Globalization and Synchronization of Innovation Cycles

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Introduction
Theoretical Motivation:

- How does globalization affect macro co-movements across countries?
- Most economists address this question by assuming that some *exogenous* processes drive productivity movements in each country.
- *But*, globalization (a trade cost reduction) can affect
  - productivity growth rates, as already shown by endogenous growth models
  - *synchronicity* of productivity fluctuations, as we show in an *endogenous cycle model*

Empirical Motivation:

- Countries that trade more with each other have more synchronized business cycles
  - Particularly among developed countries (EU, OECD, etc)
  - Not so between developed and developing countries
- Hard to explain this “*trade-comovement puzzle*” in models with exogenous shocks
  - Common shocks would cause synchronization *regardless* of the trade intensity
  - With country-specific shocks, more trade lead to *less* synchronization
  - Attempts to resolve it by global supply chains met limited success
- Easier (perhaps too easy) in models of endogenous fluctuations. No need to appeal to global supply chains.
**Intuition We Want to Capture**

- Two *structurally identical* countries
- Each country (in autarky) is subject to endogenous fluctuations, due to strategic complementarities in the *timing* of innovation among firms competing in the same market
- Without trade, fluctuations in the two countries are obviously *disconnected*.
- Trade integration makes firms based in different countries compete against each other and respond to an increasingly global (hence common) market environment.
- *Even with partial integration*, this causes an alignment of innovation incentives, *synchronizing* innovation activities and productivity fluctuations across countries

**What We Do:** To capture this intuition in a simplest possible manner,

A two-country model of endogenous innovation cycles with *two* building blocks
- **Judd (1985; sec.4)** Endogenous innovation cycles due to imitation lag
- **Helpman & Krugman (1985; ch.10)**, Home market effect/intra-industry trade between structurally identical countries with iceberg trade cost.

Conceptually, this is a study of *Synchronization of (Weakly) Coupled Oscillators*
The Two Building Blocks
**Judd (1985);** Dynamic Dixit-Stiglitz monopolistic competitive model; Innovators pay fixed cost to introduce a new (horizontally differentiated) variety

**Judd (Sec.2);** Innovators keep their monopoly power. Unique steady state globally stable.

*What if competitive fringes can imitate, but only with a lag?*
- Each variety sold initially at monopoly price; later at competitive price
- Impact of an innovation, initially muted, reach its full potential *with a delay*
- Past innovation discourages innovators more than contemporaneous innovation
- **Temporal clustering of innovation**, leading to aggregate fluctuations

**Judd (Sec.3); Continuous time** and monopoly lasting for $0 < T < \infty$
- *Delayed differential equation* with an infinite dimensional state space

**Judd (Sec.4); also Deneckere & Judd (1992);** Discrete time and one period monopoly
- **1D state space** (the measure of competitive varieties inherited from past innovation determines how saturated the market is)
- Expectations do not matter!
- **Unique** equilibrium path, obtained by iterating a **1D-map**
Deneckere-Judd (DJ) in a Nutshell: A Skew-Tent Map

\( n_t \): (Measure of) competitive varieties (per labor supply) inherited

\[
n_{t+1} = f(n_t) = \begin{cases} 
  f_L(n_t) & \text{if } n_t < 1 \\
  f_H(n_t) & \text{if } n_t > 1 
\end{cases}
\]

\( \delta \in (0,1) \), Survival rate of varieties due to obsolescence (or exogenous labor supply growth)

\( \theta = \left( 1 - \frac{1}{\sigma} \right)^{1-\sigma} \in (1,e) \), increasing in \( \sigma \) (EoS)

Market share of a competitive variety relative to a monopolistic variety

\( \theta - 1 > 0 \): the delayed impact of innovations

- Steady state (SS) globally stable for \( \delta(\theta - 1) < 1 \)
- Unstable SS; Converging to the unique 2-cycle from a.e. for \( \delta^2(\theta - 1) < 1 < \delta(\theta - 1) \)
- No stable cycle; Robust chaotic attractor for \( \delta^2(\theta - 1) > 1 \)
**Helpman & Krugman (1985; Ch.10):**

Trade in horizontally differentiated (Dixit-Stiglitz) goods with *iceberg trade costs* between two *structurally identical* countries; only their sizes may be different.

- **In autarky**, the number of firms based in each country is proportional to its size.
- **As trade costs fall,**
  - Differentiated goods produced in the two countries mutually penetrate each other’s home markets (Two-way flows of goods).
  - Firm distribution becomes increasingly skewed toward the larger country (*Home Market Effect and its Magnification*)

**Two Parameters:** \( s_1 \) & \( \rho \)

\[ s_1 = 1 - s_2 \in [1/2,1) \]:

Bigger country’s share in market size

\[ \rho \equiv (\tau)^{1-\sigma} \in [0,1) : \text{Degree of Globalization: inversely related to the iceberg cost, } 1 < \tau \leq \infty \]

\( s_n \): Bigger country’s share in firm distribution
A Two-Country Model of Endogenous Innovation Cycles
Our Main Results: By combining DJ (1992) and HK (1985):

- **2D state space:** (Measures of competitive varieties in the two countries)

- Unique equilibrium path obtained by a **2D map** with **4 parameters**: $\theta$, $\delta$, $s_1$, $\rho$
  
  - One unit of competitive varieties = $\theta$ (> 1) units of monopolistic varieties
  - One unit of foreign varieties = $\rho$ (< 1) unit of domestic varieties

- For $\delta^2(\theta - 1) < 1 < \delta(\theta - 1)$, either **Synchronized 2-cycle** or **Asynchronized 2-cycle**

- **Autarky** ($\rho = 0$): Dynamics of the two countries **decoupled**. Whether synchronized or not depends entirely on how you draw the initial condition

- **As trade costs fall** (a higher $\rho$), they become more **synchronized**:
  - **Basin of attraction** for Asynchronized 2-cycle shrinks & disappears
  - **Basin of attraction** for Synchronized 2-cycle expands & covers the full state space

**Fully synchronized with partial trade integration** ($\rho < 1$)
  - At a smaller $\rho$ (i.e., at larger trade cost) with more unequal country sizes
  - Even a small size difference makes a big difference
  - The larger country sets the tempo of global innovation cycles, with the smaller country adjusting its rhythm
2D Dynamical System; \( n_{t+1} = F(n_t) \) with \( n_t = (n_{1t}, n_{2t}) \in \mathbb{R}_+^2 \); 
\((0 < \delta < 1; 1 < \theta < \epsilon; 0 \leq \rho < 1; 1/2 \leq s_1 < 1)\)

\[
\begin{align*}
  n_{1t+1} &= \delta \left( \theta s_1(\rho) + (1-\theta)n_{1t} \right) & \text{if } n_t \in D_{LL} = \{(n_1, n_2) \in \mathbb{R}_+^2 | n_j \leq s_j(\rho) \} \\
  n_{2t+1} &= \delta \left( \theta s_2(\rho) + (1-\theta)n_{2t} \right)
\end{align*}
\]

\[
\begin{align*}
  n_{1t+1} &= \delta n_{1t} & \text{if } n_t \in D_{HH} = \{(n_1, n_2) \in \mathbb{R}_+^2 | n_j \geq h_j(n_k) \} \\
  n_{2t+1} &= \delta n_{2t}
\end{align*}
\]

\[
\begin{align*}
  n_{1t+1} &= \delta \left( \theta h_2(n_{1t}) + (1-\theta)n_{2t} \right) & \text{if } n_t \in D_{HL} = \{(n_1, n_2) \in \mathbb{R}_+^2 | n_1 \geq s_1(\rho); n_2 \leq h_2(n_1) \} \\
  n_{2t+1} &= \delta \left( \theta h_1(n_{2t}) + (1-\theta)n_{1t} \right) & \text{if } n_t \in D_{LH} = \{(n_1, n_2) \in \mathbb{R}_+^2 | n_1 \leq h_1(n_2); n_2 \geq s_2(\rho) \} \\
  n_{2t+1} &= \delta n_{2t}
\end{align*}
\]

where \( s_1(\rho) = 1 - s_2(\rho) = \min \left\{ \frac{s_1 - \rho s_2}{1-\rho}, 1 \right\} \), \( 0.5 \leq s_1 = 1 - s_2 < 1 \);

\[
h_j(n_k) > 0 \text{ defined implicitly by } \frac{s_j}{h_j(n_k) + \rho n_k} + \frac{s_k}{h_j(n_k) + n_k / \rho} = 1.
\]
State Space & Four Domains for the Symmetric Case: $0 < \rho < s_2 / s_1 = 1$

$D_{LL}$

$D_{HL}$

$D_{HH}$

$D_{LH}$

Innovation Active in 1

Innovation Active in Both

Innovation Active in 2

$\rho = 0$

$\rho = 1$

$\rho = 0$

$\rho = 1$

$O$
State Space & Four Domains for the Asymmetric Case: $0 < \rho < s_2 / s_1 < 1$

$\rho s_2 + \frac{s_1}{\rho}$

$n_{1t} = h_1(n_{2t})$

$n_{1t} = \frac{s_1(\rho)}{s_2(\rho)}$

$\frac{n_{1t}}{n_{2t}} = \frac{s_1(\rho)}{s_2(\rho)}$

$n_{2t} = h_2(n_{1t})$

$D_{HH}$

$D_{HL}$

$D_{LL}$

$D_{LH}$

Innovation Active in 1

Innovation Active in Both

Innovation Active in 2

Innovation Active in 2
Synchronized vs. Asynchronized 2-Cycles in Autarky: \( \rho = 0; \ \delta(\theta - 1) > 1 > \delta^2(\theta - 1), \)

As a 2D-map, this system has

- **An unstable steady state:** \( (n_1^*, n_2^*) \)

- **A pair of stable 2-cycles**
  - **Synchronized:** \( (n_{1L}^*, n_{2L}^*) \leftrightarrow (n_{1H}^*, n_{2H}^*) \),
    
    *Basin of Attraction* in red.
  
  - **Asynchronized:** \( (n_{1L}^*, n_{2H}^*) \leftrightarrow (n_{1H}^*, n_{2L}^*) \),
    
    *Basin of Attraction* in white.

- **A pair of saddle 2-cycles:**
  
  \( (n_{1L}^*, n_2^*) \leftrightarrow (n_{1H}^*, n_2^*) \); \( (n_1^*, n_{2H}^*) \leftrightarrow (n_1^*, n_{2L}^*) \)
Symmetric Synchronized & Asynchronized 2-Cycles: $s_1 = 0.5; \theta = 2.5; \delta = 0.75$

Red (Sync. 2-cycle) becomes dominant.

Sym. Async. 2-cycle becomes a node at $\rho = .817867$, a saddle at $\rho = .833323$. 
Asymmetric Synchronized & Asynchronized 2-Cycles  $s_1 = 0.7, \theta = 2.5; \delta = 0.75$

By $\rho = .165$, infinitely many Red islands appear inside White.

By $\rho = .19$, the stable asynchronized 2-cycle collides with its basin boundary and disappears, leaving the **Synchronized 2-cycle as the unique attractor**.
Three Effects of Globalization:

Home Market Effect

Productivity Gains

Synchronization

\[ s_1 = 0.7 \quad \delta = 0.75 \quad \theta = 2.5 \quad \rho = 0.2 \]

\[ s_1 = 0.7 \quad \delta = 0.75 \quad \theta = 2.5 \quad \rho = 0.3 \]

\[ z_1(t+1)/z_1(t) \quad z_2(t+1)/z_2(t) \]
Concluding Remarks
Summary:
- A hybrid of Judd’s (1985; Sec.4) innovation cycles based on imitation lag and Helpman-Krugman (1985) home market effect/intra-industry trade with iceberg cost
- 1st two-country model of endogenous fluctuations
- Adding endogenous sources of fluctuations helps to understand “the trade-comovement puzzle.”

Next Steps:
- **Different Models of Endogenous Innovation Cycles:**
  - *My conjecture:* Globalization should cause synchronization as long as it causes innovators based in different countries to operate in a common market environment.
  - The assumption of structural similarity seems crucial.

What if two countries are structurally dissimilar?
- **Different Models of Trade:** For example,
  - What if the two countries become vertically specialized?; e.g., global supply chains
  - Two Industries: **Upstream & Downstream,** each produces DS composite as in DJ.
  - One country has comparative advantage in U; the other in D
  - *My conjecture:* Globalization leads to an asynchronization

Empirically consistent, as the evidence for the synchronizing effect of trade is strong among developed countries, but *not so* btw developed and developing countries