Industrial Revolutions and Global Imbalances[1]

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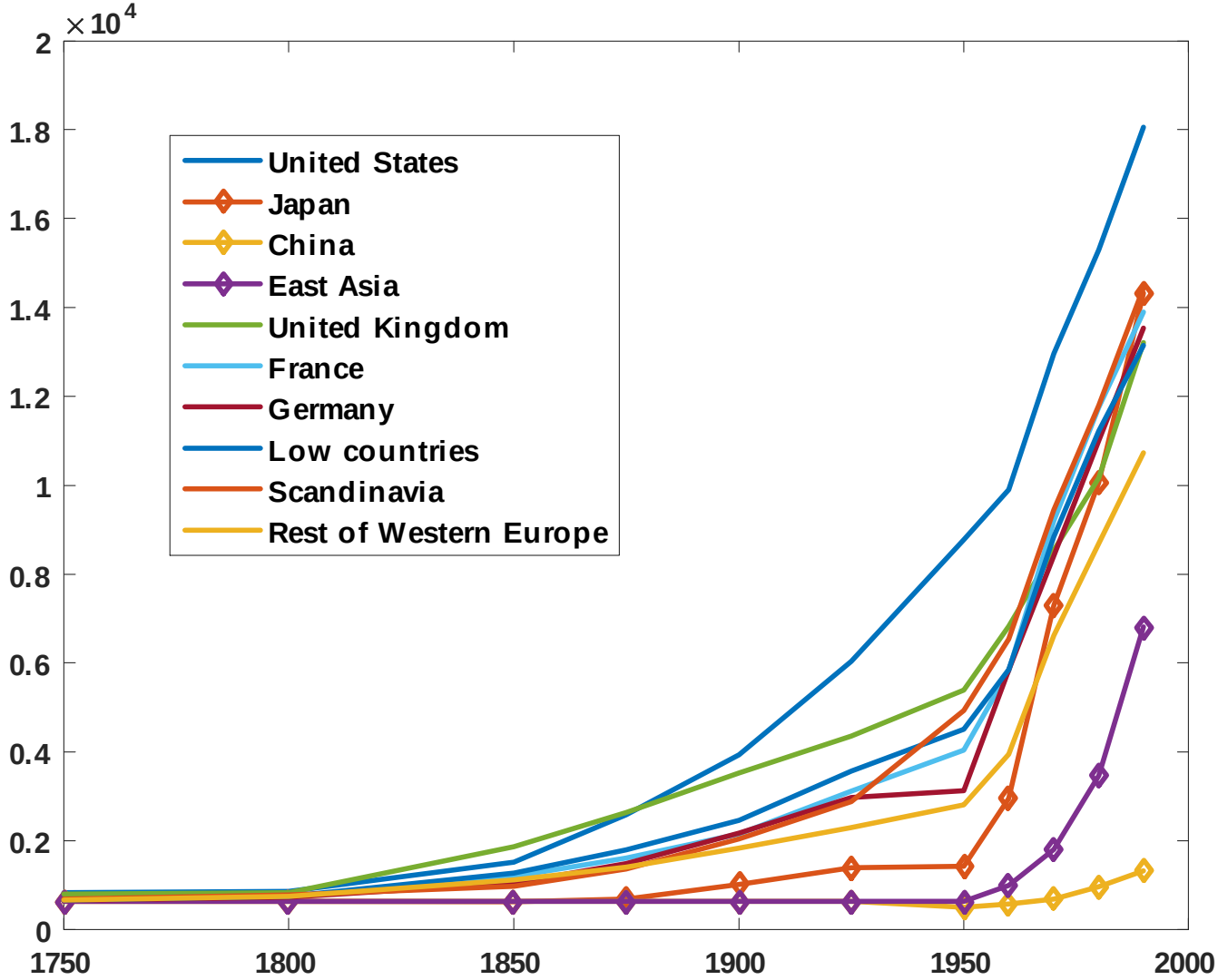
[1]The views expressed here are those of the authors and do not necessarily reflect the opinion of the Federal Reserve Bank of St. Louis or the Federal Reserve System.

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.

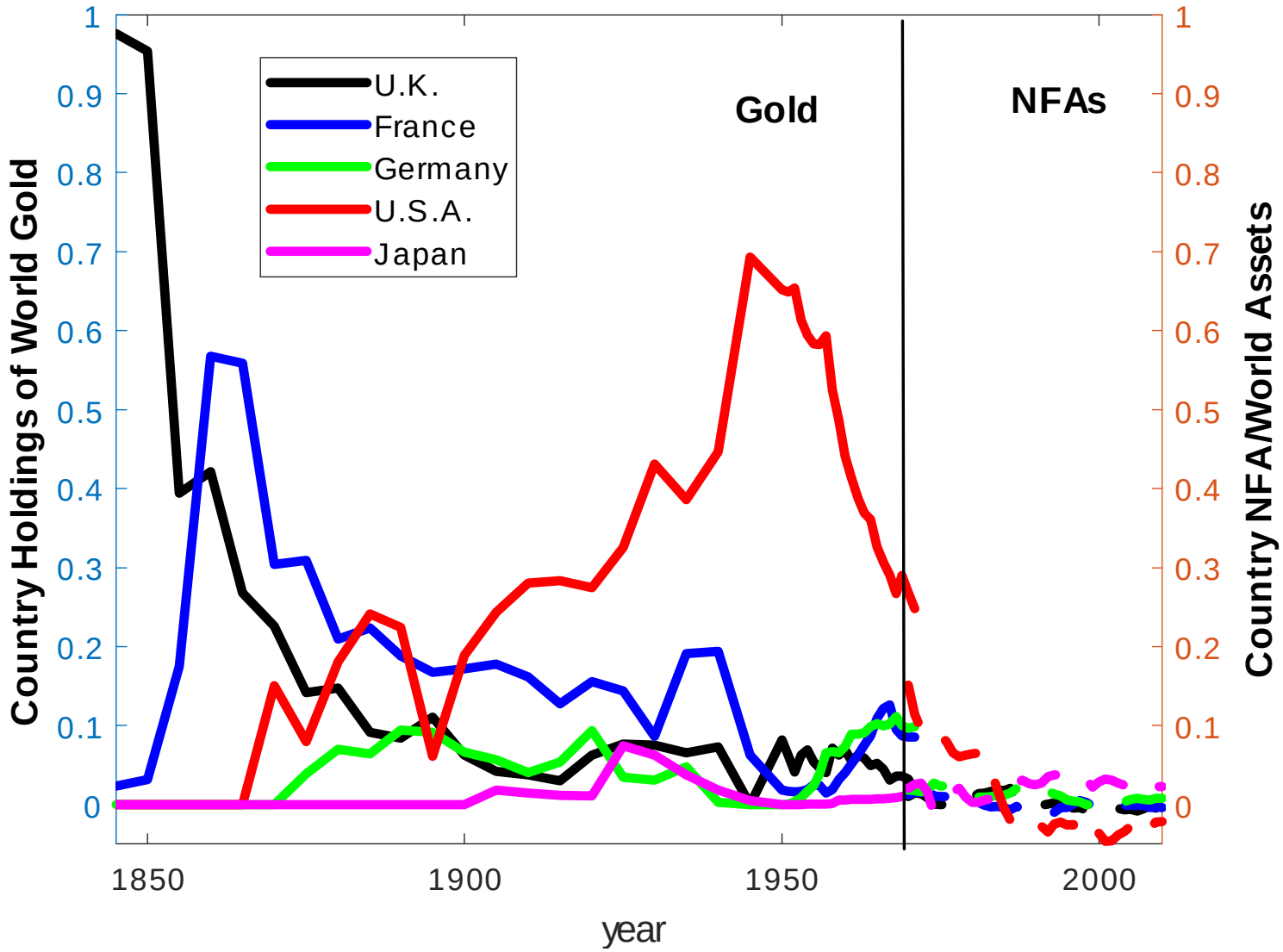
Industrial Revolutions and the World Income Distribution.

Figure: Per Capita Incomes, Maddison Data



Global Imbalances

Figure: The Long History of Global Imbalances



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.
    - Hard-Currency/Gold-in-Advance Constraint.
    - 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: $t = 0, 1, 2, ...$
  - 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 $\pi(t)$:

$$\pi(t) = \underbrace{\lambda(t)}_{\textbf{Hazard Rate}} \times \underbrace{\left[1 - \sum_{s<t} \pi(s)\right]}_{\textbf{Mass in Pre-Modern}}.$$

    - **Lucas:** $\lambda(t)$: Increasing in Modern-to-Pre-Modern gap.

The Economic Environment

- **Preferences:** For all s

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

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

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

- **TFP:** $z\left(s,t\right)$:

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

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:

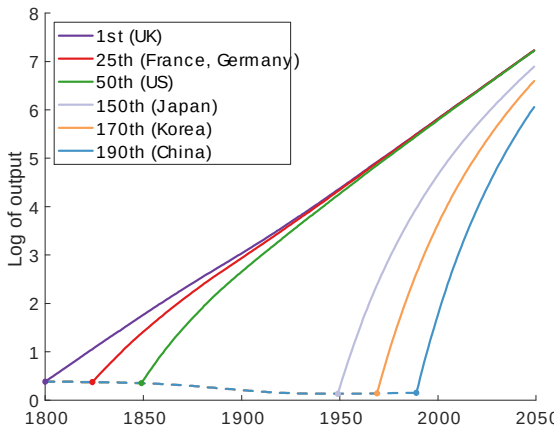
$$\begin{aligned}
\textbf{TFP} \quad &: \quad Z_t = \left[\sum_{s=0}^{\infty} \pi(s) \left[z(s,t) \right]^{\frac{1}{1-\nu}} \right]^{1-\nu}. \\
\textbf{Output} \quad &: \quad Y_t = Z_t \cdot (K_t)^{\nu}. \\
\textbf{Capital} \quad &: \quad K_{t+1} = Y_t + (1-\delta) K_t - C_t. \\
\textbf{MPKs} \quad &: \quad R_t = \nu Z_{t+1} \cdot (K_{t+1})^{\nu-1} + 1 - \delta. \\
\textbf{Cons.} \quad &: \quad \left(\frac{C_{t+1}}{C_t} \right)^{\sigma} = \beta \cdot R_t.
\end{aligned}$$

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

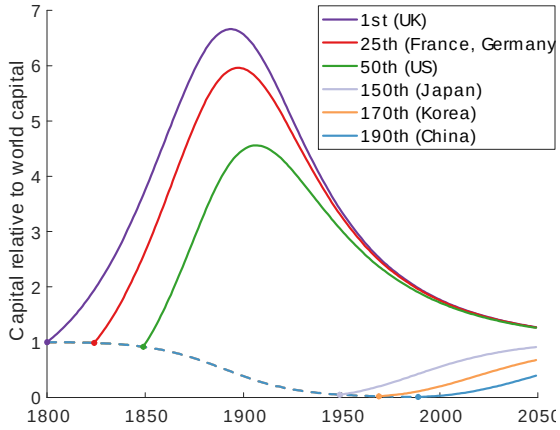
$$\begin{aligned}
\textbf{Cons.} \quad &: \quad \left(\frac{c(s,t+1)}{c(s,t)} \right)^{\sigma} = \beta \cdot R_t. \\
\textbf{B.C.} \quad &: \quad \text{NPVC}(s,\mathbf{0}) = \text{NPVY}(s,\mathbf{0}). \\
\textbf{NFPs} \quad &: \quad a(s,t) = \sum_{\tau=t}^{\infty} \text{Q}(t,\tau) \left[k(s,\tau+1) + c(s,\tau) - y(s,\tau) - (1-\delta) k(s,\tau) \right].
\end{aligned}$$

Universal Participation

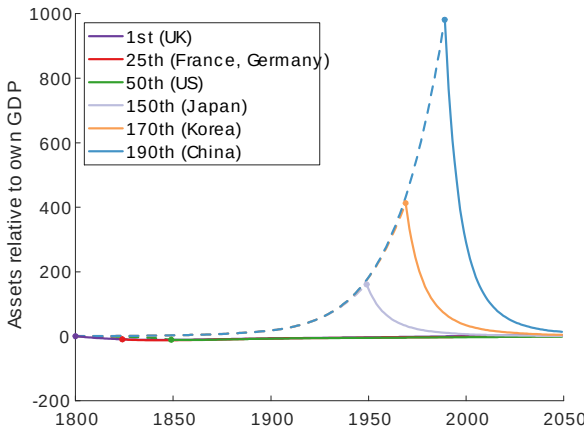
Known Ascension Dates, Lucas' parameters



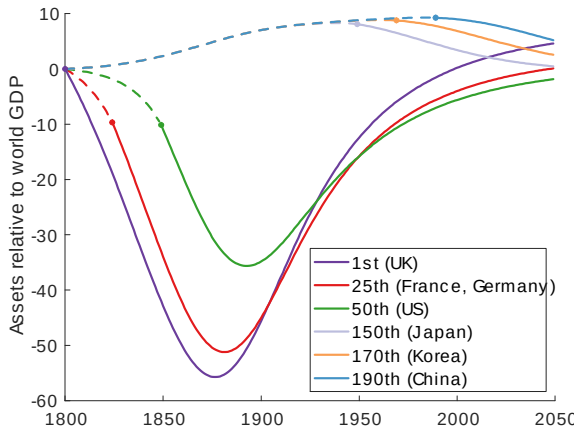
GDP



Relative Capital



NFP/ own GDP



NFPs/World GDP

Universal Participation

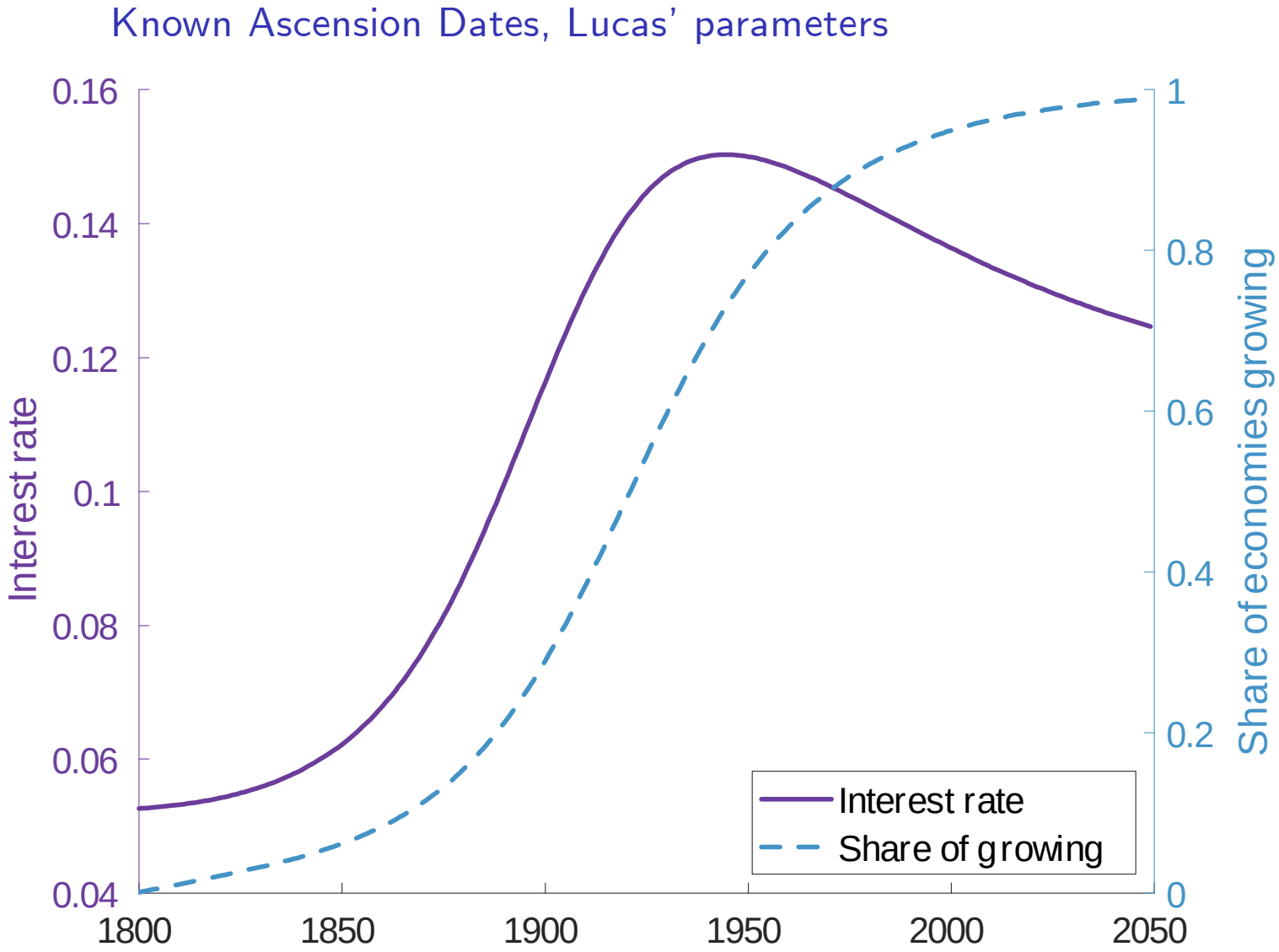


Figure: A Global Savings Glut?

Sequential Participation

Ascension = Diffusion + Participation in Global Capital Markets

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

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

$$\textbf{Capital} \quad : \quad K_{t+1}^A = Y_t^A + (1-\delta) K_t^A - C_t^A + \pi(\mathbf{t}+\mathbf{1}) \mathbf{k}(\mathbf{t}+\mathbf{1}, \mathbf{t}+\mathbf{1}).$$

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

- **Ascended Countries:** Equalization of *MPKs* across all $\mathbf{s} \leq \mathbf{t}$:

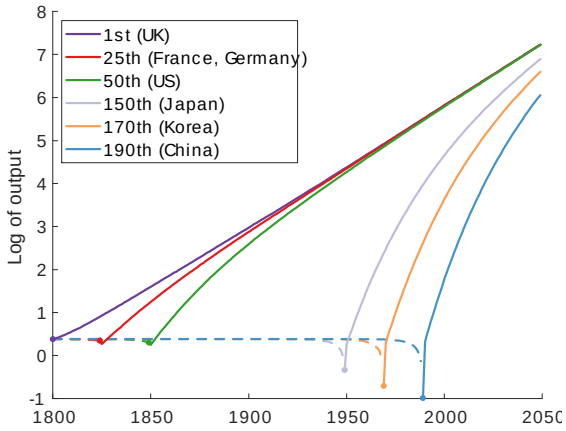
$$\textbf{CONS.} \quad : \quad \left[c^A(s, t+1) \div c^A(s,t) \right]^{\sigma} = \beta \cdot R_t.$$

$$\textbf{B.C.} \quad : \quad \text{NPVC}(s, \mathbf{s}) = \text{NPVY}(s, \mathbf{s}).$$

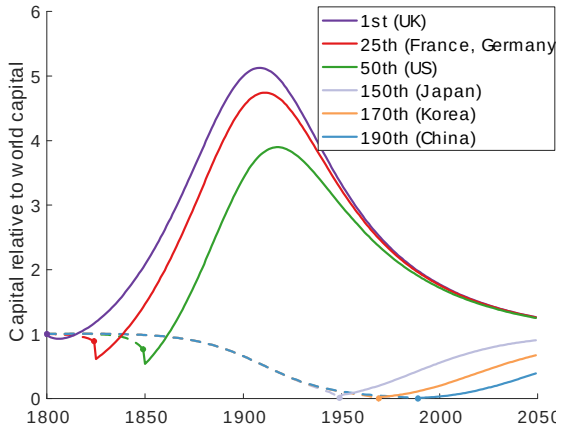
$$\textbf{NFPs} \quad : \quad a(s,t) = \sum_{\tau=t}^{\infty} \text{Q}(t,\tau) \left[k(s, \tau+1) + c(s,\tau) - y(s,\tau) - (1-\delta) k(s,\tau) \right].$$

- **Pre-Modern** (yet to ascend): $\mathbf{s} > \mathbf{t}$: $z(s,t) = z_0, \quad a(s,t) = 0.$
  - $k(s,t)$: Variations: **(a)** known-dates; **(b)** unknown dates; **(c)** complete unawareness.

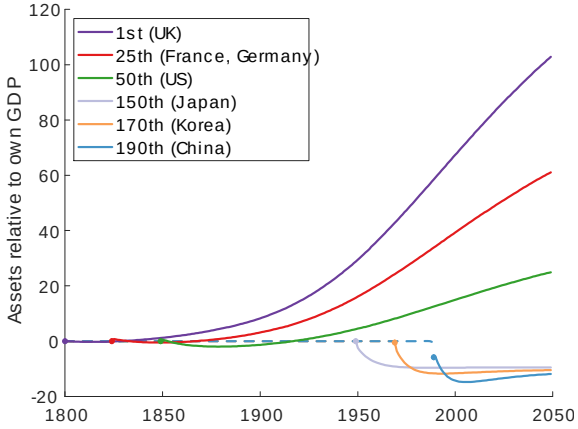
Sequential Participation



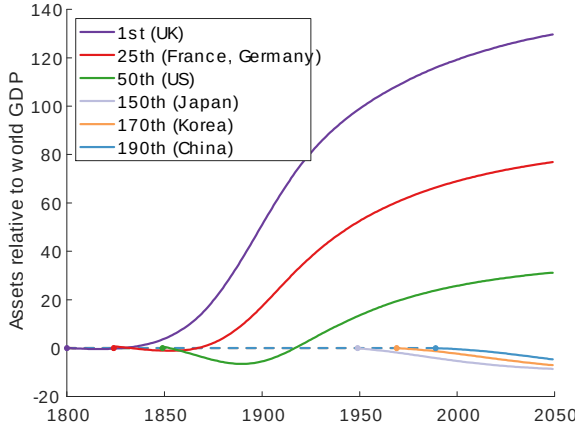
Outputs



Relative Capital



NFPs/own GDP



NFPs/World GDP

Sequential Participation

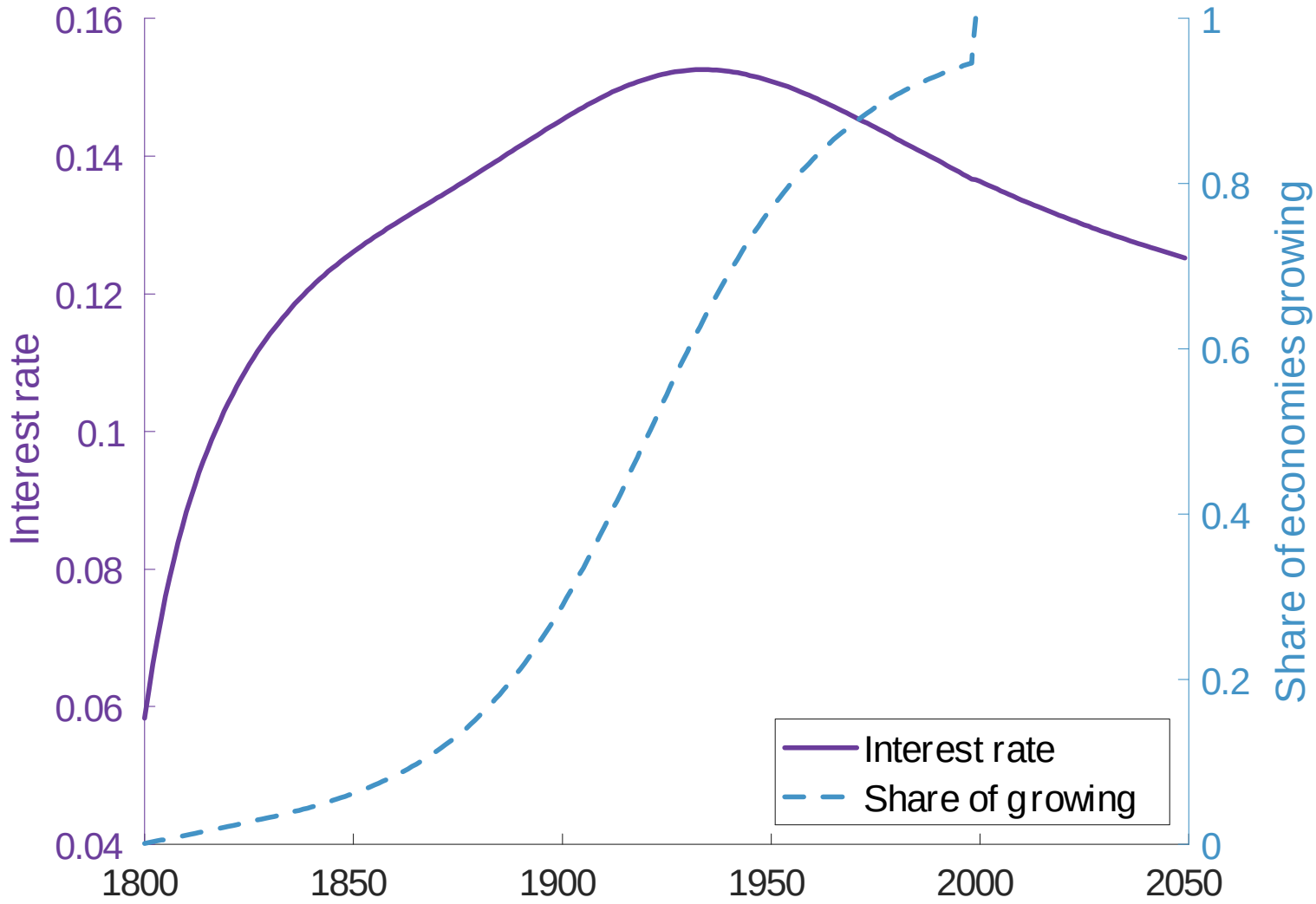


Figure: A Global Savings Glut....

Extensions and Frictions

- **Diffusion of Industrial Revolutions:** Beyond Lucas
  - **States:** Pre-Modern (PM), Middle-Income (MI), Advanced (IR)
  - **Transitions:**
    - **PM** $\Longrightarrow$ { **PM, MI, IR** }
    - **MI** $\Longrightarrow$ { **MI, IR** }
    - **IR** $\Longrightarrow$ { **IR** }
- **Hard-Currency/Gold-In-Advance Constraint**
- **Limited Commitment**

Hard-Currency/Gold-In-Advance Constraint

- **Gold**: Country's Holdings: $\mathbf{g}(s,t)$. World Price: $p^G(t)$.

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

  - **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: $\mathrm{V}^{R}\left(k;\,\mathbf{s},\,\mathbf{t}\right)$.
- **Participation Constraints**:

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

- **Implications of Limited Commitment:**

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

Reduces k: $\mu\left(s,t\right)+\zeta\left(s,t\right)\frac{\partial\mathrm{V}^{R}\left(k;\,\mathbf{s},\,\mathbf{t}\right)}{\partial k}=\beta\cdot MPK\left(s,t\right)\cdot\mu\left(s,t+1\right),$

Enhances a: $\mu\left(s,t\right)q_{t}=\beta\mu\left(s,t+1\right).$

- Non-Stationary $\xi\left(s,\ell\right)$: **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:
  - More realistic model for the World Income Distribution.
  - Richer contractual arrangements.