Globalization and Synchronization of Innovation Cycles

By

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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
- Difficult 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; also awkward
- Easier 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.
- Strategic complementarities in the ***timing*** of innovation across countries
- ***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 manner, we develop a 2-country model of endogenous innovation cycles with *two* building blocks

Judd (1985; sec.4), also Deneckere & Judd (1992), for endogenous innovation cycles
Unique equilibrium path exhibits fluctuation; which can be obtained by iterating a 1D-noninvertible PWL map, commonly called “a skew-tent map”

Helpman & Krugman (1985; ch.10) for intra-industry trade with iceberg trade cost, which is used as a *coupling* parameter.

Conceptually, this is a study of ***Synchronization of (Weakly) Coupled Oscillators***

Synchronization of (Weakly) Coupled Oscillators

Natural Science: A Major Topic. Thousands of examples: Just to name a few,

- Christiaan Huygens' pendulum clocks
- The Moon's rotation and revolution
- London Millennium Bridge

Also, search videos "Synchronization of Metronomes" on Youtube!

But, we cannot use the existing studies of "coupled skew-tent maps."

- Without microfoundations, we cannot give structural interpretation to their "synchronizing forces" nor "coupling" parameters.
- Subject to the Lucas critique. In GE, innovation incentive might change with trade.

Economics: None? To the best of our knowledge, this is

- First 2-country, dynamic GE model of endogenous fluctuations
- Our companion piece, "Interdependent Innovation Cycles"
  - Two-sector, closed economy
  - Each sector produces a Dixit-Stiglitz composite, as in DJ
  - CES preferences over the two composites
  - Fluctuations in the two sectors are decoupled for Cobb-Douglas
  - Synchronized (asynchronized) if EoS increases (decreases) from one.

The Two Building Blocks

Judd (1985); Dynamic Dixit-Stiglitz monopolistic competitive model; Innovators pay fixed cost to introduce a new (horizontally differentiated) variety
Judd (1985; Sec.2); They keep their monopoly power. Unique steady state globally stable due to *intertemporal smoothing* of innovation activities

Main Question: What if they have monopoly for a limited time?

- 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 (1985; Sec.3); *Continuous time* and monopoly lasting for $0 < T < \infty$

- *Delayed differential equation* with an infinite D state space
- For $T > T_c > 0$, the economy oscillates between the phases of active innovation and of no innovation along any equilibrium path for almost all initial conditions.

Judd (1985; Sec.4); *also* ***Deneckere & Judd (1992; DJ for short)***

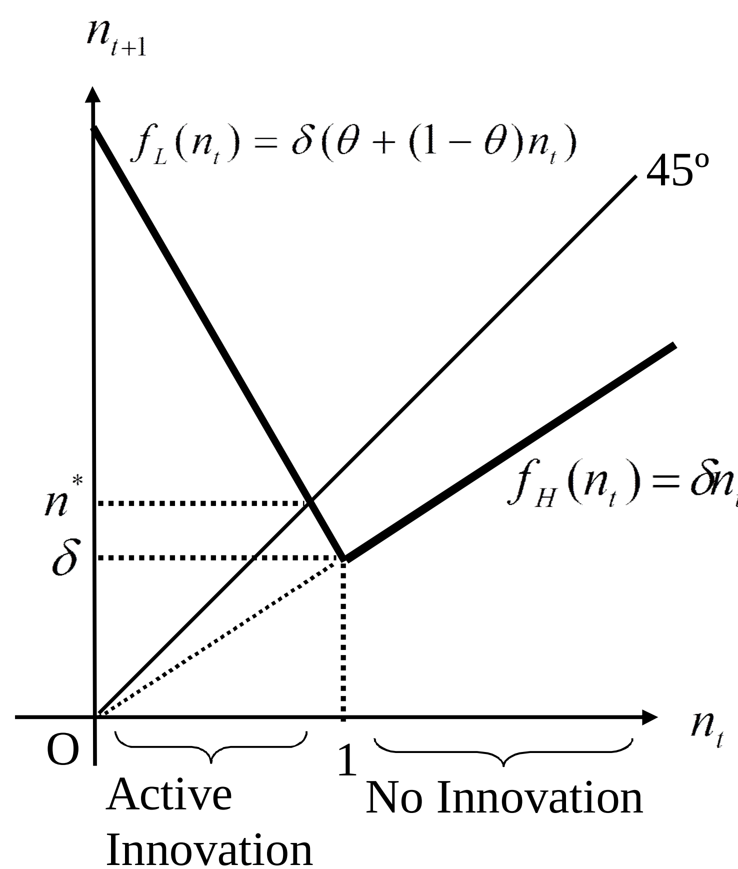
- *Discrete time* and *one period monopoly* for analytical tractability
- **1D state space** (the measure of competitive varieties inherited from past innovation determines how saturated the market is)
- Unique equilibrium path generated by a **1D PWL noninvertible (i.e., skew-tent) map**
- When the unique steady state is unstable, converging to a ***2-cycle*** or to a *chaotic attractor* from almost all initial conditions.

Deneckere-Judd (DJ) in a Nutshell

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

Noninvertible PWL (Skew Tent) map

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



$\delta \in (0,1)$, 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)

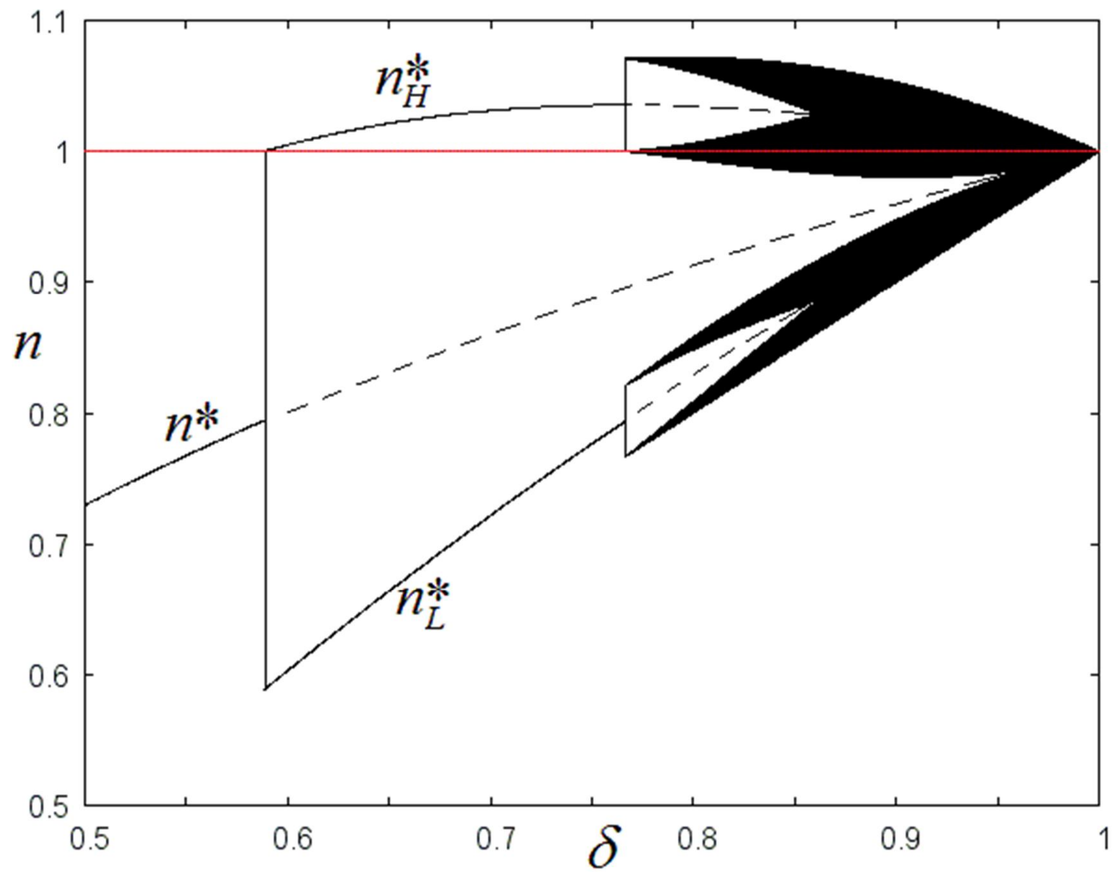
Market share of a competitive variety relative to a monopolistic variety

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

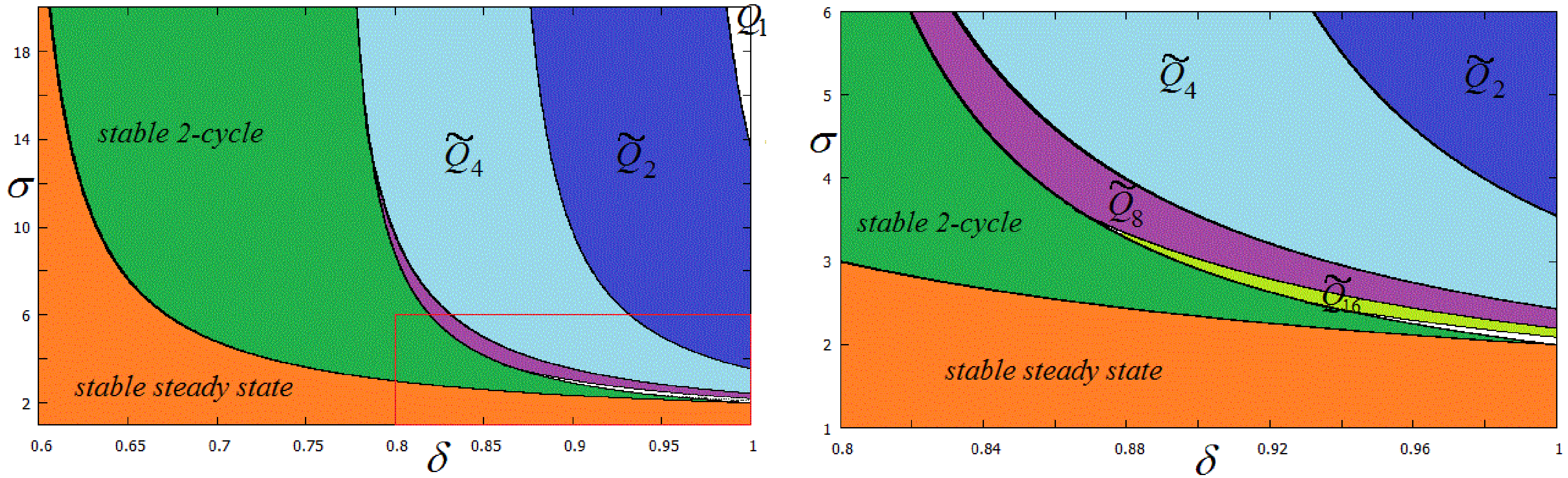
A *Unique* Attractor:

- Stable steady state for $\delta(\theta - 1) < 1$
- Stable 2-cycle for $\delta^2(\theta - 1) < 1 < \delta(\theta - 1)$
- Robust chaotic attractor (of various types) for $\delta^2(\theta - 1) > 1$

Effects of a higher *δ*



Bifurcation diagram in the (σ, δ)-plane and its magnification



Endogenous fluctuations with
a higher σ (more substitutable, strong incentive to avoid competition)
a higher δ (more past innovation survives to crowd out current innovation).

We focus on **the stable 2-cycle case**, $\delta^2(\theta-1)<1<\delta(\theta-1)$.

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.

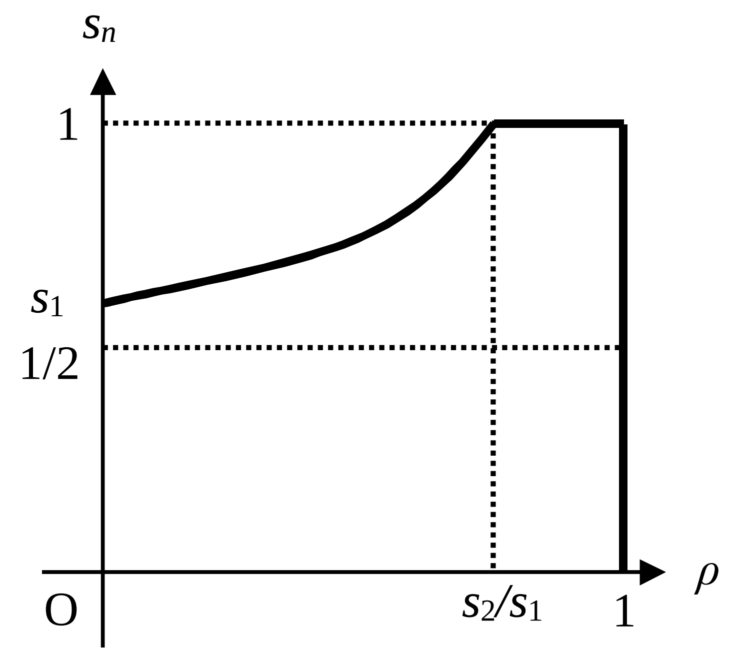
- **In autarky**, the number of firms based in each country is proportional to its size.
- **As trade costs fall,**
  - Differentiated goods produced in the two countries mutually penetrate each other's home markets (Two-way flows of goods).
  - Firm distribution becomes increasingly skewed toward the 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 iterating a **2D-PWS, noninvertible map** with ***four parameters***: θ & δ & s_1 & ρ
  One unit of competitive varieties = θ (> 1) units of monopolistic varieties
  One unit of foreign varieties = ρ (< 1) unit of domestic varieties

- **In autarky (**$\rho = 0$**),** the dynamics of the two are **decoupled.** Whether they converge to synchronized or asynchronized 2-cycles depends on how you draw the initial condition

- **As trade costs fall** (a higher ρ), they become more **synchronized**:
  - *Basin of attraction* for asynchronized 2-cycles ***shrinks*** and ***disappears***
  - *Basin of attraction* for synchronized 2-cycles ***expands.***

Full synchronization occurs with partial trade integration (i.e., $\rho < 1$)

- Fully synchronized at a larger trade cost if country sizes are more unequal
- Even a small size difference speeds up synchronization significantly
- 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 < δ < 1; 1 < θ < e; 0 ≤ ρ < 1; 1/2 ≤ s_1 < 1)

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

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

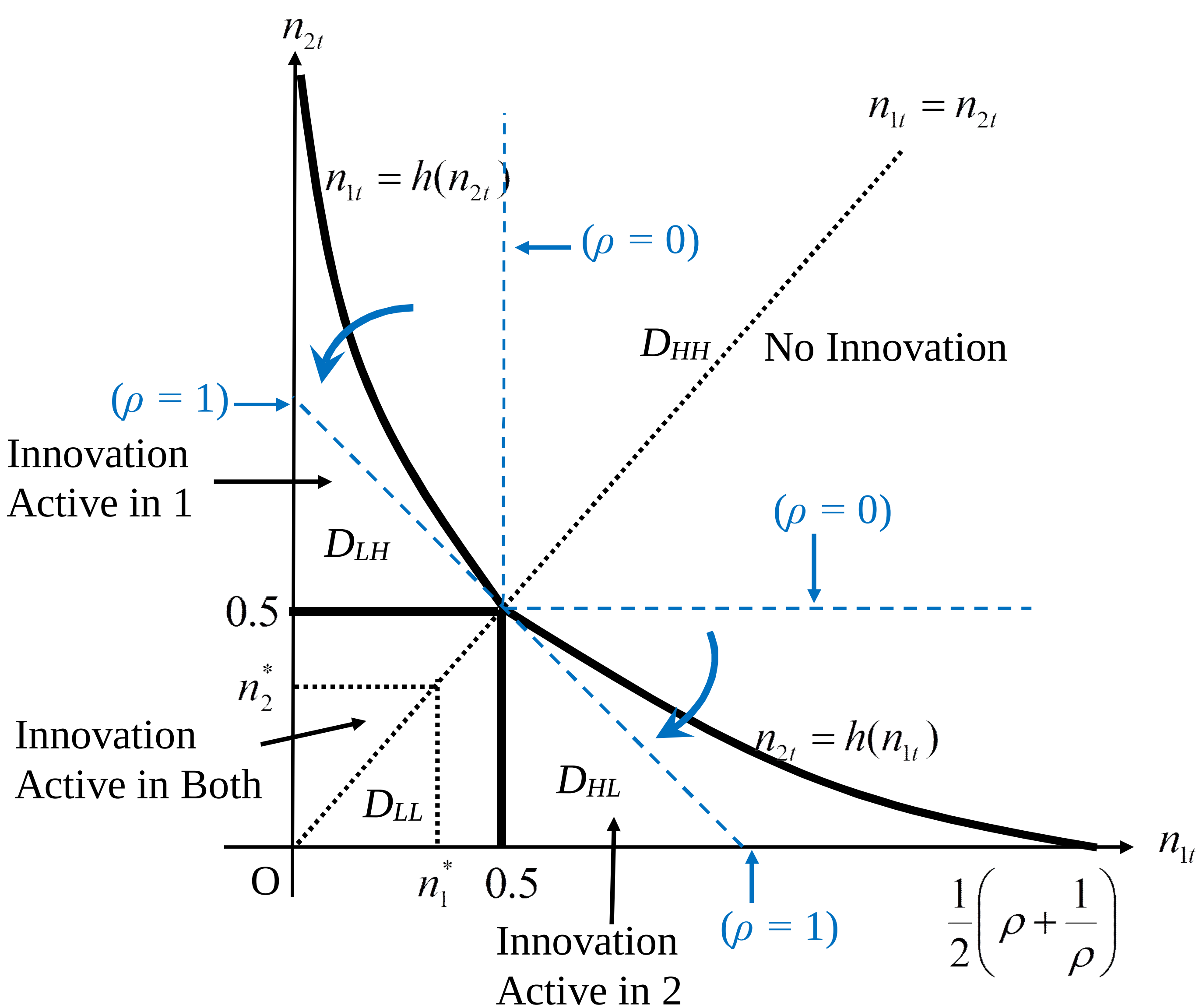
$$n_{1t+1} = \delta n_{1t} \qquad \text{if } n_t \in D_{HL} \equiv \{(n_1, n_2) \in R_+^2 \mid n_1 \ge s_1(\rho); n_2 \le h_2(n_1)\}$$
$$n_{2t+1} = \delta(\theta h_2(n_{1t}) + (1-\theta)n_{2t})$$

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

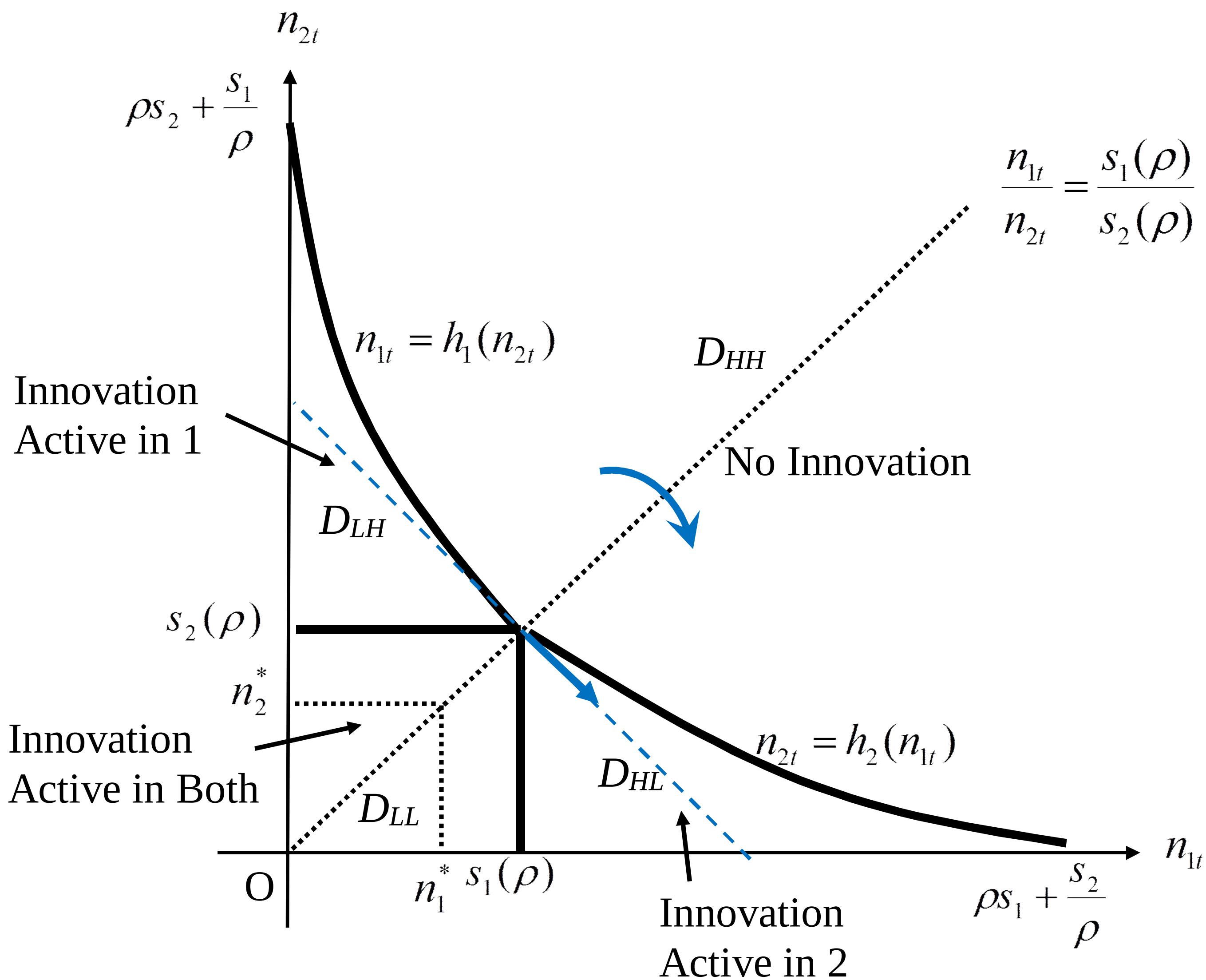
where $s_1(\rho) = 1 - s_2(\rho) = \min\left\{\frac{s_1 - \rho s_2}{1-\rho}, 1\right\}$, $\quad 0.5 \le s_1 = 1 - s_2 < 1$;

$h_j(n_k) > 0$ 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: $\rho = 0;\ \delta(\theta - 1) > 1 > \delta^2(\theta - 1)$,

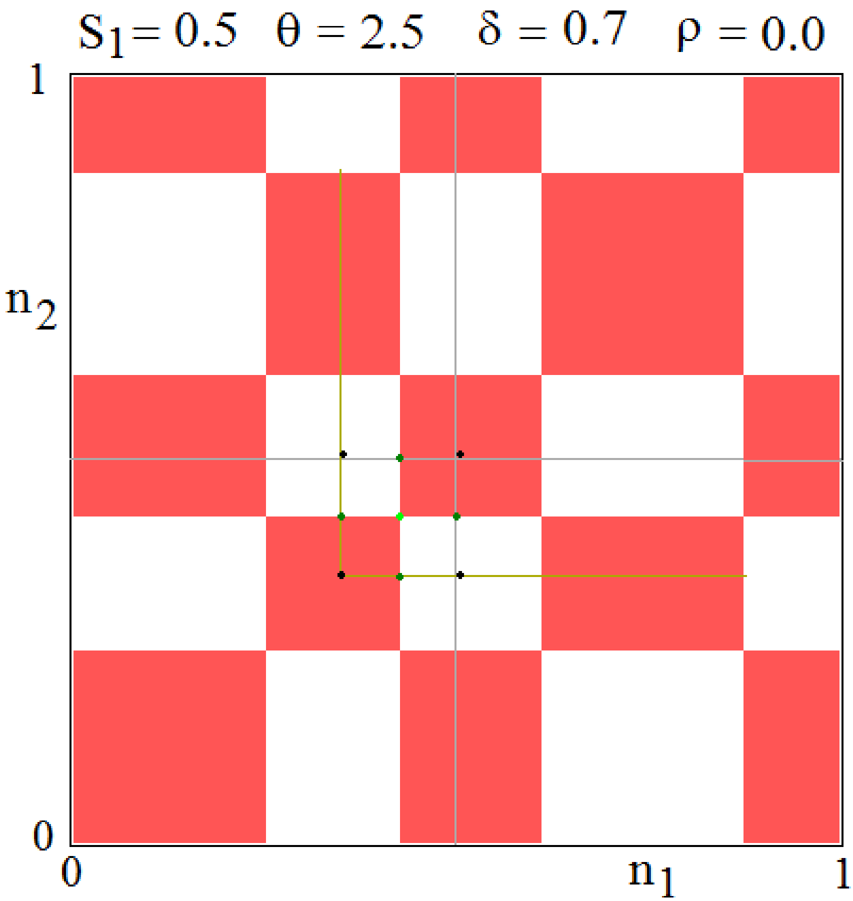
As a 2D-map, this system has

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

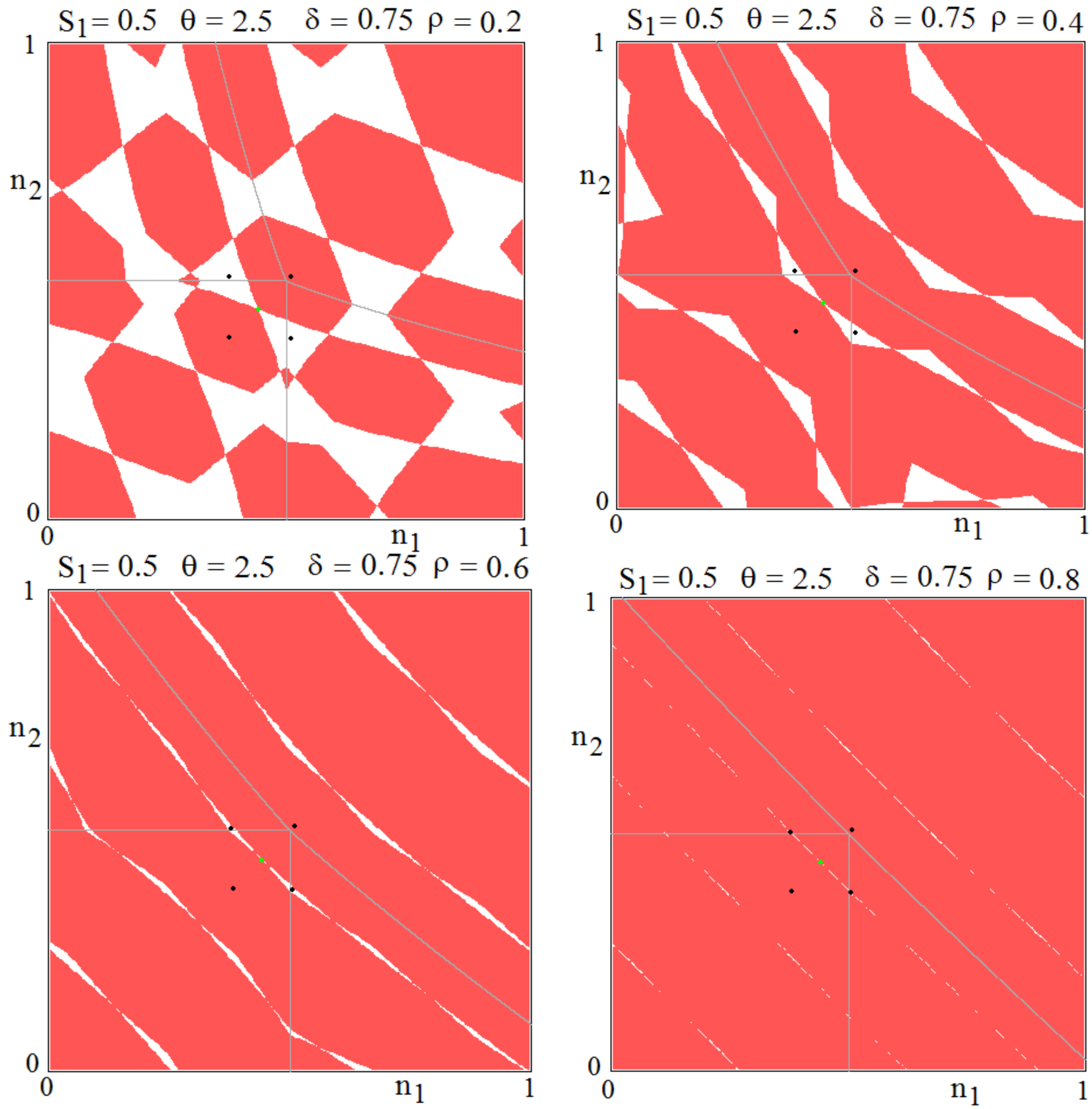
- **A pair of stable 2-cycles**
  - **Synchronized;** $(n_{1L}^*, n_{2L}^*) \leftrightarrow (n_{1H}^*, n_{2H}^*)$, *Basin of Attraction* in red.
  - **Asynchronized;** $(n_{1L}^*, n_{2H}^*) \leftrightarrow (n_{1H}^*, n_{2L}^*)$, *Basin of Attraction* in white

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

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



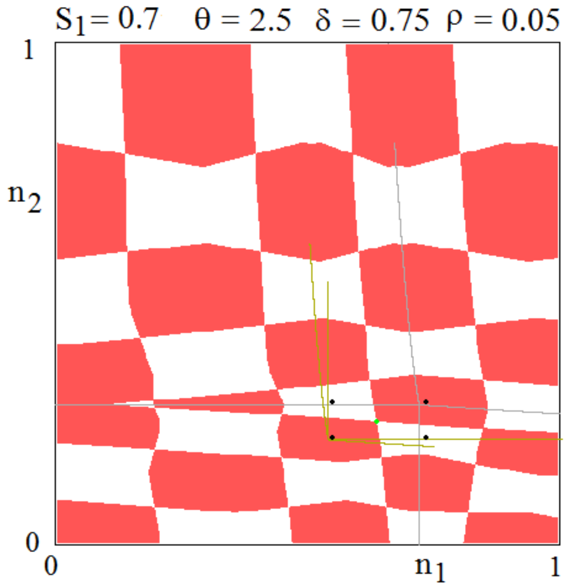
Symmetric Synchronized & Asynchronized 2-Cycles: $s_1 = 0.5$; $\theta = 2.5$; $\delta = 0.75$

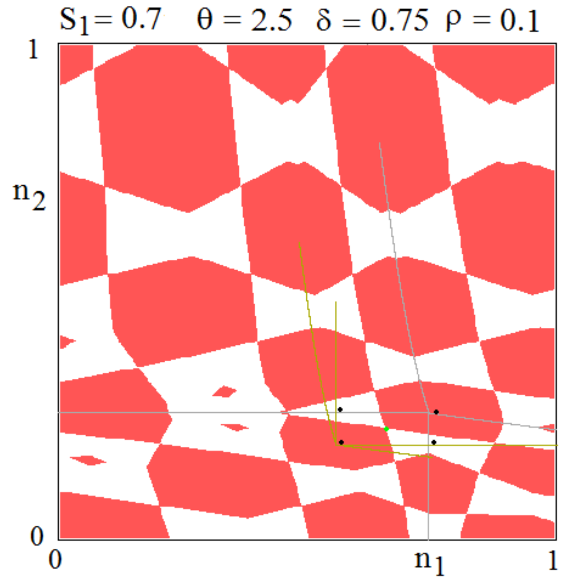


Red (Sync. 2-cycle) becomes dominant.

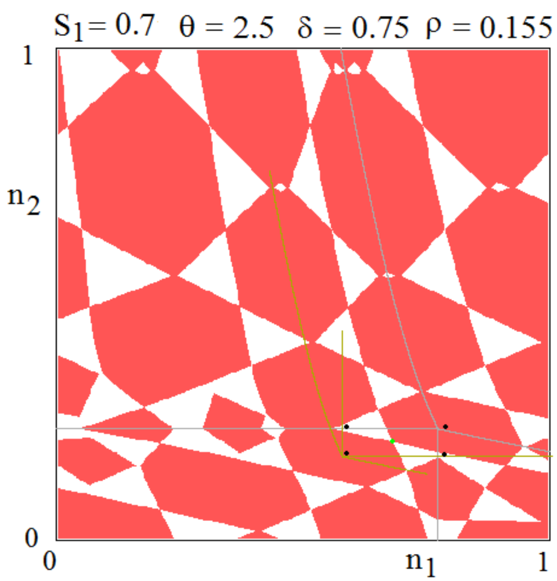
Sym. Async. 2-cycle becomes
a node at $\rho = .817867$,
a saddle at $\rho = .833323$.

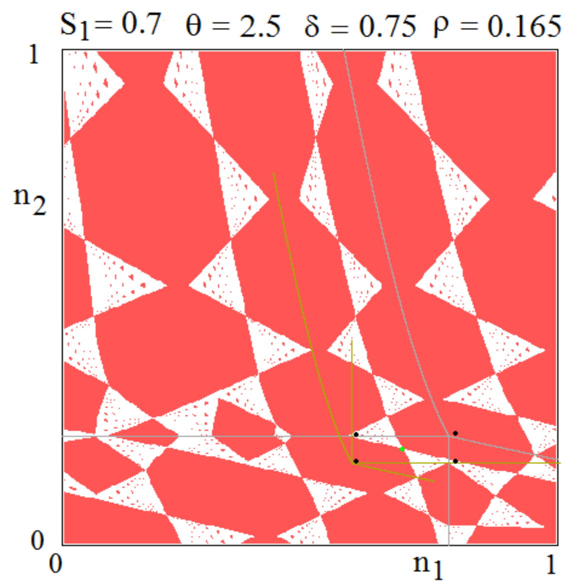
Asymmetric Synchronized & Asynchronized 2-Cycles $s_1 = 0.7$, $\theta = 2.5$; $\delta = 0.75$





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



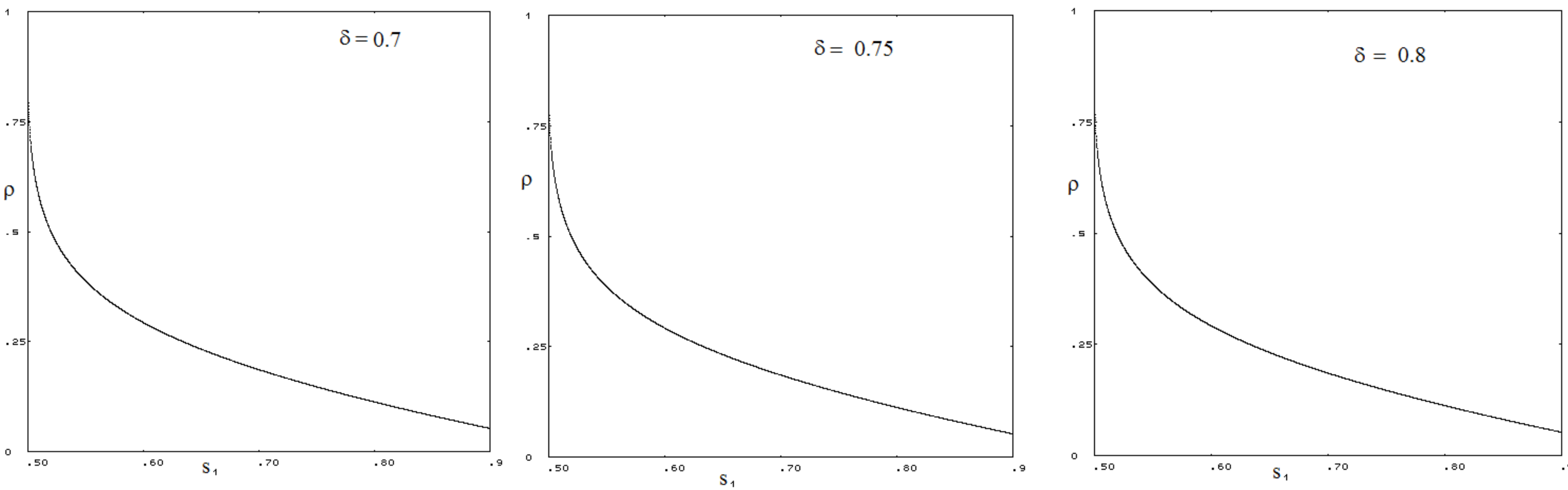


By ρ =.19, the stable asynchronized 2-cycle collides with its basin boundary and disappears, leaving **the Synchronized 2-cycle as the unique attractor**.

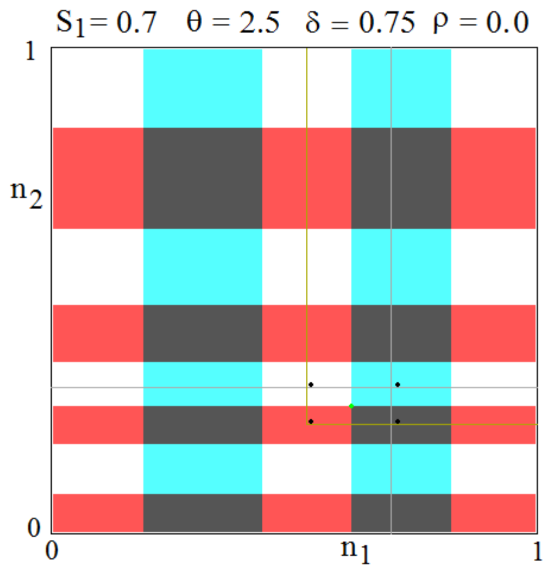
A Smaller Reduction in Trade Costs Synchronizes Innovation Cycles with Country Size Asymmetries

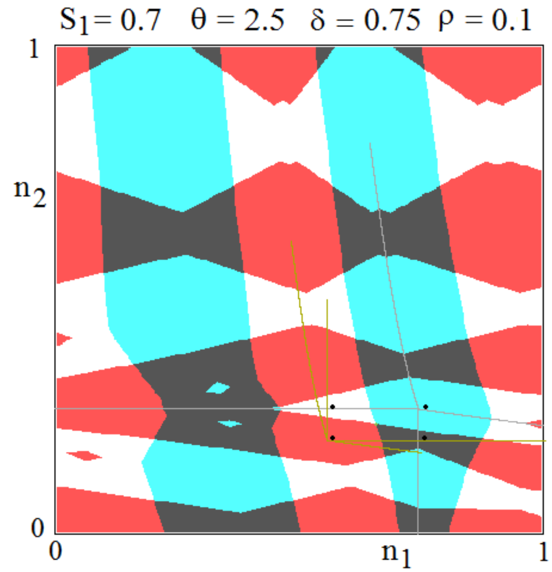
Critical Value of ρ_c at which the Stable Asynchronized 2-cycle disappears (as a function of s_1)

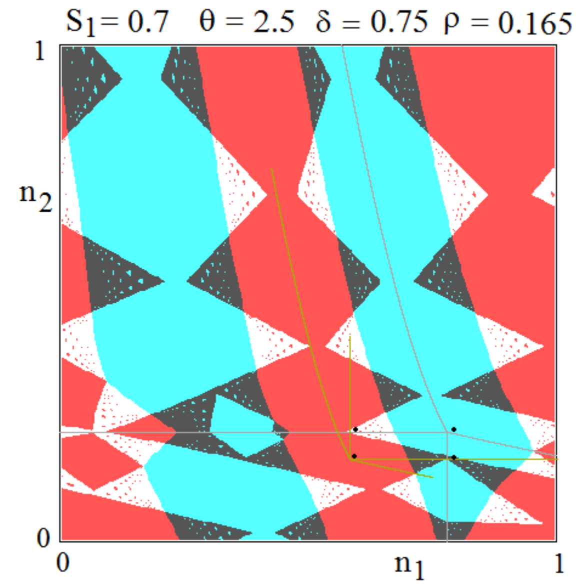
- It declines very rapidly as s_1 increases from 0.5.
- It hardly changes with δ**.**

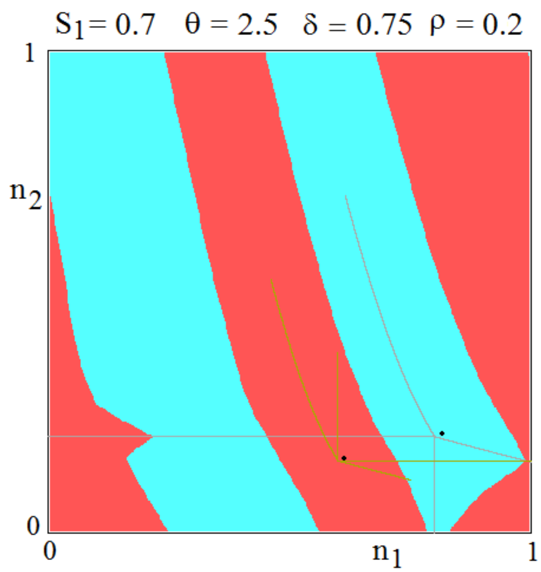


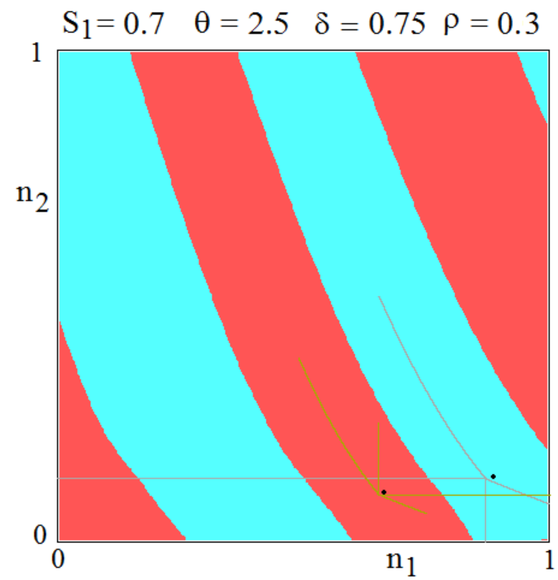
Four Basins of Attraction ($s_1 = 0.7$, $\theta = 2.5$, $\delta = 0.75$)











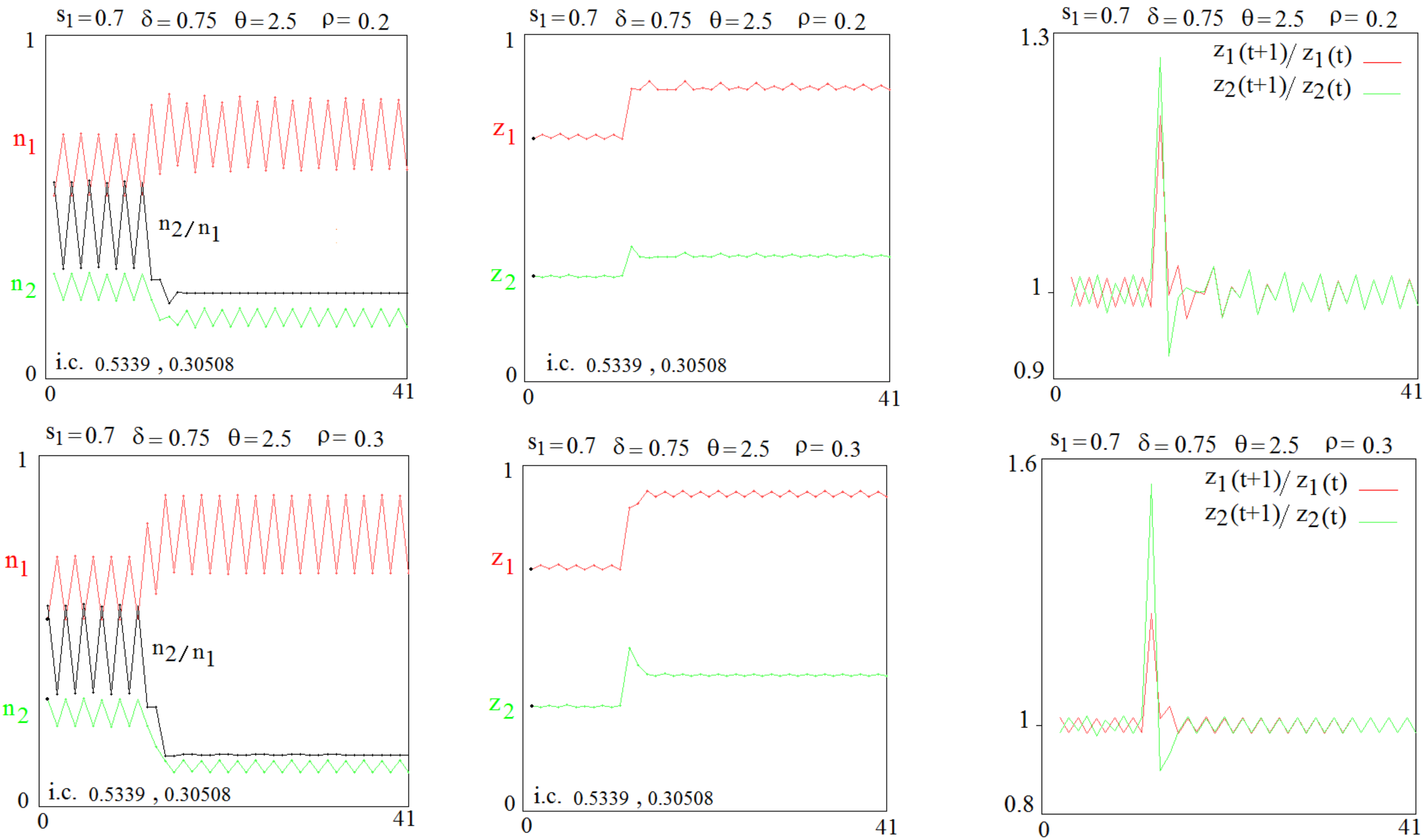
As ρ rises,
Red invades White, and Azure invades Gray, and vertical slips of Red and Azure emerge.

Three Effects of Globalization:

Home Market Effect

Productivity Gains

Synchronization



Concluding Remarks

Summary:

- 1st attempt to explain why globalization might synchronize endogenous productivity fluctuations

- *Key Mechanism*: Globalization → Innovators from everywhere competing against each other in more integrated (hence common) market → Alignment of Incentives to Innovate → Synchronization

- Captured in a 2-country model of endogenous innovation cycles, built on DJ and HK
  - In autarky, innovation dynamics of the two countries are decoupled.
  - As trade cost falls and intra-industry trade rise, they become more synchronized.
  - Full synchronization at a larger trade cost with more unequal country sizes.
  - The smaller country adjusts its rhythm to the rhythm of the bigger country.

- Adding endogenous sources of fluctuations helps to understand "the trade-comovement puzzle."

- Technical Contributions
  - 1^{st} two-country model of endogenous fluctuations
  - A New Model of Coupled Oscillators
  - Application of 2D noninvertible, PWS, discrete time dynamic system

Next Steps:

- **Synchronization of Chaotic Fluctuations**

- **Many Countries**

- **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