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Industrial Revolutions and Global Imbalances

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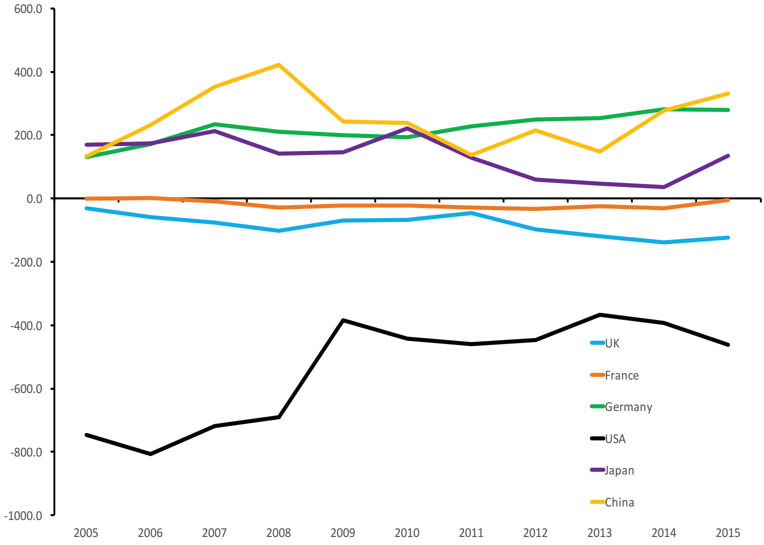
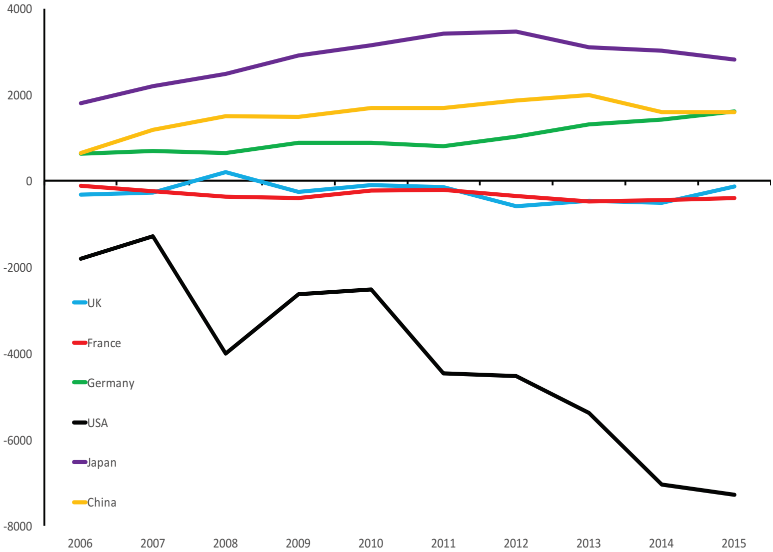
Introduction: Global Imbalance Debate

- China and Japan (and Germany) have run trade surpluses over time and accumulated external wealth.
- Some policy makers and academics accuse them as the source of the financial crisis and global recession.
- They view something wrong in policies and institutions of these countries.
- Some serious researchers support these claims.
  - Jeanne and Ranciere (2011): East Asian countries' reserves are too large from the viewpoint of self insurance against business cycles.
  - Ju and Wei (2010): China's investments in the US is a result of financial frictions in China.
- We would like to present a new theory that can justify large external surplus based on a long-run historical viewpoint.

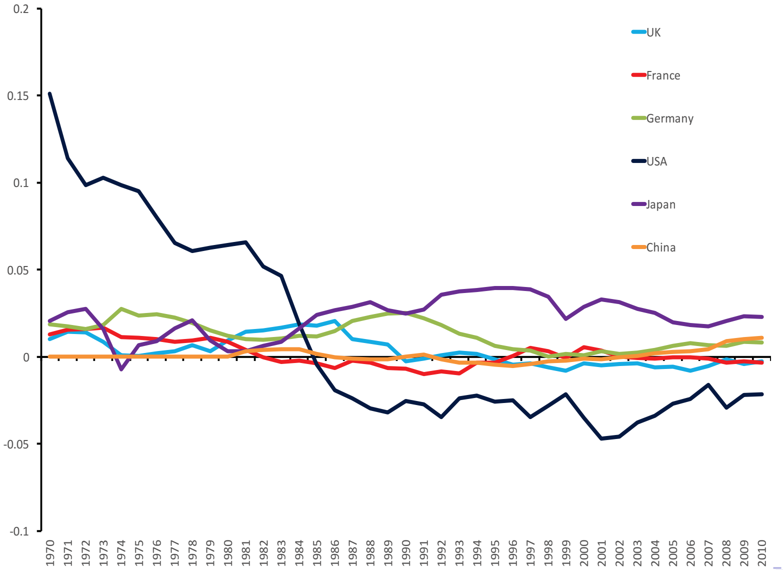
Recent Current Account (bill. USD, IMF)



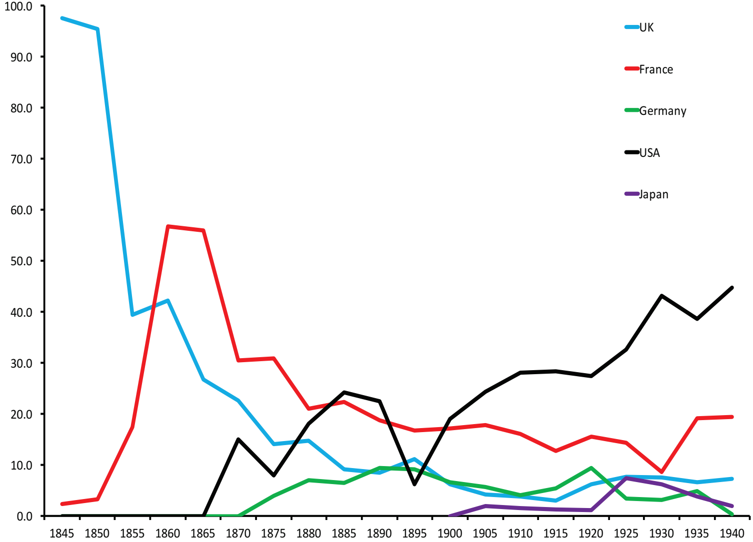
Recent International Investment Position (bill. USD, IMF)



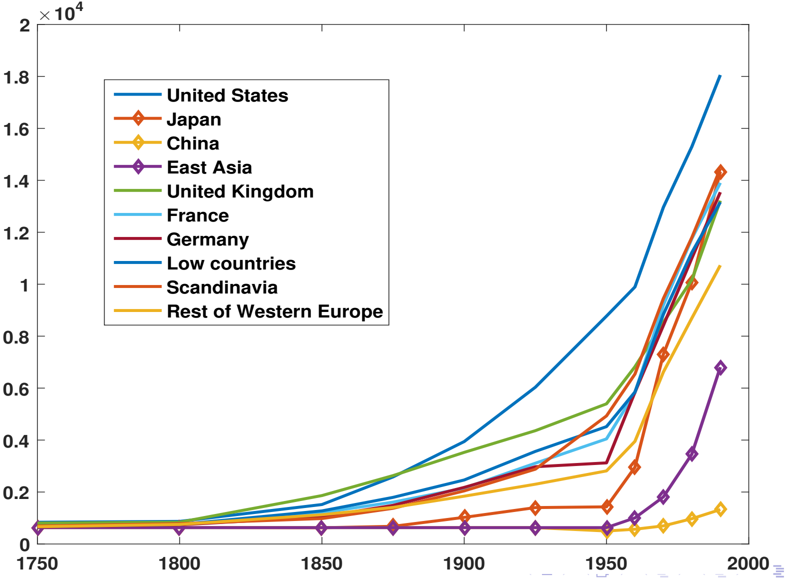
Net Foreign Assets (%, Lane and Milesi-Ferretti (2007))



World Gold Holdings Share (%, World Gold Council)



A Long View: Staggered Industrial Revolutions



New Stylized Facts on Global Imbalances

- Global imbalances have always been present in the world, at least since 19th century after the UK's industrial revolution.
- During the process of rapid industrialization, a country accumulated external wealth.
- A next industrializing country, when it takes off, often accumulates the external wealth more than the predecessors.

Industrial Revolutions and Global Imbalances

- **Motivation:**
  - *Global Imbalances:* Saving gluts and other demons...
  - *Industrial Revolutions:* Countries with fast & sustained growth.
- **What we do:**
  - Identify new stylized facts.
  - Explore underlying mechanisms, esp. regarding market frictions:
    - Benchmark Arrow-Debreu Arrangements
    - Sequential Participations
    - Friction I: Hard-Currency Constraint
    - Friction II: Limited Commitment. [TBD]
  - **Simulation Challenge:** Inherently **a non-stationary** environment. [TBD]
- **What we do not do:** Endogenize Industrial Revolutions.
  - Take the exogenous diffusion model of Lucas (2000, 2004)

Modeling Challenges: Lucas Paradox

- Industrial revolution should be understood as rapid adoption of new technologies in production.
  - Then, the capital demand is high in such countries, demanding capital inflows from the rest of the world.
  - We allow this capital flow in our model.
  - However, the data shows such a country accumulate wealth, rather than borrow (a variant of Lucas Paradox).

Modeling Challenges: Realistic Incomplete Market

- If the international financial market is perfect, even the timing of industrial revolutions can be insured against.
  - Then, the ex ante identical countries should have contingent contracts before the UK's industrial revolutions to share consumption across countries and to smooth consumption over time.
  - The contingent claims markets for timing of industrial revolutions were not available in the real world. We need to assume this.
- To tackle on Lucas Paradox, we need to assume one more friction, either of the two.
  - A hard-currency constraint for consumption. We can still assume availability of equity and bond financing for capital investments.
  - Limited commitment. Countries may default. [TBD]

The Basic Model: Endowment Economy

- Following Lucas (2000, 2004):
  - Exogenous Industrialization.

- A continuum of ex-ante identical countries.

- Discrete time:
  - **Calendar time:** $t = 0, 1, 2, ...$ indicate calendar time
  - **Ascention times** to "modern growth": $s = 1, 2, 3, ...$
    - $s < t$: Countries who started industrialization before t
    - $s = t$: Countries which are starting industrialization right now.
    - $s > t$: Countries still in the pre-modern age.

The Basic Model

- Output levels: for some $y_0 > 0$, $\alpha > 0$

$$y(s,t) = \begin{cases} y_0 (1+\alpha)^t & s = 0 & \text{I.R. Leader} \\ (1+\alpha)\left[\frac{y(0,t)}{y(s,t)}\right]^{\theta} y(s,t) & s = 1, \ldots t & \text{Ascended} \\ y_0 & s > t & \text{Not yet...} \end{cases}$$

- Probability of ascending $\pi(t)$ (complicated in Lucas)

Preferences:

- Preferences of country i

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

where $\beta \in (0,1)$ is a discount factor and $E[\cdot]$ denotes expectations.

  - Sole risk/uncertainty is wrt ascention dates.

- Budget Constraints (in sequence form): For a country ascending in period s is

$$\sum_{t=0}^{\infty} c\left(s,t\right)p\left(t\right)=\sum_{t=0}^{\infty} y\left(s,t\right)p\left(t\right). \tag{1}$$

Standard (Boring) Benchmarks

- **Autarky:**

$$c(s,t) = y(s,t).$$

  - *No imbalances whatsovered.*

Standard (Boring) Benchmarks

- **Arrow-Debreu (at $t = 0$):**
  - Trading in complete markets before knowing s of countries.
  - Full insurance: For all s:

$$c(s,t) = C^W(t) \equiv \sum_{s<t} \pi(s)\, y(s,t) + \left[1 - \sum_{s<t} \pi(s)\right] y_0$$

    - *Potentially large, but counterfactual imbalances.*

Standard (Boring) Benchmarks

common knowledge.

- **Arrow-Debreu with Ascention dates s common knowledge.**
  - Country s: Lagrangean:

$$L = \max \sum_{t=0}^{\infty} \beta^t \frac{[c(s,t)]^{1-\sigma}}{1-\sigma} + \mu(s)\left[\sum_{t=0}^{\infty} p(t)[y(s,t) - c(s,t)]\right]$$

  - **Implications:**
    - Common consumption growth:

$$\frac{c(s,t+1)}{c(s,t)} = \left[\beta \frac{p(t)}{p(t+1)}\right]^{\frac{1}{\sigma}}.$$

    - Asset Prices:

$$p(t) = \beta^t \left[\frac{C^W(0)}{C^W(t)}\right]^{\sigma}.$$

Standard (Boring) Benchmarks

common knowledge.

- **Wealth of Nations:**

$$PY(s) \equiv \sum_{t=0}^{\infty} \beta^t \left[\frac{C^W(0)}{C^W(t)} \right]^\sigma y(s,t).$$

  - **Early Industrializers: Richer** because
    - higher incomes in all periods.
    - higher incomes early on.

- **Consumption levels:**

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

  - **Current Accounts:** $y(s,t) - c(s,t)$**:**
    Early Industrializers: Early deficits; late surpluses.
  - Late Industrializers: Early surpluses; late deficits.
  - Intermediate Industrializers: ????

- Countries in autarky up until $s-1$.
- At $t=s$, the country solves

$$L = \max \sum_{t=s}^{\infty} \beta^t \frac{[c(s,t)]^{1-\sigma}}{1-\sigma} + \mu(s) \left[\sum_{t=s}^{\infty} p(t) [y(s,t) - c(s,t)] \right]$$

- Implication: For $t,\ t' \geq s,\ s'$:

$$\beta^{t'-t} \left[\frac{c(s,t')}{c(s,t)} \right]^{-\sigma} = \left[\frac{p(t')}{p(t)} \right] = \beta^{t'-t} \left[\frac{c(s',t')}{c(s',t)} \right]^{-\sigma}$$

- **Constant Pairwise ratios of consumptions** of participant/ascendent countries:

$$c(s', t) = \theta(s, s')\, c(s, t), \text{ for all } t \geq s,\ s'$$

where

$$\theta(s, s') = \frac{PY_{t=s'}(s')}{PY_{t=s'}(s)} = \frac{\sum_{t=s'}^{\infty} y(s', t)\, p(t)}{\sum_{t=s'}^{\infty} y(s, t)\, p(t)},$$

for any $s' \geq s = t$.

- **Asset Prices:**

$$p(t) = \frac{\beta^t [c(0, t)]^{-\sigma}}{\mu(0)},$$

i.e. not driven by the average consumption of ascendent countries

$$c^A(t) = \frac{\sum_{s \leq t} \pi(s)\, y(s, t)}{\sum_{s \leq t} \pi(s)}.$$

Alternative Representation:

- Since for $0 < s' < s''$

$$\theta\left(0, s''\right) = \theta\left(0, s'\right)\theta\left(s', s''\right),$$

then, define

$$\bar{\theta}\left(t\right) \equiv \frac{\sum_{s=0}^{t} \pi\left(s\right)\theta\left(0, s\right)}{\sum_{s=0}^{t} \pi\left(s\right)}.$$

- **Asset Prices:**

$$p\left(t\right) = \beta^{t}\left[\frac{c^{A}\left(t\right)}{\bar{\theta}\left(t\right)}\right]^{-\sigma}.$$

- **Discussion: Current Accounts.**

Algorithm

- **Iterating over $\{p(t)\}$:**
  - Take $c^A(t) = \sum_{s\leq t} \pi(s)\, y(s,t) / \sum_{s\leq t} \pi(s)$ and $y(s,t)$ as exogenously given.
  - Start with $p^0(t) = \beta^t \left[c^A(t)\right]^{-\sigma}$.
  - For iteration $n = 0, 1, ...,$ take $p^n(t)$ solve for all $s = 1, 2, ...\infty$

$$\theta^n(0,s) = \frac{PY^n_{t=s'}(s)}{PY^n_{t=s}(0)} = \frac{\sum_{t=s}^{\infty} y(s,t)\, p^n(t)}{\sum_{t=s}^{\infty} y(0,t)\, p^n(t)},$$

    and

$$\bar{\theta}^n(t) \equiv \frac{\sum_{s=0}^{t} \pi(s)\, \theta^n(0,s)}{\sum_{s=0}^{t} \pi(s)}.$$

  - Compute, the new implied :

$$p^{n+1}(t) = \beta^t \left[\frac{c^A(t)}{\bar{\theta}^n(t)}\right]^{-\sigma}.$$

  - Iterate, until $\left\| p^{n+1} - p^n \right\| < \epsilon$.

Hard Currency Constraint Model Setup

- A continuum of agents live in finitely many countries (total S countries).
- Countries with the same population are distributed uniformly in $[1, S]$, indexed by s with the cumulative distribution denoted by Ω.
- The world total population mass is normalized to be 1, i.e., $\Omega(S) = 1$ and $\Omega(1) = 0$.
- Production of a representative firm in country s in year t is given as

$$Y_{s,t} = K_{s,t}^{\nu} \left(\gamma_{s,t} L_{s,t}\right)^{1-\nu}, \tag{2}$$

where $K_{s,t}$ is capital, $L_{s,t}$ is labor, and $\gamma_{s,t}$ is productivity of a representative firm of country s in year t.

Sequential Industrial Revolutions

- $t = 0, 1, 2, \cdots$ indicate the calendar time and s indicate the entry year of a country into industrial, modern growth. The country indexed by s is the country that starts industrialization from year s.
- Each country starts with very low level of productivity (pre-industrial stage), $\gamma_{s,t} = \underline{\gamma}$ for $t < s$.
- Country $s = 1$ is the "frontier" country, which is industrialized at time 1, with exogenous TFP growth

$$\gamma_{1,t} = (1+\alpha)\gamma_{1,t-1} = (1+\alpha)^t \underline{\gamma}. \tag{3}$$

- All countries $s = 1, 2, 3, \cdots$ have a chance of industrialization with probability $\rho = \pi_t$ in every year until they begin industrialization. They catch up gradually following Lucas (2002), i.e., for $t \geq s$

$$\gamma_{s,t} = (1+\alpha)\gamma_{1,t}^{\theta}\gamma_{s,t-1}^{1-\theta}. \tag{4}$$

- A country s's representative firm's problem is, for each year,

$$\max_{K_{s,t}, L_{s,t}} K_{s,t}^{\nu}\left(\gamma_{s,t} L_{s,t}\right)^{1-\nu} - r_t K_{s,t} - w_{s,t} L_{s,t}. \tag{5}$$

Household Problem after Industrial Revolution

A country s's representative household's problem

$$V_{s,t}(M_s, k_s, R, R_m) = \max_{M'_s, k'_s} u(c_s) + \beta V_{s,t+1}(M'_s, k'_s, R', R'_m), \tag{6}$$

subject to the budget constraint

$$c_s + i_s + QM'_s = rk_s + w_s l_s + QM_s, \tag{7}$$

the gold-in-advance (GIA) constraint

$$c_s \leq m_s = QM_s \tag{8}$$

and the law of motion of capital

$$k'_s = (1 - \delta)k_s + i_s. \tag{9}$$

Note: $R = r + (1 - \delta)$ and $R_m = Q'/Q$. Both are functions of the current state, which consists of the distribution of capital k, the distribution of gold M, and time t.

Household Problem before Industrial Revolution

A country s's representative household's problem before industrialization cannot depend on time s of industrialization, as it is not yet known. Instead, their value functions depend on the current period $t = n$, because these countries have lost chances to become industrialized up to $t = n$. For $t = n < s$,

$$W_n(M_p, k_p, R, R_m) = \max_{M'_p, k'_p} u(c_p)$$
$$+ \beta\{(1-\rho)W_{n+1}(M'_p, k'_p, R', R'_m) + \rho V_{n+1,n+1}(M'_{s=n+1}, k'_{s=n+1}, R', R'_m)\}, \tag{10}$$

with no difference in capital and gold stock in the beginning of the next period with or without industrialization,

$$M'_p = M'_{s=n+1}; k'_p = k'_{s=n+1}, \tag{11}$$

and subject to the same constraints (7) - (9) above.

Resource Constraints and Market Clear Conditions

The resource constraint for capital in country s's representative firm

$$K_{s,t} = \int_1^S \psi_{j,s} k_{j,t} d\Omega(j). \tag{12}$$

The world wide capital market clears

$$\int_1^S K_{j,t} d\Omega(s) = \int_1^S k_{j,t} d\Omega(j) = \overline{K}_t. \tag{13}$$

The labor market clears in each country,

$$L_s = l_s. \tag{14}$$

The world wide goods market clears,

$$\int_1^S Y_{j,t} d\Omega(s) = \int_1^S \left(c_{j,t} + i_{j,t}\right) d\Omega(j). \tag{15}$$

The world-wide gold quantity in ton is fixed

$$\int_1^S M_{s,t} d\Omega(s) = \overline{M}. \tag{16}$$

Allow Capital Flows: Potential Lucas Paradox

Lemma 1
Capital employed in each country's representative firm is proportional to the productivity level.

$$K_{s,t} = \frac{\gamma_{s,t}}{\gamma_{1,t}} K_{1,t}. \tag{17}$$

The marginal product of capital is equalized among countries.

- The return from capital investment:

$$R_t \equiv \nu K_{s,t}^{\nu-1} \left(\gamma_{s,t} L_{s,t}\right)^{1-\nu} + (1-\delta) = MPK_{s,t} + (1-\delta) = r + (1-\delta). \tag{18}$$

- The real return from gold investment:

$$R_{mt} \equiv Q_t / Q_{t-1}. \tag{19}$$

Euler Equations

Industrialized countries

$$\frac{u'(c_s) - \lambda_{V,s}}{u'(c_s') - \lambda'_{V,s}} = \beta R'. \tag{20}$$

$$\frac{u'(c_s) - \lambda_{V,s}}{u'(c_s')} = \beta R'_m < \beta R'. \tag{21}$$

Pre-industrial countries

$$\frac{u'(c_p) - \lambda_W}{u'(c_p') - E[\lambda'_n]} = \beta R', \tag{22}$$

$$\frac{u'(c_p) - \lambda_W}{u'(c_p')} = \beta R'_m < \beta R'. \tag{23}$$

where $E[\lambda'_n] = (1-\rho)\lambda'_W + \rho\lambda'_{V,s=n+1}$

Period 0: Initial Steady State

Assumption 1
At $t = 0$, when no country is industrialized yet, every country is assumed to be identical and in the steady state expecting probability ρ of starting industrialization next period.

Period 1: Industrialization by the First Country

Proposition 1

- Consumption of the first country is higher than the others that remains at the pre-modern stage.
- In period 1, with probability ρ of industrialization, the first country attracts capital and buys gold from the ROW.

Sketch of Proof: Compare Euler equations

$$\frac{u'(c_1) - \lambda_{V,1}}{u'(c_1')} = \frac{u'(c_p) - \lambda_W}{u'(c_p')} = \beta R_m'. \tag{24}$$

Shadow price of GIA constraint is higher in the first country by PIH: $\lambda_{V,1} > \lambda_{W,1}$.

Corollary 1 The gold price goes up in period 1.

Positive Net External Assets of the First Country

Capital inflow:

$$K_1 - K_p = \left(\frac{\gamma_1}{\overline{\gamma}} - 1 \right) K_p. \tag{25}$$

Gold accumulation:

$$Q_1 M_1' - Q_1 M_1 = \frac{c_1'}{R_m'} - c_1 = \left(\frac{g_{c1}'}{R_m'} - 1 \right) c_1 = \left(\frac{g_{c1}'}{\overline{g}_c'} - 1 \right) c_1. \tag{26}$$

Net external assets is positive if

$$\left(\frac{\gamma_1}{\overline{\gamma}} - 1 \right) \frac{K_{p,1}}{Y_{1,1}} < \left(\frac{g_{c1}'}{\overline{g}_c'} - 1 \right) \frac{c_{1,1}}{Y_{1,1}}. \tag{27}$$

For developing countries, K/Y is likely smaller than one (Klenow and Rodríguez-Clare, 1997) and C/Y is also near one (hand to mouth). So,

$$\frac{g_{c1}'}{\overline{g}_c'} > \frac{\gamma_1}{\overline{\gamma}}. \tag{28}$$

But, consumption growth is indeed higher than the TFP growth when TFP trend changes (Aguiar and Gopinath, 2006).

Period 2: Industrialization by the Second Country

Proposition 2

The growth of consumption, and thus gold holdings, by the second country are higher than those of the first country from period 2 to 3.

Sketch of Proof: Can show that the shadow price of GIA constraint is higher for the second county than the first country in period 2, i.e., $\lambda_{V,1} < \lambda_{V,2}$, Then, compare Euler equations:

$$\frac{u'(c_1) - \lambda_{V,1}}{u'(c_1')} = \frac{u'(c_2) - \lambda_{V,2}}{u'(c_2')} \tag{29}$$

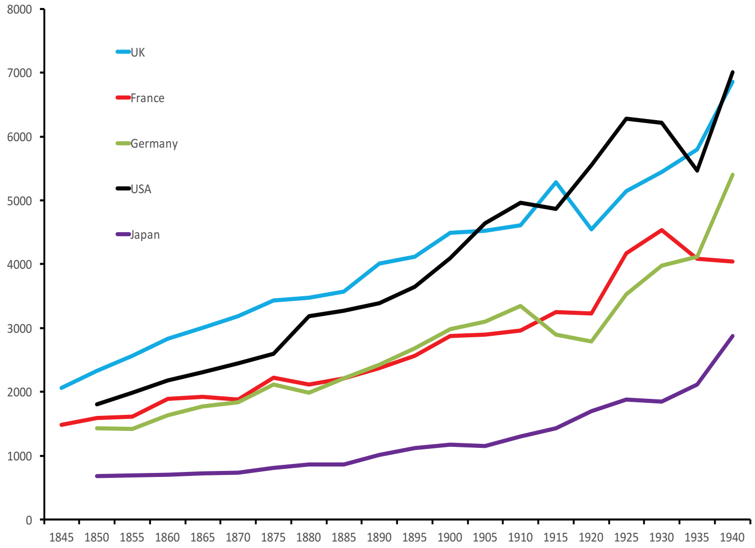
$$\frac{u'(c_2')}{u'(c_1')} = \frac{u'(c_2) - \lambda_{V,2}}{u'(c_1) - \lambda_{V,1}} < \frac{u'(c_2)}{u'(c_1)} \tag{30}$$

$$1 > \frac{\frac{u'(c_2')}{u'(c_1')}}{\frac{u'(c_2)}{u'(c_1)}} = \frac{g_{c,1}^{\sigma}}{g_{c,2}^{\sigma}}. \tag{31}$$

Conclusion

- We have identified a little-recognized stylized fact: alternating waves in global imbalances by sequential industrializations.
- We examine a few models to explain this and clarify necessary frictions.
- We propose a new model by applying the sequential industrial revolution model of Lucas (2002) to an open economy setup, with a hard-currency constraint to buy consumption goods.
- In the period when a country takes off, the country faces a severe gold constraint to limit consumption. As the country becomes sure to receive permanently higher income, it accumulates gold rapidly initially to have higher consumption in near future.
- Net external assets accumulates because this gold accumulation is likely larger than the capital inflow stemming from productivity difference. An answer to Lucas Paradox.
- Sequentially, newly industrializing countries increase their shares of world assets.

GDP per Capita (1990 Int'l USD, Maddison Project)



Net Foreign Assets and Gold Holdings (World Gold Council and Goldsmith (1985))

	Year	1850	1875	1895	1915	1930	1940	*Correlation*
UK	Net Foreign Assets	3.1	9.7	14.6	17.8	10.8	9.0	
	Official Gold Holdings	0.07	0.11	0.20	0.16	0.67	1.57	*-0.12*
	Year	1850	1880	1915				
France	Net Foreign Assets	1.7	5.1	8.5				
	Official Gold Holdings	0.00	0.16	0.66				*0.96*
	Year	1930	1940					
Germany	Net Foreign Assets	-1.3	0.9					
	Official Gold Holdings	0.28	0.06					*-1.00*
	Year	1900	1910	1930	1940			
USA	Net Foreign Assets	-1.5	-0.7	1.3	2.4			
	Official Gold Holdings	0.39	1.07	3.86	9.66			*0.94*
	Year	1915	1930	1940				
Japan	Net Foreign Assets	-2.5	1.0	0.3				
	Official Gold Holdings	0.06	0.56	0.41				*0.99*
Average Correlation								*0.35*
Average Correlation without Germany (interwar years)								*0.69*