Globalization and Synchronization of Innovation Cycles

Kiminori Matsuyama, *Northwestern University, USA*
Iryna Sushko, *Institute of Mathematics, National Academy of Science of Ukraine*
Laura Gardini, *University of Urbino, Italy*

International Trade and Macroeconomics Program
NBER Summer Institute
July 14, 2016

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 puzzl***e" 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

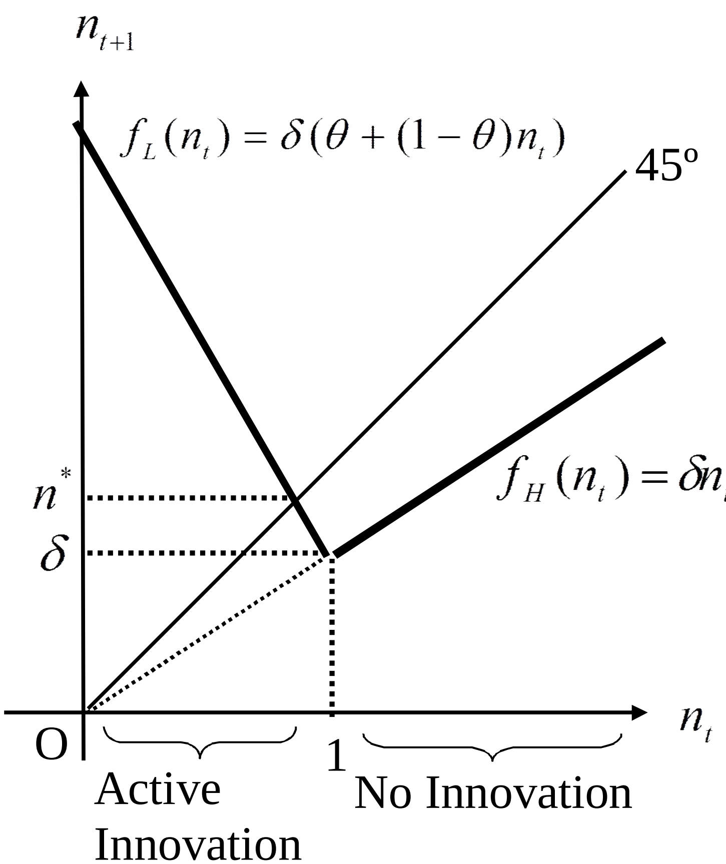
Judd (Sec.4); *also* ***Deneckere & Judd (1992):*** *Discrete time* and *one period monopoly*

- **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

$$n_{t+1} = f(n_t) \equiv \begin{cases} f_L(n_t) \equiv \delta\big(\theta + (1-\theta)n_t\big) & \text{if } n_t < 1 \\ f_H(n_t) \equiv \delta n_t & \text{if } n_t > 1 \end{cases}$$



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

$\theta \equiv \left(1 - \frac{1}{\sigma}\right)^{1-\sigma} \in (1, e)$, increasing in σ (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.

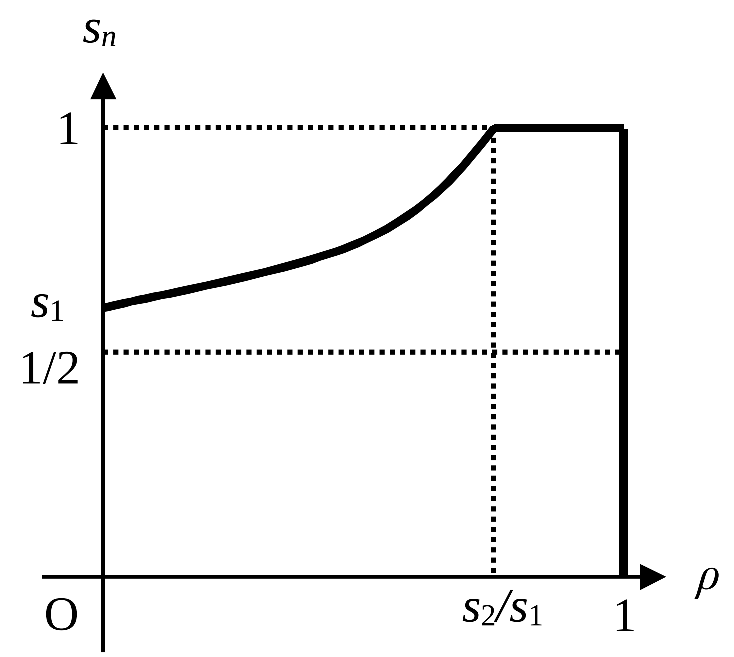
- **In autarky**, the number of firms based in each country is proportional to its size.
- **As trade costs fall,**
  - Differentiated goods produced in the two countries mutually penetrate each other's home markets (Two-way flows of goods).
  - Firm distribution becomes increasingly skewed toward the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

Two Parameters: s_1 & ρ

$s_1 = 1 - s_2 \in [1/2, 1)$:
Bigger country's share in market size

$\rho \equiv (\tau)^{1-\sigma} \in [0,1)$: 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 = θ (> 1) units of monopolistic varieties
  One unit of foreign varieties = ρ (< 1) unit of domestic varieties

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

- **Autarky (**ρ = 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 ρ), 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 (**ρ < 1)**
  - At a smaller ρ (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 $n_t \equiv (n_{1t}, n_{2t}) \in R_+^2$**;**
$(0 < \delta < 1;\ 1 < \theta < e;\ 0 \le \rho < 1;\ 1/2 \le s_1 < 1)$

$$n_{1t+1} = \delta(\theta s_1(\rho) + (1-\theta)n_{1t}) \qquad \text{if } n_t \in D_{LL} \equiv \{(n_1, n_2) \in R_+^2 \mid n_j \le s_j(\rho)\}$$
$$n_{2t+1} = \delta(\theta s_2(\rho) + (1-\theta)n_{2t})$$

$$n_{1t+1} = \delta n_{1t} \qquad \text{if } n_t \in D_{HH} \equiv \{(n_1, n_2) \in R_+^2 \mid n_j \ge h_j(n_k)\}$$
$$n_{2t+1} = \delta n_{2t}$$

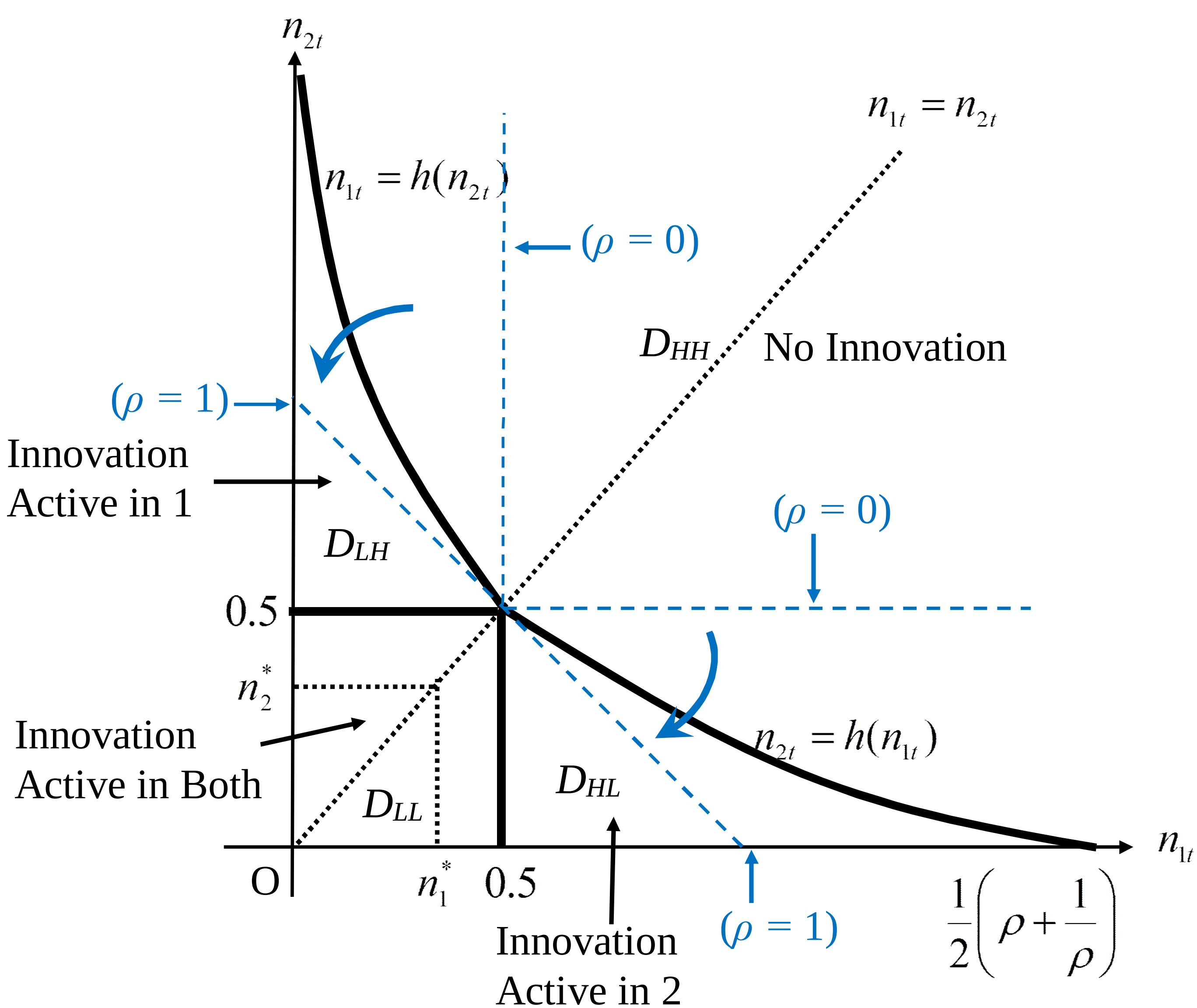
$$n_{1t+1} = \delta n_{1t} \qquad \text{if } n_t \in D_{HL} \equiv \{(n_1, n_2) \in R_+^2 \mid n_1 \ge s_1(\rho); n_2 \le h_2(n_1)\}$$
$$n_{2t+1} = \delta(\theta h_2(n_{1t}) + (1-\theta)n_{2t})$$

$$n_{1t+1} = \delta(\theta h_1(n_{2t}) + (1-\theta)n_{1t}) \qquad \text{if } n_t \in D_{LH} \equiv \{(n_1, n_2) \in R_+^2 \mid n_1 \le h_1(n_2); n_2 \ge s_2(\rho)\}$$
$$n_{2t+1} = \delta n_{2t}$$

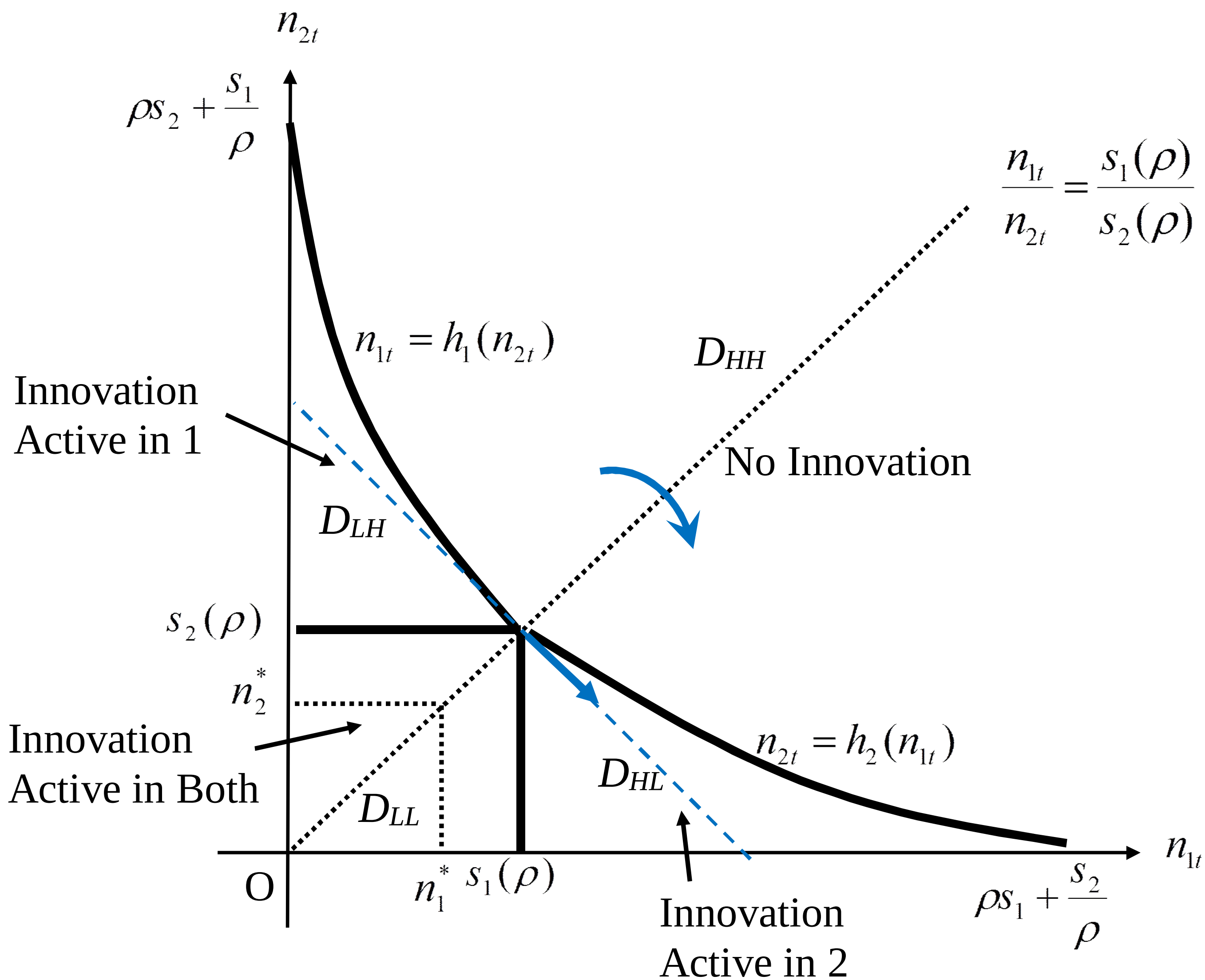
where $s_1(\rho) = 1 - s_2(\rho) = \min\left\{\frac{s_1 - \rho s_2}{1-\rho}, 1\right\}$, $\quad 0.5 \le s_1 = 1 - s_2 < 1;$

$h_j(n_k) > 0$ defined implicitly by $\dfrac{s_j}{h_j(n_k) + \rho n_k} + \dfrac{s_k}{h_j(n_k) + n_k/\rho} = 1.$

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



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



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

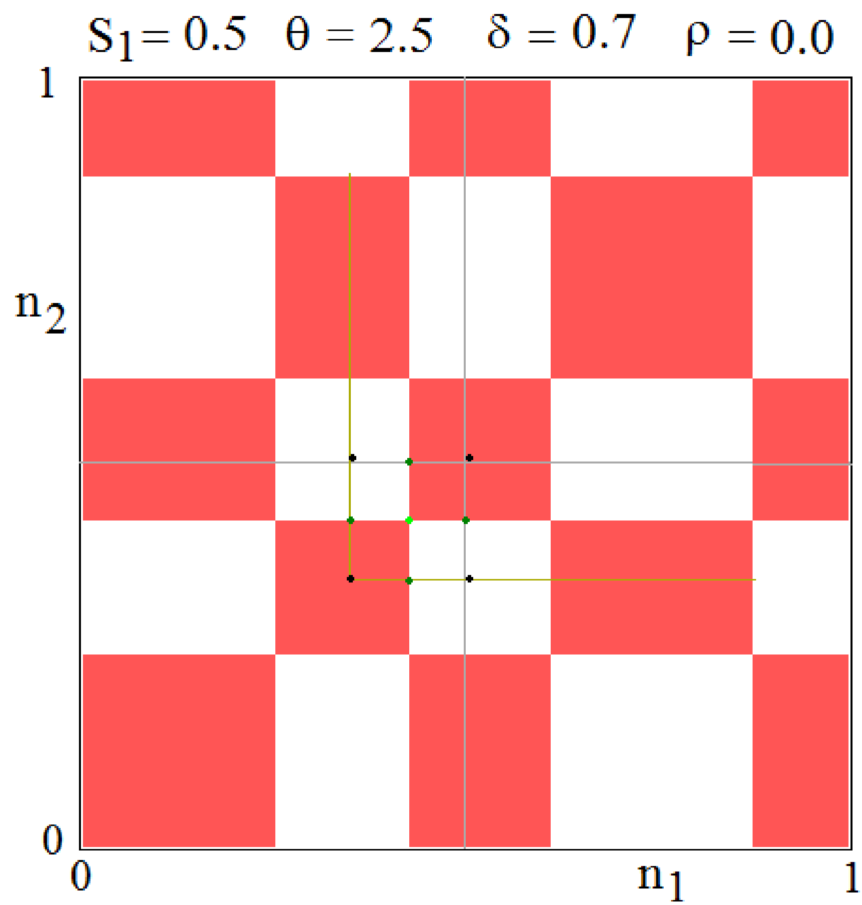
As a 2D-map, this system has

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

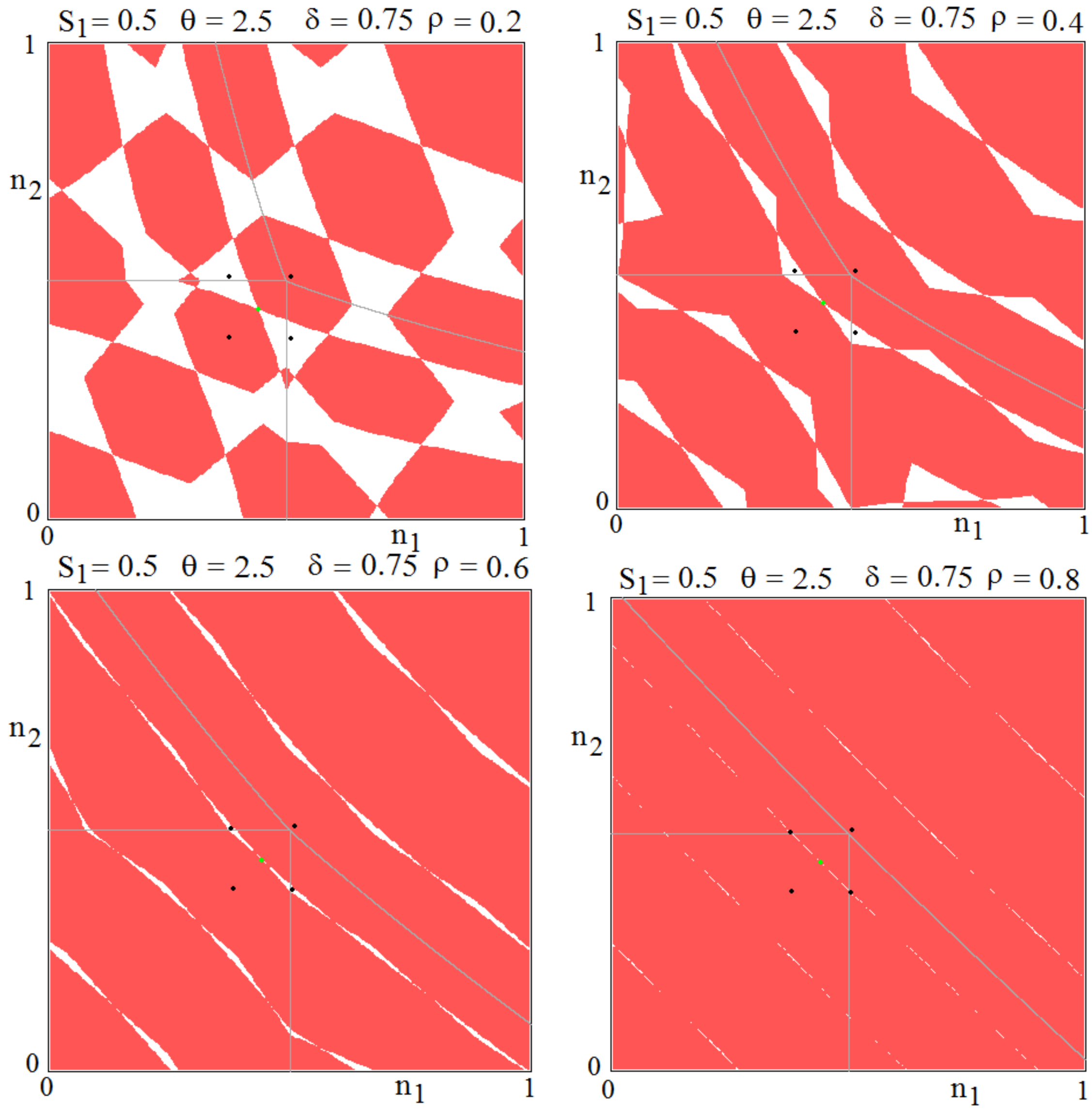
- **A pair of stable 2-cycles**
  - **Synchronized;** $(n_{1L}^*, n_{2L}^*) \leftrightarrow (n_{1H}^*, n_{2H}^*)$, *Basin of Attraction* in red.
  - **Asynchronized;** $(n_{1L}^*, n_{2H}^*) \leftrightarrow (n_{1H}^*, n_{2L}^*)$, *Basin of Attraction* in white

- **A pair of saddle 2-cycles:**

$(n_{1L}^*, n_2^*) \leftrightarrow (n_{1H}^*, n_2^*)$; $(n_1^*, n_{2H}^*) \leftrightarrow (n_1^*, n_{2L}^*)$



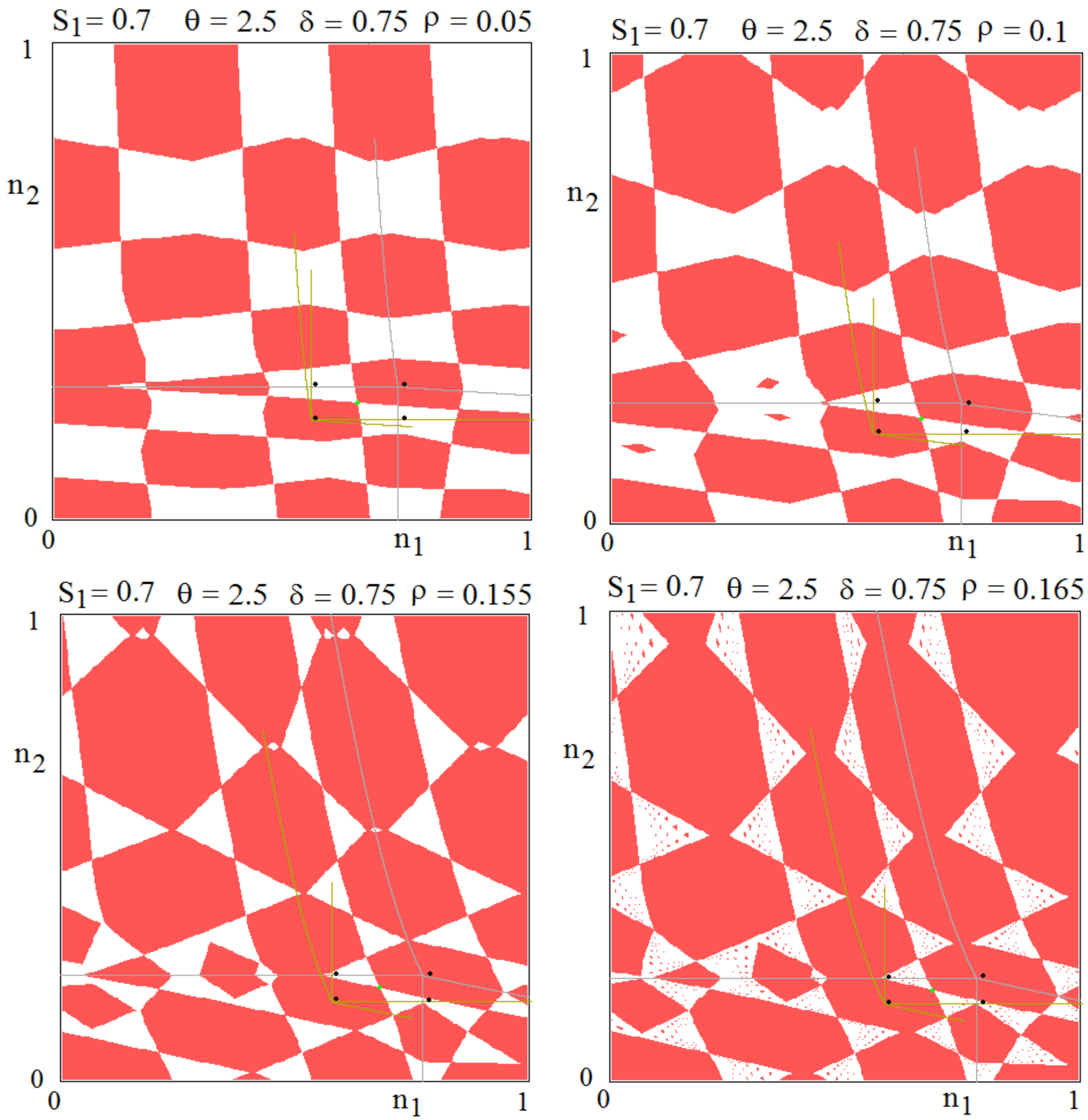
Symmetric Synchronized & Asynchronized 2-Cycles: $s_1 = 0.5$; $\theta = 2.5$; $\delta = 0.75$



Red (Sync. 2-cycle) becomes dominant.

Sym. Async. 2-cycle becomes
a node at ρ = .817867,
a saddle at ρ = .833323.

Asymmetric Synchronized & Asynchronized 2-Cycles $s_1 = 0.7$, $\theta = 2.5$; $\delta = 0.75$



By ρ = .165, infinitely many Red islands appear inside White.

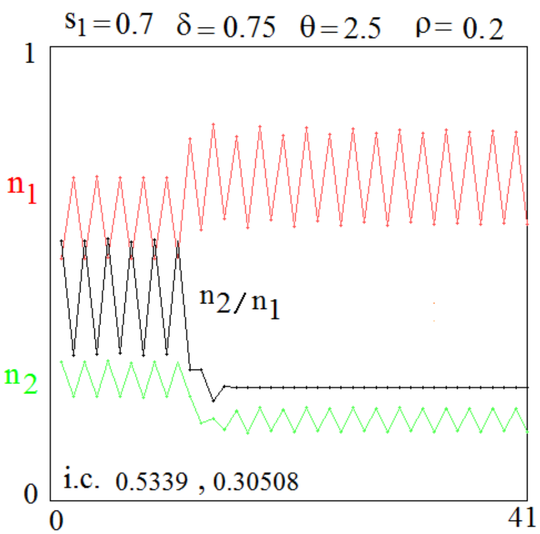
By ρ =.19, the stable asynchronized 2-cycle collides with its basin boundary and disappears, leaving **the Synchronized 2-cycle as the unique attractor**.

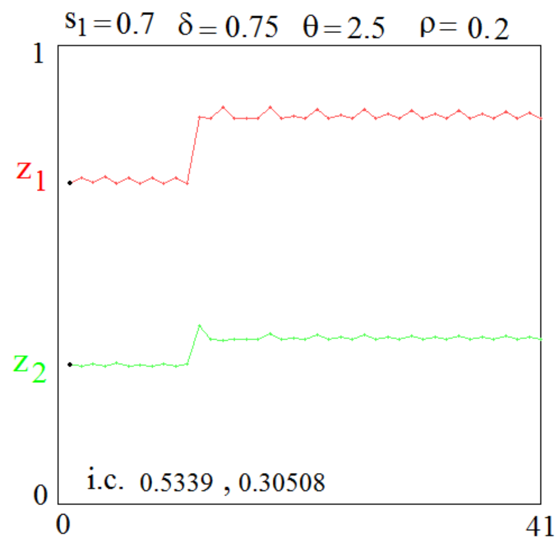
Three Effects of Globalization:

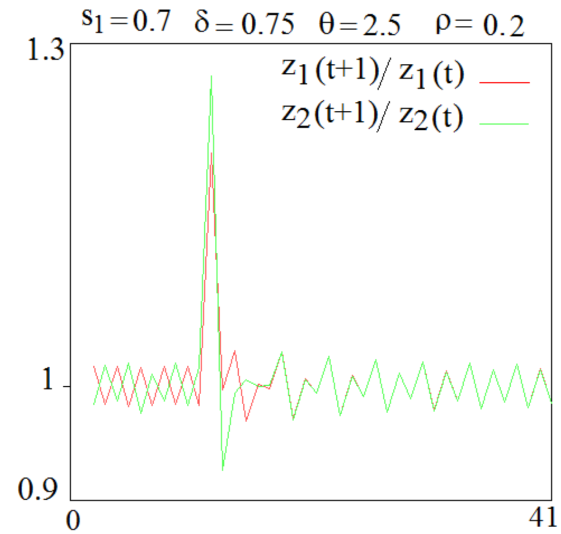
Home Market Effect

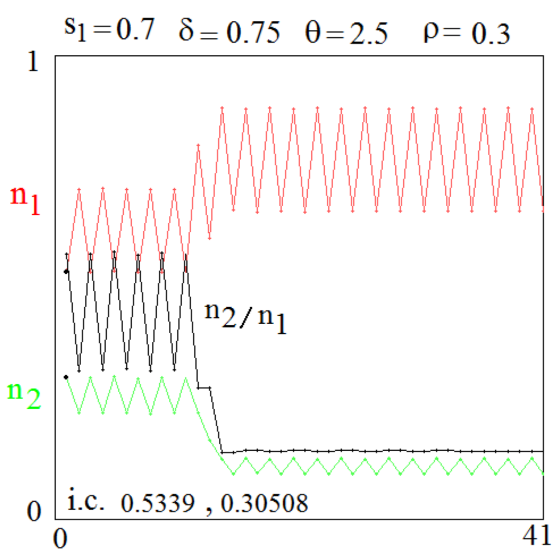
Productivity Gains

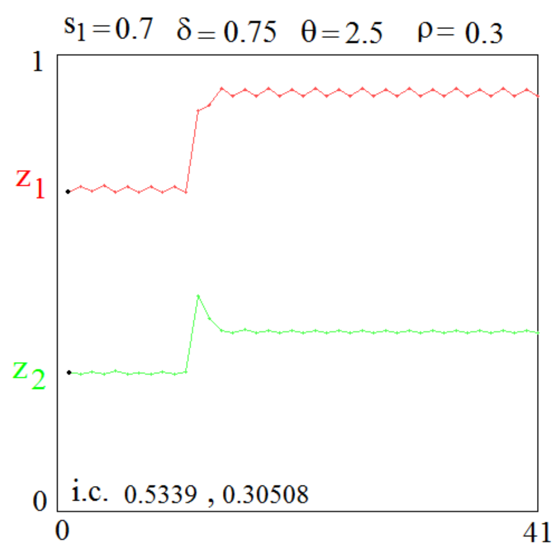
Synchronization

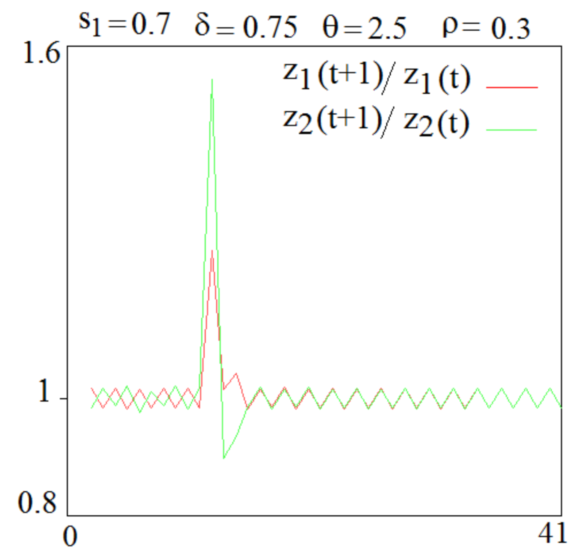












Concluding Remarks

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