} \\
  z(s,t-1)(1+\alpha) \left[ \frac{z(1,t)}{z(s,t-1)} \right]^\theta, & s = 2,...t: \text{Ascended;} \\
  z_0, & s > t: \text{Pre-Modern.}
\end{cases}$$

Pre-Modern TFP $z_0 > 0$. Growth: $\alpha > 0$. Diffusion: $\theta \in [0,1]$. 
Universal Participation

Known Ascension Dates

All countries in all $t$ participate in competitive capital markets

- **World Economy**: Aggregation:

  \[
  \text{TFP} \quad Z_t = \left[ \sum_{s=0}^{\infty} \pi(s) [z(s, t)]^{1-v} \right]^{1-v}.
  \]

  Output \quad Y_t = Z_t \cdot (K_t)^v.

  Capital \quad K_{t+1} = Y_t + (1 - \delta) K_t - C_t.

  MPKs \quad R_t = v Z_{t+1} \cdot (K_{t+1})^{\nu-1} + 1 - \delta.

  Cons. \quad \left( \frac{C_{t+1}}{C_t} \right)^{\sigma} = \beta \cdot R_t.

- **Individual Countries**: For all $s$, equalization of MPKs and

  Cons. \quad \left( \frac{c(s, t+1)}{c(s, t)} \right)^{\sigma} = \beta \cdot R_t.

  B.C. \quad (s, 0) = (s, 0).

  NFPs \quad a(s, t) = \sum_{\tau=t}^{\infty} (t, \tau) [k(s, \tau + 1) + c(s, \tau) - y(s, \tau) - (1 - \delta) k(s, \tau)].
Universal Participation

Known Ascension Dates, Lucas’ parameters

GDP

Relative Capital

NFP/ own GDP

NFPs/World GDP
Universal Participation

Known Ascension Dates, Lucas’ parameters

Figure: A Global Savings Glut?
Sequential Participation

Ascension = Diffusion + Participation in Global Capital Markets

► **World Economy:** Aggregation of all **ascended**:

\[
TFP: \quad Z_t^A = \left[ \sum_{s=0}^{t} \pi(s) \left[ z(s, t) \right]^{\frac{1}{1-\nu}} \right]^{1-\nu}.
\]

Capital: \quad \begin{align*}
K_{t+1}^A &= Y_t^A + (1-\delta) K_t^A - C_t^A + \pi(t+1) k(t+1, t+1).
\end{align*}

CONS. : \quad \left( \frac{\bar{C}_{t+1}^A}{\bar{C}_t^A} \right)^\sigma = \beta \cdot R_t.

► **Ascended Countries:** Equalization of MPKs across all \( s \leq t \):

CONS. : \quad \left[ c^A(s, t + 1) \div c^A(s, t) \right]^\sigma = \beta \cdot R_t.

B.C. : \quad (s, s) = (s, s).

NFPs : \quad a(s, t) = \sum_{\tau=t}^{\infty} \left( k(s, \tau + 1) + c(s, \tau) - y(s, \tau) - (1-\delta) k(s, \tau) \right).

► **Pre-Modern** (yet to ascend): \( s > t \): \quad z(s, t) = z_0, \quad a(s, t) = 0.

► \( k(s, t) \): Variations: \( \textbf{(a)} \) known-dates; \( \textbf{(b)} \) unknown dates; \( \textbf{(c)} \) complete unawareness.
Sequential Participation

Outputs

Relative Capital

NFPs/own GDP

NFPs/World GDP
Sequential Participation

Figure: A Global Savings Glut....
Extensions and Frictions

- **Diffusion of Industrial Revolutions**: Beyond Lucas
  - **States**: Pre-Modern (PM), Middle-Income (MI), Advanced (IR)
  - **Transitions**:
    - PM $\implies\{\text{PM, MI, IR}\}$
    - MI $\implies\{\text{MI, IR}\}$
    - IR $\implies\{\text{IR}\}$

- **Hard-Currency/Gold-In-Advance Constraint**

- **Limited Commitment**
Hard-Currency/Gold-In-Advance Constraint

- **Gold**: Country’s Holdings: \( g(s, t) \). World Price: \( p^G(t) \).

\[
\text{GIA: } c(s, t) + [k(s, t + 1) - (1 - \delta) k(s, t)] \leq p^G(t) g(s, t).
\]

- **Implications**: Ascending Countries Accumulate Gold:
- **Gold Holdings**:
  - Initially: From Pre-Modern to Early Ascending.
  - Later: From Advanced to recently Ascended.
- **Universal Participation+GIA**: Sequentially in Gold, NFP.
Limited Commitment

- A Country's value of going rogue: $R (k; s, t)$.

- Participation Constraints:

$$[\xi (s, t)] : \left[ \sum_{\tau \geq t}^{\infty} \beta^{\tau - t} \frac{c (s, \tau)^{1-\sigma}}{1 - \sigma} \right] \geq R (k; s, t), \forall t.$$

- Implications of Limited Commitment:

Backloads $c$: $[c (s, t)]^{-\sigma} \sum_{\ell = 0}^{t} \xi (s, \ell) = \mu (s, t),$

Reduces $k$: $\mu (s, t) + \xi (s, t) \frac{\partial R (k; s, t)}{\partial k} = \beta \cdot MPK (s, t) \cdot \mu (s, t + 1),$

Enhances $a$: $\mu (s, t) q_t = \beta \mu (s, t + 1)$.

- Non-Stationary $\xi (s, \ell)$: Asymmetry between Early-Late Ascenders.
Conclusions

- A long history of Global Imbalances.
  - Cycles of Accumulation and Decumulation of External Wealth.
    - Linked to Ascensions to Industrial Revolutions.

- Derived Theoretical Benchmarks on a Stylized Model.
  - Suggestive Results on "Global Savings Glut"

- Future Work:
  - Richer contractual arrangements.