

# **Catch-up Cycles**

## **and Changes in the Industry Leadership:**

Windows of opportunity and responses  
in the evolution of sectoral systems

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# **What is catch-up?**

**“Catching up, forging ahead, and falling behind” (Abramovitz, 1986 JEH)**

**1) national level:**

**per capita income, share in world GDP,**

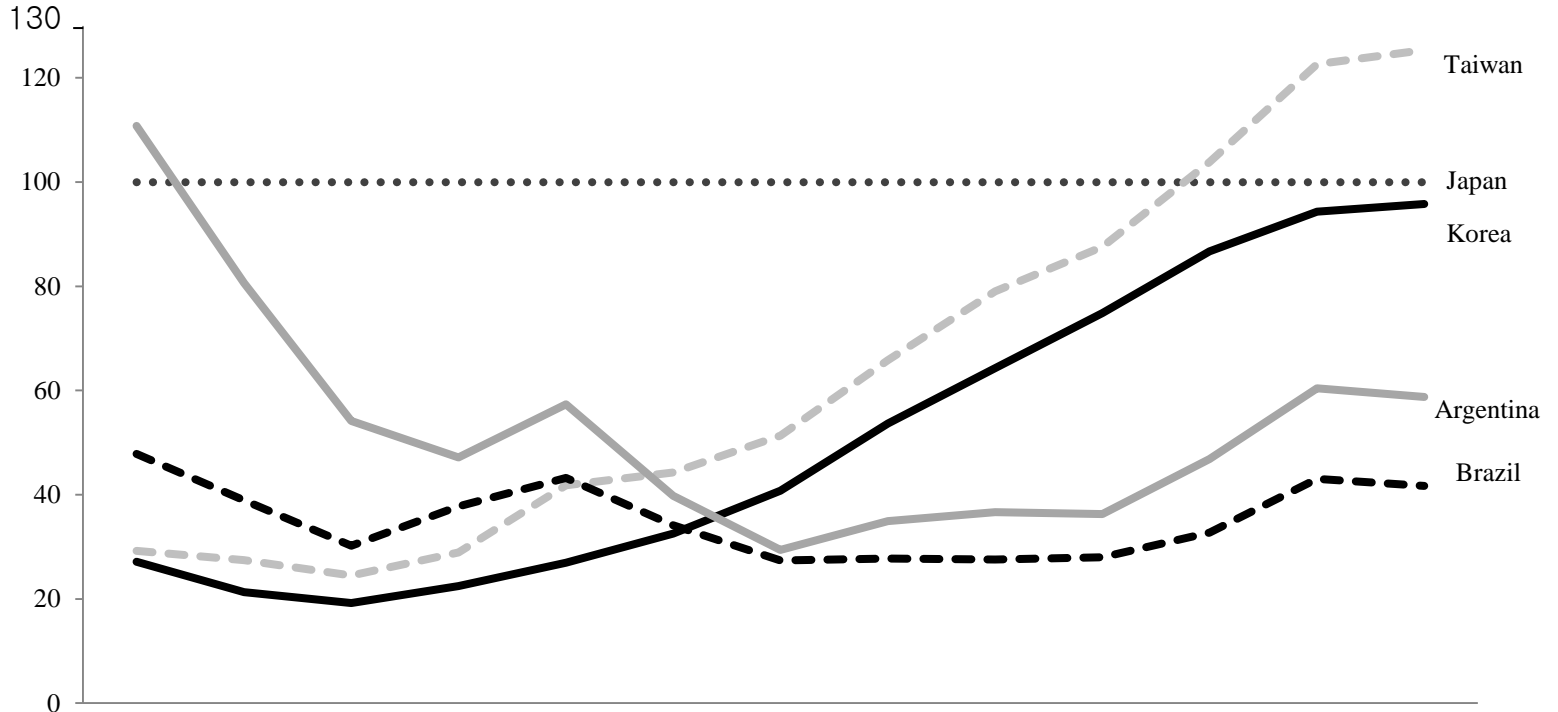
**2) firm-level:**

**market share, sales growth, productivity**

**=> rise and decline of nations and firms  
(and sectors)**

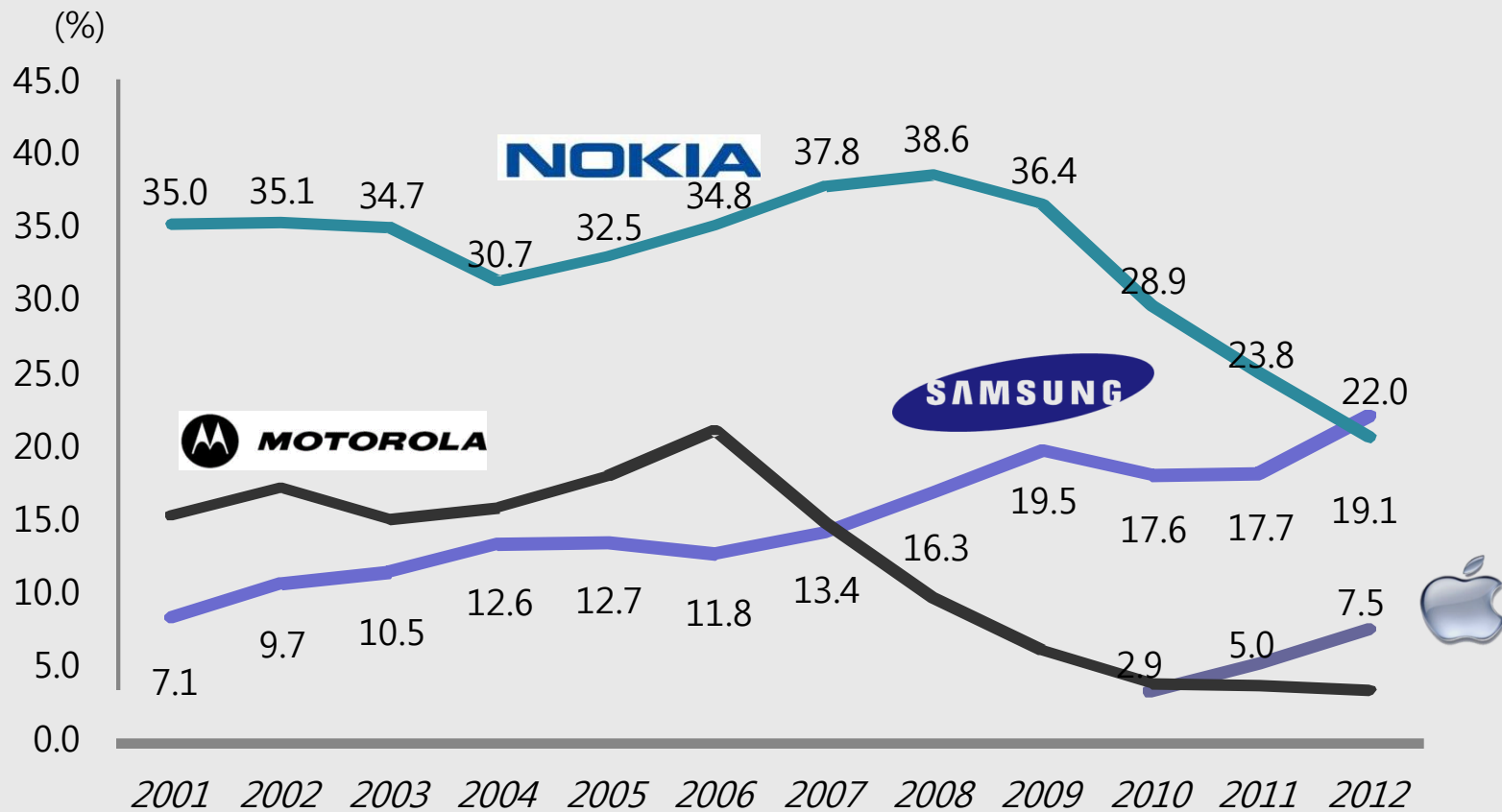
# % of Japan's GDP per capita: Taiwan surpassed Japan: Korea's is 94.4%(14'), 95.8%(15') of Japan

% (of Japan's GDP per capita in PPP \$)



	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005	2010	2014	2015
Japan	100	100	100	100	100	100	100	100	100	100	100	100	100
Korea	27.2	21.3	19.2	22.5	27.0	32.6	40.8	53.7	64.3	74.8	86.7	94.4	95.8
Taiwan	29.2	27.5	24.5	28.9	41.8	44.3	51.3	65.8	79.0	87.6	103.9	122.6	125.3
Argentina	110.8	80.6	54.1	47.2	57.3	39.8	29.4	34.9	36.7	36.3	46.9	60.4	58.8
Brazil	47.8	39.0	30.2	37.8	43.2	34.1	27.4	27.7	27.6	28.0	32.7	43.1	41.7

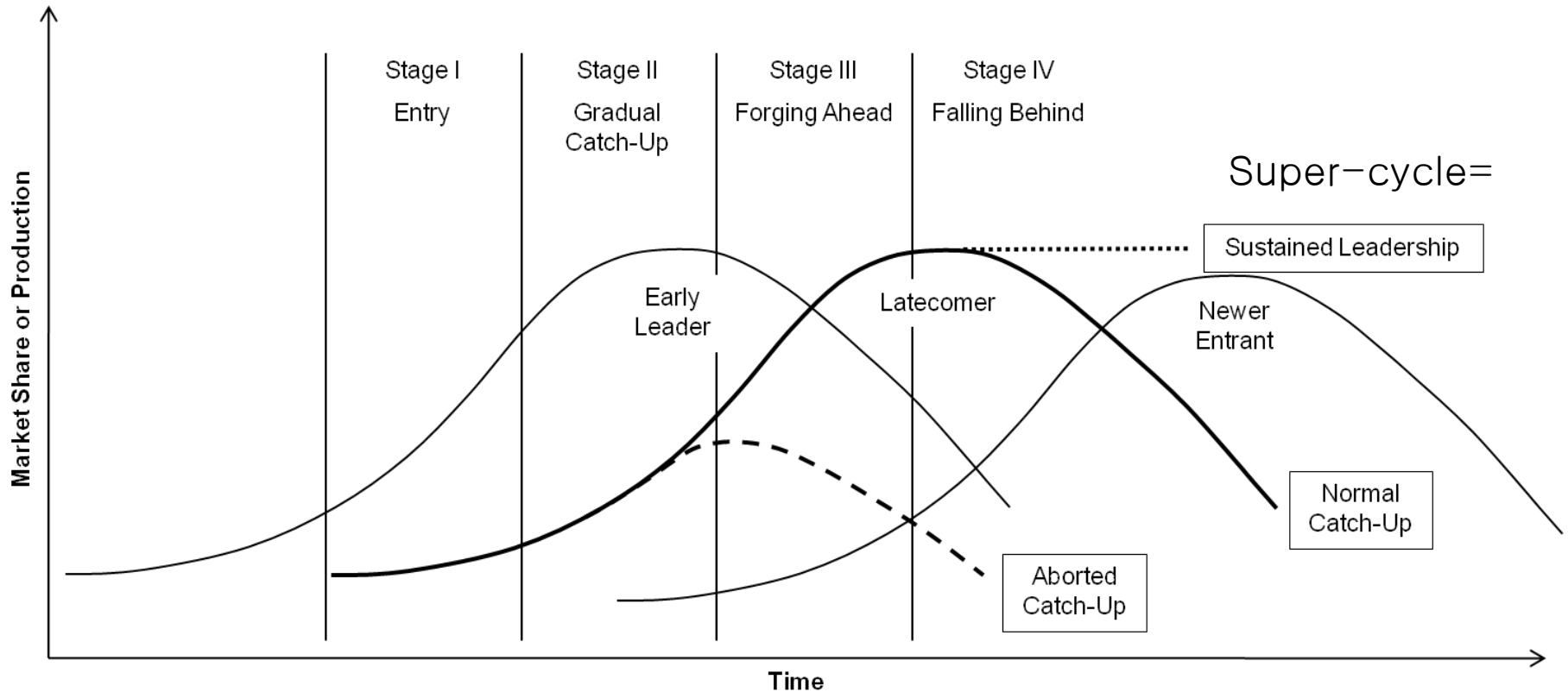
# Catch-up cycles in MOBILE PHONES



Source: Gartner presentation

# Our Theory: Industry Catch-Up Cycle

3 Windows of Opportunity, 3 strategies, 3 Cycles



Each cycle is that of a leading firm or a collection of firms in a nation;

# ***Research Question: Why More than 2 times Changes in industry leadership?***

- Mobile phones: Motorola -> Nokia -> Samsung ( Apple)
- Mid size jet: Europe -> Canada (Bombardier) – Brazil (Embraer)
- Semi-conductor (memory chips): US-> Japan -> Korea
- Steel: U.S. → Japan → Korea → (partly) China
- Camera: Germany -> Japan 1 -> Japan 2
- Wine: France -> US, Australia -> Italy

++More cases: Autos: U.S. → Japan → partly Korea ; China

Shipbuilding: Britain → Japan → Korea → partly China

IT service: US – Ireland(partly) –India

**→ Why do this often occur in many sectors?**

**→ Why the leader cannot persist but decline?**

**→ Need a new theory than ‘product life cycle’(Vernon)**

# Criticism of Existing Theories

- Product Life Cycle (Vernon, 1966)
  - A product has a life cycle (3 stages: introduction – maturity – standardization),
  - as a product technology standardizes, comparative advantage based on production cost shifts from advanced countries to less developed countries.
  - He stopped there
  - did not go further to consider the possibility that latecomer firms take control of not only production but also R&D/Marketing;
    - while products by MNCs from advanced countries lose in competition.

# A Neo-Schumpeterian Theory: national/sectoral innovation systems -> Catch-up cycle theory

- The theory should consider diverse factors beyond the level of a firm and their interactions
- SSI (Sectoral Systems of Innovation: (Malerba, 2004)
  - 4 building blocks of SSI :
    - 1) technological regimes,
    - 2) demand conditions,
    - 3) actors and their networks,
    - and 4) the surrounding institutions (IPRs, laws, culture, etc.)



## Initial idea

= Leapfrogging and Window of Opportunity

(Perez and Soet 1988)

= Neo-Schumpeterian concept

“Techno-economic paradigm change can be a window of opportunity for late-comers

→ bypass the old paradigm to jump into the new paradigm and thereby leapfrog”

and to be a new leader

Example: Digital paradigm as window of opportunity for Korea (Samsung) to catch up with Japan (Sony)

# Four Windows of Opportunity for Latecomers

## 1) New Techno-Economic Paradigm (Perez & Soete 1988)

Analogue → Digital: Korean Digital TV (Lee, Lim & Song, 2005)

mini paradigm or new generations of tech. new trajectories, disruptive innovations eg) Japan to Korea: Motorola to Nokia

## 2a) Business Cycle: Downturns

- TFT-LCD Industry (Mathews, 2005)

## 2b) Changes in Demand Conditions

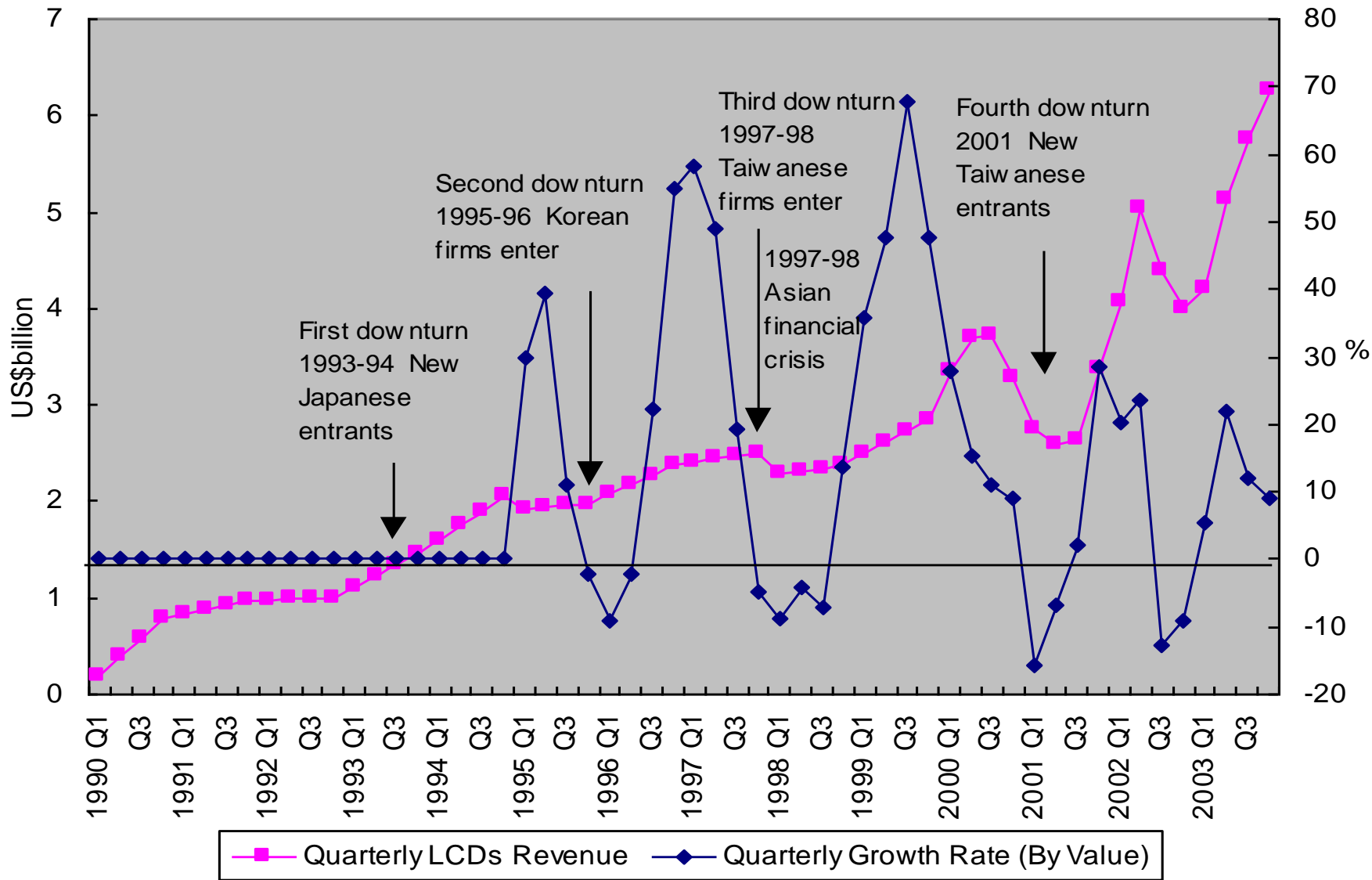
## 3) Industrial Policy & Government regulation

- Indian pharmaceutical industry (Guennif & Ramani, 2012)

- Telecom in Korea & China (vs, India, Brazil: Lee, et al 2012)

# Crystal cycles and Late Entries during Downturns (Mathews 2005 in CMR)

## LCDs Market Growth, 1990 - 2003



# **Downturns in business cycles = small window of opportunity**

Downturns provide a time for economic cleansing and also entries

Set a brake on incumbents ;

Release of resources provides opportunity for challengers –  
newcomers and latecomers,

Tech. Transfer and Knowledge Access become easier and cheaper

Provide opportunity for fast followers to create supply chain and to  
move up in rankings

Strategy for challengers – timing of entry, making use of released  
resources and knowledge;

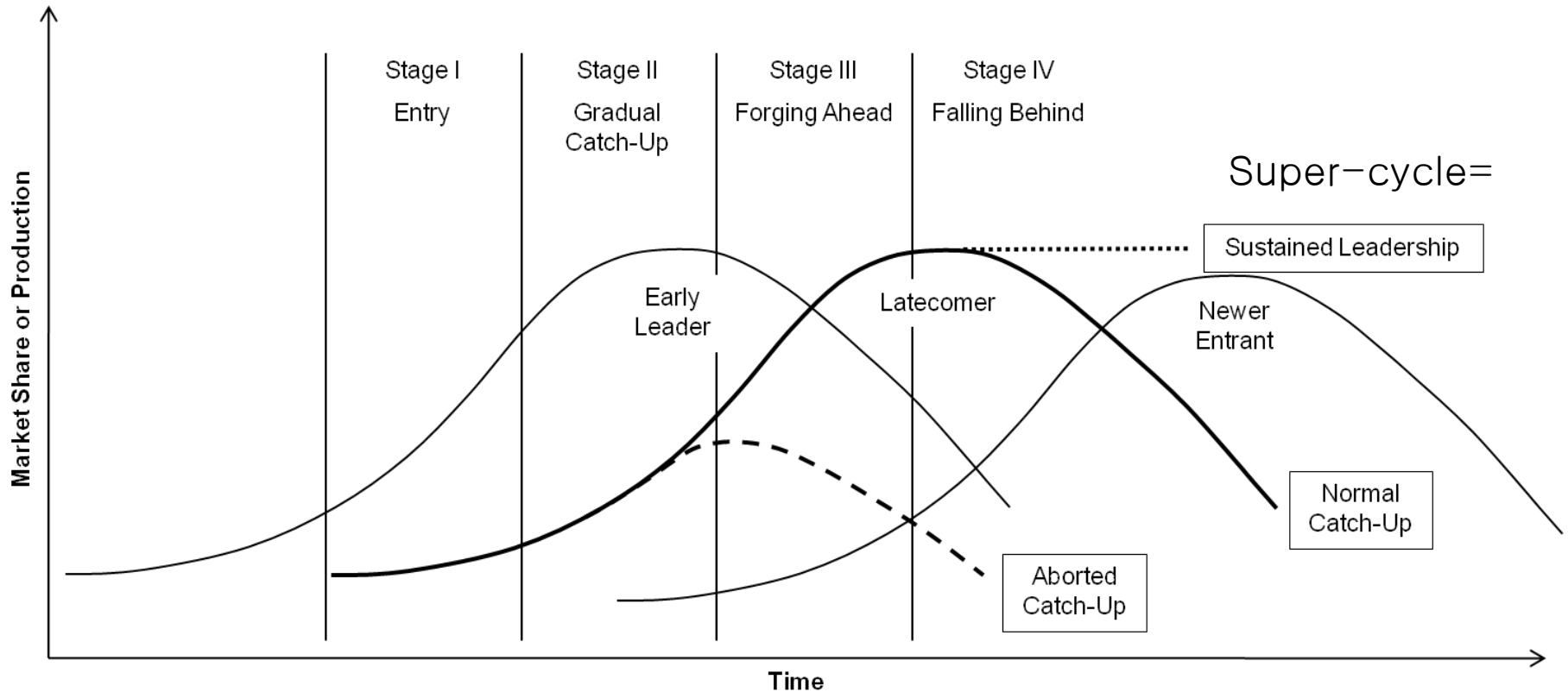
Example)

1930s Great Depression = Window for the Soviet Union

2008/9 Global Crisis → window for China

# Our Theory: Industry Catch-Up Cycle

3 Windows of Opportunity, 3 strategies, 3 Cycles



Each cycle is that of a leading firm or a collection of firms in a nation;

Secrets of Catch-up Cycles

=

windows of opportunity

+

Incumbents Responses

(incumbents' trap)

and

Latecomer's Advantages and

Disadvantages

# Why Incumbent declines?

## -> Incumbent Trap/Lock-in

Winners tend to falling into trap: (of ignoring new technologies)

-> be complacent with the current success

(with the current/dominant technologies).

→ not necessarily by their mistakes but by rational choice;  
-- given uncertainty of new tech, and given fixed investment whose life cycle has not finished

-> emergence of new paradigm/generations of technologies  
+ incumbent trap

→ leadership changes

Eg) from Motorola to Nokia

# Three Catch-Up Strategies

(Lee & Lim, 2001 Research policy)

Path of the Forerunner: stage A --> stage B --> stage C --> stage D

1) Path-Following : stage A --> B --> C --> D

e.g. PC, some consumer goods, and machine tools industries in Korea

2) Stage-Skipping (leapfrogging 1) stage A -----> C --> D

e.g. Hyundai's fuel-injection engine development (cf. carburetor engine)

Samsung's 64K DRAM prod. technology; 256K DRAM design technology

China: telephone switch development

3) Path-Creating (leapfrogging2) : stage A --> B --> C' --> D'

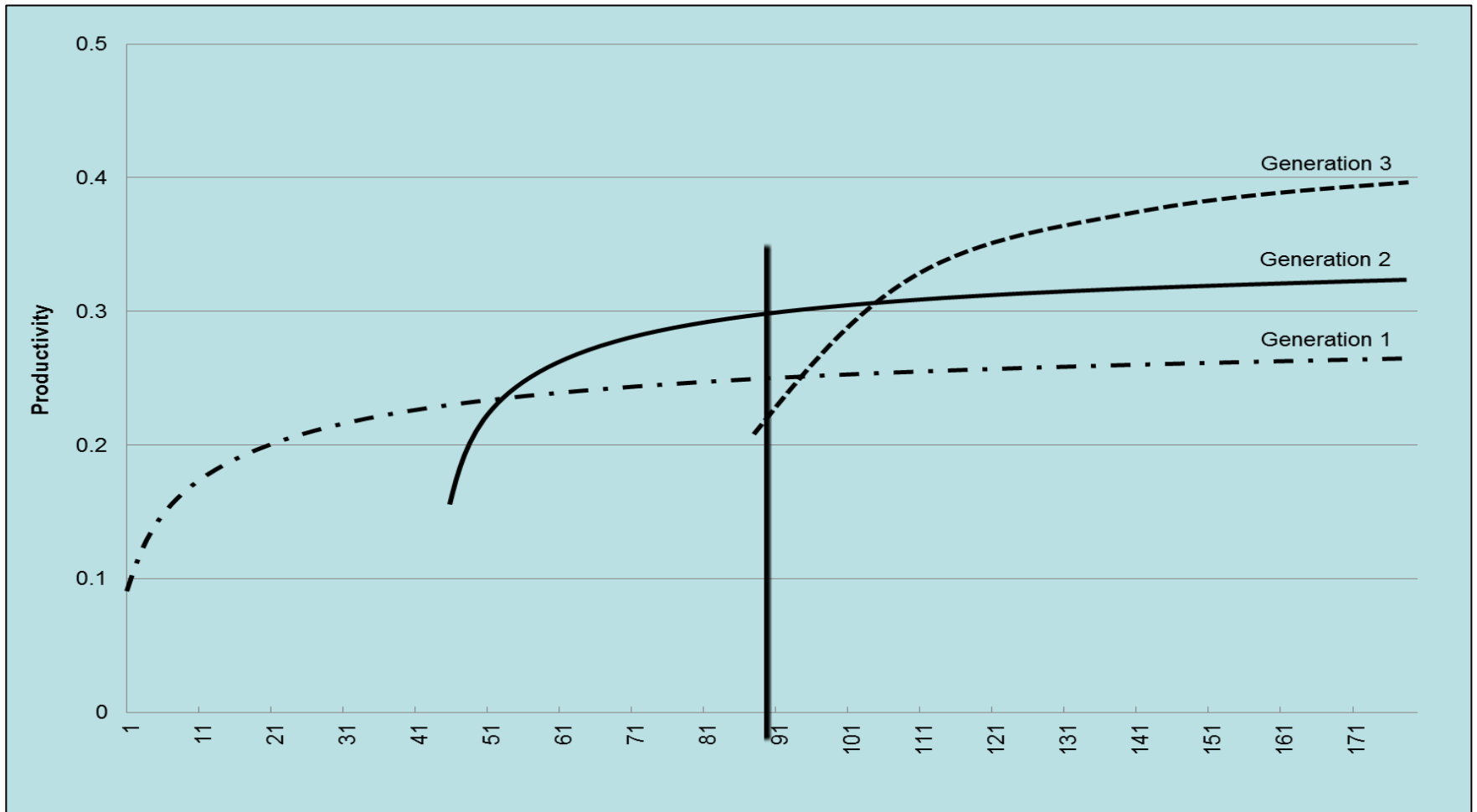
e.g. Korea's CDMA and digital TV development

(C and C' represent competing technologies)

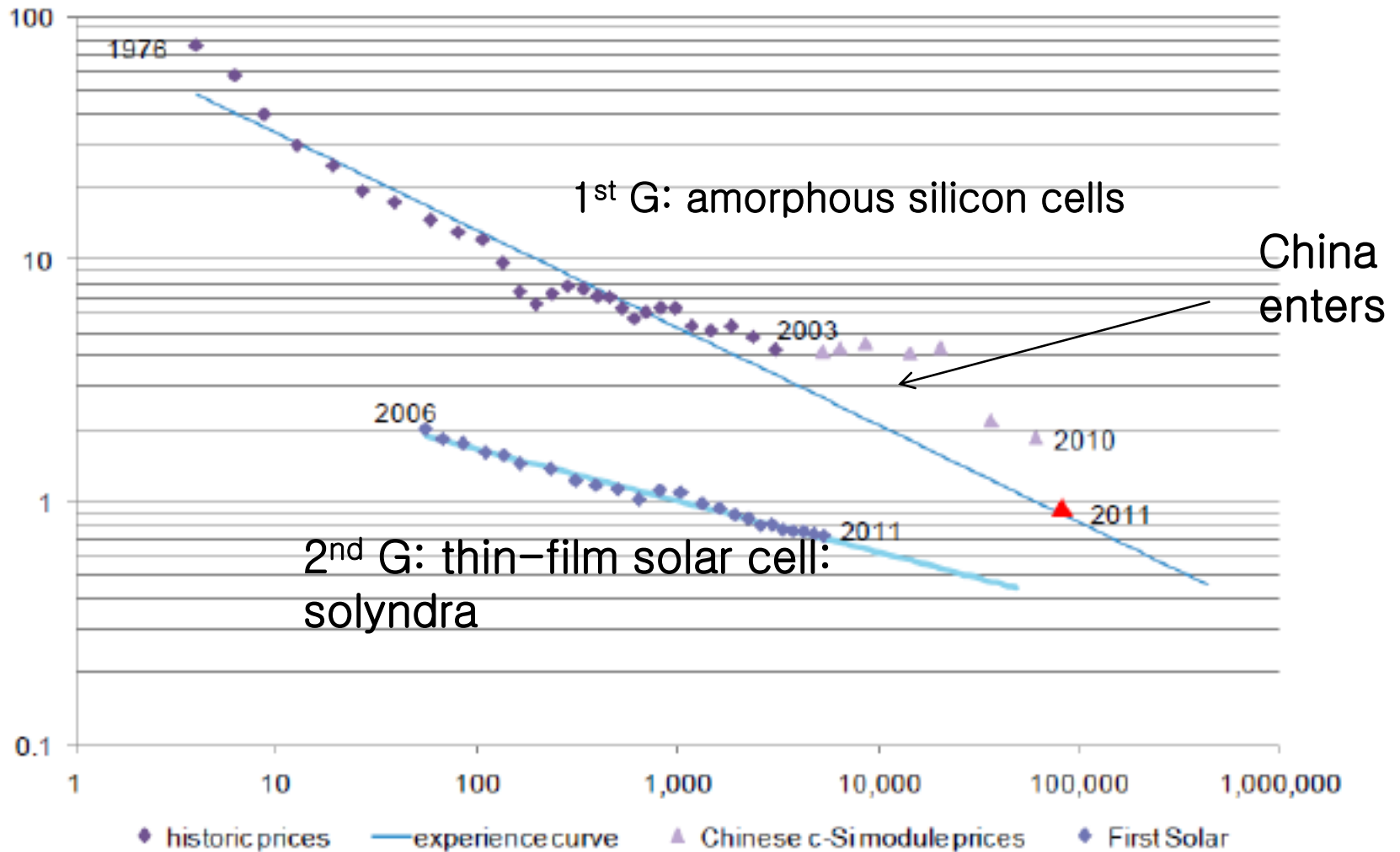


### 3 catchup strategies: including Leapfrogging

- Path-following strategy = start from generation 1 technologies
- stage-skipping = entry with generation 2 tech (most productive and stable)
- Path-creating/ leapfrogging = jump to generation 3 (emerging) technology)



# Risk of leapfrogging without Ind. Policy: Solyndra in US; Solar panel cost in 2 generation technologies



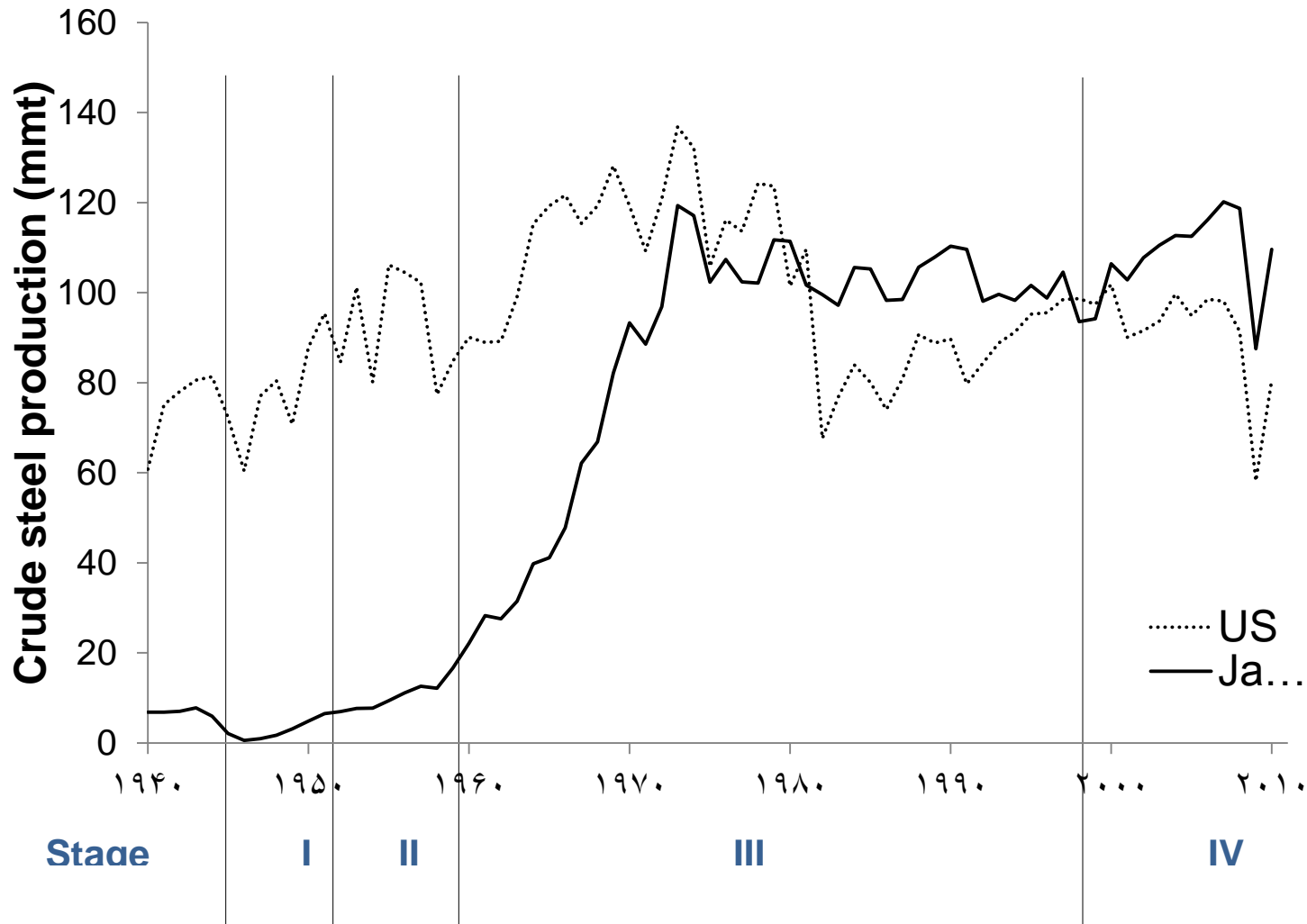
Solyndra entered with 2 generation tech → failed:

Source: BNEF Bazilian et al (2012), Fig. 1

Example:  
Catch-Up Cycles  
in the World Steel Industry:

1. From the US to Japan
2. From Japan to Korea
3. Brazil 's Aborted Catch-Up

# Catch-Up Cycle 1: US to Japan (1946 - present)



Sources: 1900-79 – Mitchell (1995, pp. 456-62, 1992, pp. 417-19); 1980-2010 – World Steel Association

# Japan's Catch-Up Cycle: The Forging Ahead: 1959- the '80s

- Rise of New Technology: **Basic Oxygen Furnace**
  - Commercialized in 1952; the US ('56) vs. Japan ('57)
  - BOF is much cheaper in construction and operation
  - The US clung to old technology, Open Hearth Furnace

Table 1. Diffusion of BOF in Japan and the US (%)

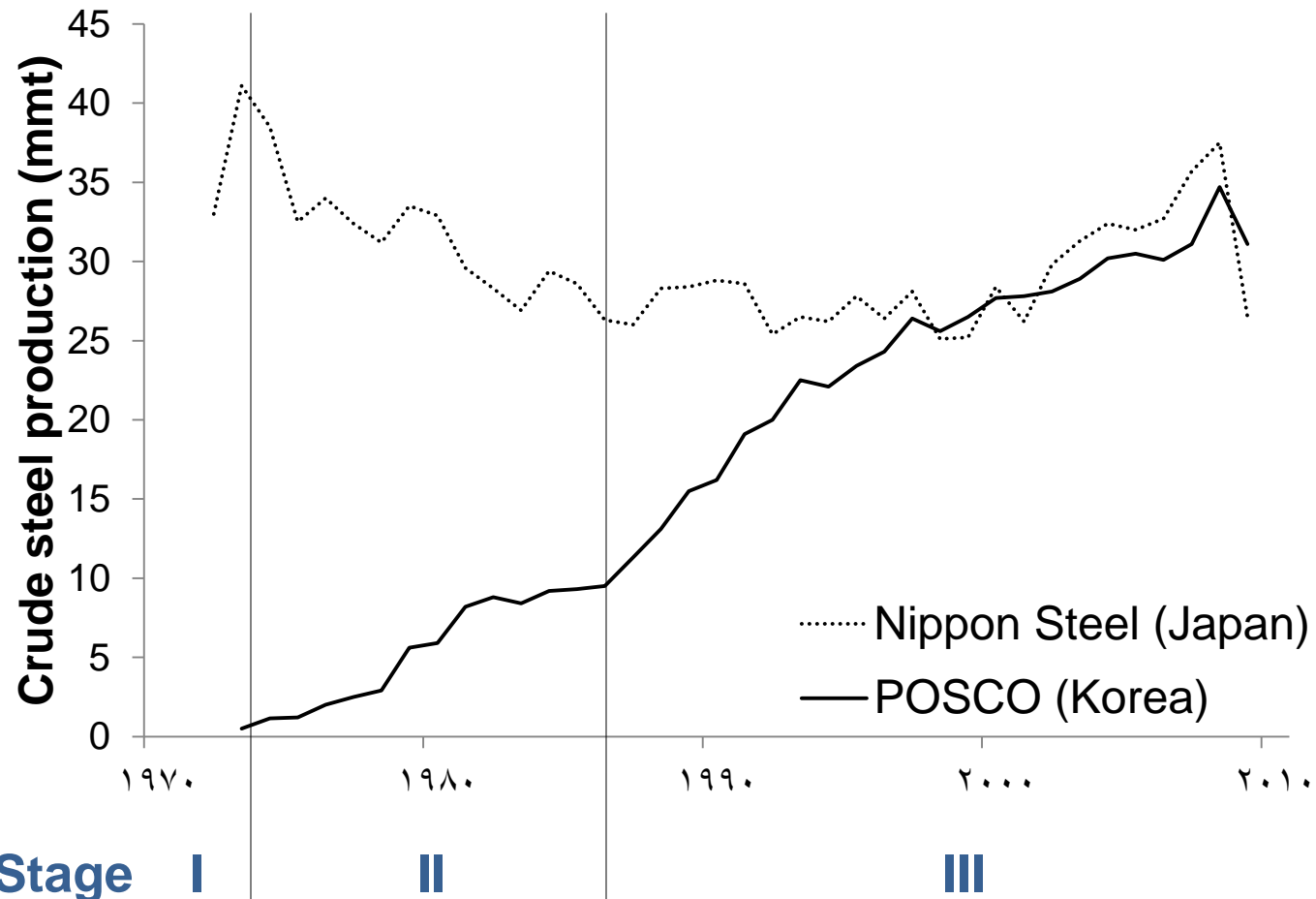
	1960	1965	1970	1975	1980	1985	1990	1995
Japan	14.9	69.0	95.0	98.7	100.0	100.0	100.0	100.0
US	3.7	19.4	55.8	74.3	83.9	89.0	94.3	100.0

Source: D'Costa ([1999, p. 111](#))

# Role of the Gov't in Japan's Forging ahead: Collective licensing coordinated by MITI

- A significant role of the government in the adoption of BOF
  - The MITI arranging a collective licensing of the BOF method for significantly reduced royalty fees;
  - the MITI formed a group of Japanese steel makers, and negotiated as a single buyer over a technology license with the patent holder (Austrian firm) for a substantially lower licensing fee.
- Path creating as adoption and follow-on innovation mode
  - Japanese firms initiated two innovative improvements for BOF;
  - These follow-on innovations solved the two major problems with BOF: that blocked its wider diffusion:
  - Nakamura and Ohashi (2011): these reinventions accounted for more than 30 percent of TFP change by the BOF

# Catch-Up Cycle 2: Japan to Korea (1973 - present)



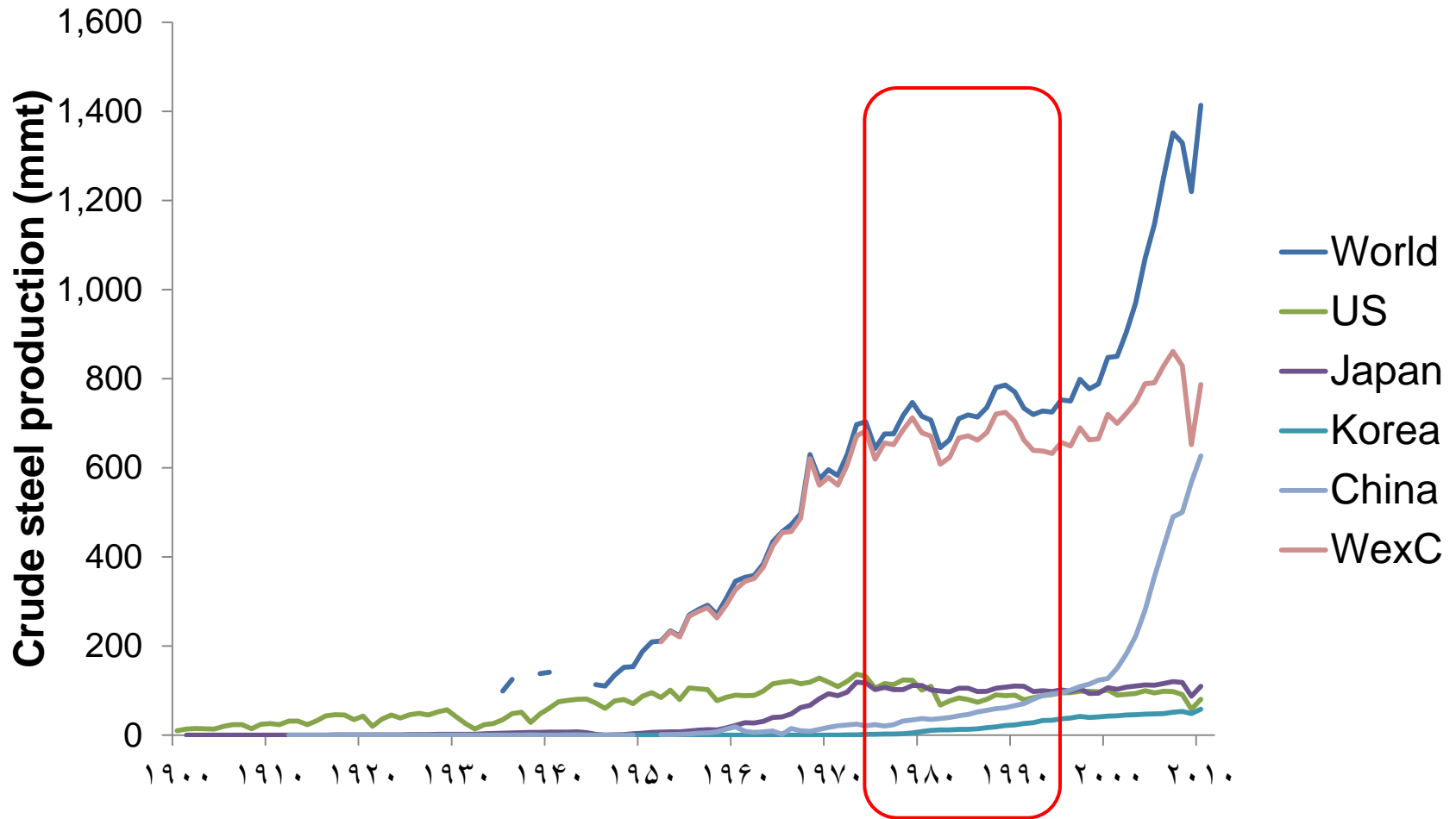
Sources: 1973-4, POSCO – Song (2002, p. 150); others – World Steel Association

## Stage II. Gradual Catch-Up: 1973-86: Downturn of Oil Shocks = Window

- Entry by Low Cost & Low end products
  - POSCO's first steel works started steel production in 1973 and kept expanding production capacity by 1983.
  - Business Downturn after 1973 Oil Crisis → POSCO was able to purchase old equipment at lower cost
  - **> Path-following catch-up**
- Govt. Activism to support demand sectors
  - Heavy and Chemical Industrialization Program (1973-9) to foster six selected sectors (Steel, Petrochemical, Machinery, Shipbuilding, Electronics, Nonferrous metals)  
→ steel demand ↑



# Impact of two Downturns (Oil Shocks)



# Korea's Catch-Up Cycle:

## Stage III. Forging Ahead: 1987-present

- The 2<sup>nd</sup> steel works construction since 1981
- Business Downturn after 1979 Energy Crisis
  - POSCO promoted a competition among equipment suppliers and, thereby, purchased equipment at much lower price .
  - The downturn also provided POSCO a opportunity to introduce state-of-art technologies at low prices
  - -> **Stage-skipping catch-up**
- ➔ POSCO achieved more cost advantage

# Summary of steel: catch-up cycles

- 1) US=> Japan: Two windows of opportunity for Japan:
  - (1) the appearance of the new technologies, and
  - (2) Faster adoption by Japan > Path-creating
  
- 2) Japan->Korea : entry of POSCO as a SOE;
  - steel industry's downturns and the Korean government's industrial policies served as windows of opportunity
    - > path-following entry
  - The 1970s and 1980s (expansion with second mill) recessions contributed to adoption of state-of-art technologies at lower costs
    - > stage-skipping
  
- 3) initially path-following then to stage-skipping strategy.

# **Summary**

## **of the 6 sectors**

Events/ Time	Cell Phones	Memory	Camera	Jets	Steel	Wines
Event (1)	1998	1982	Mid 1960s	1995	1980	Mid 1990s*
	USA (Motorola) Finland (Nokia)	USA → Japan	Germany → Japan SLR camera	Netherlands → Canada (Fokker → Bombardier)	USA → Japan	Rise of New World (USA, Australia,)
Event (2)	2012	1993	1980s	2005	1998	Mid 2000s
	Finland (Nokia) Korea (Samsung)	Japan → Korea	No change (Digital SLR camera)	Canada To Brazil (Embraer)	Japan (Nippon steel) → Korea (Posco)	Return of Old World (Italy, etc)
Event(3)		By today	Mid 2010s*			
		No Change= Korea leader	rise of new entrants (Mirrorless camera)			
Interval years?	14	11	50 or so	10	18	10
No. of events	2	3	3	2	2	2

Total No of events = 14; Events with leadership change = 11  
(including 2 substantial rise: Wine1, Camera3);  
Event without leadership change = 2; Returning of the old = 1

# Catch up Cycles in mobile phones: Incumbent traps in Motorola to Nokia and then to Samsung

## **Traps :**

- 1) Motorola tried to improve further the analogue tech. despite arrival of digital technologies (led by Nokia).
- 2) Nokia hesitant to switch to Smartphones and sticking to its own Symbian, not adopting Google's Android OS

## **Windows:**

- 1) Institutional Window for Nokia: EU single standard for GSM
- 2) Tech Window for Samsung: quickly adopted the Android OS.

# Catch-up Cycles in Semi-conductor (memory chips)

- Two events in leadership change  
and one event of persistent leadership
  - > 1<sup>st</sup> from the US to Japan in 1982,
  - 2nd: from Japan to South Korea in 1993 (after 11 years).
  - After 1993 to today for 23 years more -> no sign of change:
- technological regime = rapid technological progress with generational changes of products being developed every three to four years; cyclical & predictable nature of technological change
- The both cases of change involved the role of demand windows (business cycles) plus leapfrogging (stage-skipping) strategies:
- Incumbent trap of weak investment during the downturns in both cases
- Latecomer invested into both the current and next generations of chips, during downturns.

# Catch-up-cycle in Camera 1

- This sector experienced three major technological shifts.
- Changes in industrial leadership: 1st and 3rd shifts, but the incumbents retained their market during the 2nd shift.
- 1st: the mid-1950s when German companies rangefinder (RF) cameras were replaced by Japanese firms involving SLR camera.
  - SLR was German invention but Japanese companies adopted, improved, and commercialized the technology.
  - German firms fell into the incumbent trap of no adoption.
- 2<sup>nd</sup> in the 1980s from analog SLR to digital SLR (DSLR): no change in leadership : Japanese firms: Canon and Nikon.

DSLR = “not much competence-destroying” :

a large part of the DSLR technology was primarily developed from existing SLR technology.



# Catch-up-cycle in mid-sized Jets:

## Demand & institutional windows

- 1<sup>st</sup> shift in 1995 : from Bae & Fokker Canada's Bombardier;
  - Bombardier responded to the 50-seat market (new rising demand). Bae and Fokker covered 70 to 120 seat ranges.
- 2<sup>nd</sup> in 2005 with Brazilian Embraer (75 to 120 seats).
- Regulatory changes in the US : Scope Clauses = agreements between the US pilots' unions & airlines restricting subcontracted pilots of smaller Co's flying aircraft with more than 50 seats.
  - excluded large aircraft from the regional/feeder market
  - In the 2000s, the scope clauses were relaxed from 50 to 70 seats  
and beyond-> good news for the 75- to 120-seat segment
- institutional changes in the latecomer's context (privatization of Embraer & export supports by Gov't)

# Findings 1: Driving force of leadership changes = 3 windows

- 1) Windows are always doomed to open  
as new technologies, new demand, business  
cycles, & government policies are to change.  
→ driving forces of the successive changes of leadership
- 2) Tech. windows involved not always but in  
many cases ( 7 of 11 events; 4 cases of no role)  
cf) Demand windows: significant in 5 of 11,  
7 marginal roles

## Findings 2: Sectoral Specificities of Windows and Leadership Dynamics

- Sectors differ in terms of the type of windows that most frequently open up and in the type of catch-up cycle.
  - 1) In sectors (wine, Jets and auto) with demand windows.
    - new firms often co-exist with old incumbents rather than replace them completely
  - 2) In sectors with technology windows (semiconductors and mobile phones),
    - a high probability of radical replacement of incumbent by new entrants, esp in short cycle sectors;
      - cf) steel: US to Japan: long cycles.

## Findings 3: Leapfrogging/stage–skipping observed in 11 cases out of 11 cases

### 1) stage–skipping (3 cases):

eg) memory chips to adopt emerging generations technologies;  
steel in Korea to adopt latest tech.

### 2) Path–creating 1: radical, endogenous innovations

**5 cases:** cell phones in Nokia;

mirrorless camera in 2000s;

Jets in Canada/Brazil; Wines by new worlds

### 3) Path–creating 2: adoption and follow on innovations:

**3 cases;** steel in Japan (BOF method)

Samsung to adopt Android

Camera in Japan to adopt SLR and improve

# Findings 4: Incumbent Trap: involved in 10 out of 11 cases

Examples)

- 1) Cell phones: Motorola tried to improve further the analogue tech. despite arrival of digital technologies.
- 2) Camera: German firms not to adopt new SLR camera; stuck to RF camera  
(German invention adopted by Japan)
- 3) Memory chips: weak investment during downturns (USA / Japan)
- 4) Regional jets/ wines: slow response to newly rising demands
- 5) Steel: US refused to adopt new BOF method  
(Austrian invention adopted by Japan with Gov't initiatives)

\* WHY?: incumbents who command the highest productivity from the existing technologies feel no reason to adopt new technologies.

# 5. Exogeneity/Endogeneity of Windows and Super-cycles

- Windows may be endogenously created by actors
- the current leaders have a reason to lead innovations into the direction of competence-enhancing way.

→ If the leaders succeed, they are likely to maintain leadership → **super-cycle**

- **Ex 1) Samsung's memory chip** business: leader since the 1992 (23 yrs); cf) industry had several leadership changes before the rise of Samsung. (11 year interval)
- **EX 2) Cannon's continued leadership in Camera**

# More on Super-cycle by Samsung

- **Samsung in memory chip** leader since the 1992 (23 yrs);.
- 
- From a Leader in DRAMs to a leader in NAND flash memories; graphic memories, and SRAMs
  - able to use existing wafer manufacturing facilities.
- Its foray into mobile-related memories; boosted by its first-mover advantages as a tech. standard setter;
- Mobile memories require many technical standards to establish interfaces with mobile products.
  - Samsung played a leading role in standard setting associations like MIPI (Mobile Industry Processor Interface) and MMCA (Multimedia Card Association).

# One final message: “Schumpeterian”

While consider all the ‘three windows’ of opportunity,  
we confirm the supremacy of technological innovation as  
the critical interface connecting the three windows.

- 1) demand-related windows have an influence because  
they lead to demand-driven innovation or adoption of  
new technologies.  
eg) jets, or wines
  
- 2) institution window: ‘significant’ in 2 cases, but  
its actual impact was realized through affecting the  
adoption or diffusion of new innovations.  
eg) steel in Japan; in GSM adoption by EU



Catch-up Cycles

=

windows of opportunity

+

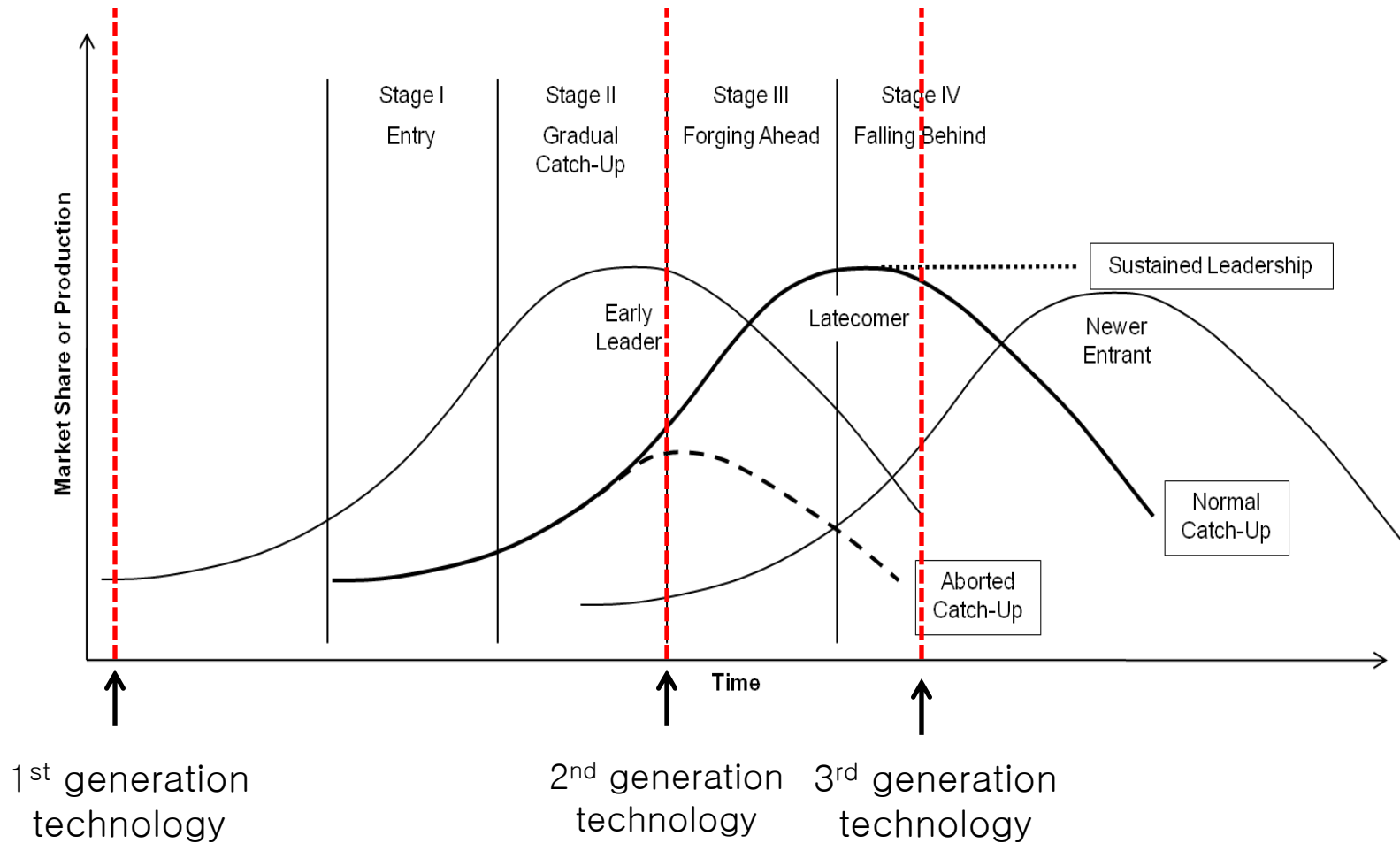
Incumbents Responses (incumbents'  
trap)

and

Latecomer's responses  
(stage-skipping or leapfrogging plus  
follow-on innovations)

and overcoming disadvantages (often  
with industrial policy)

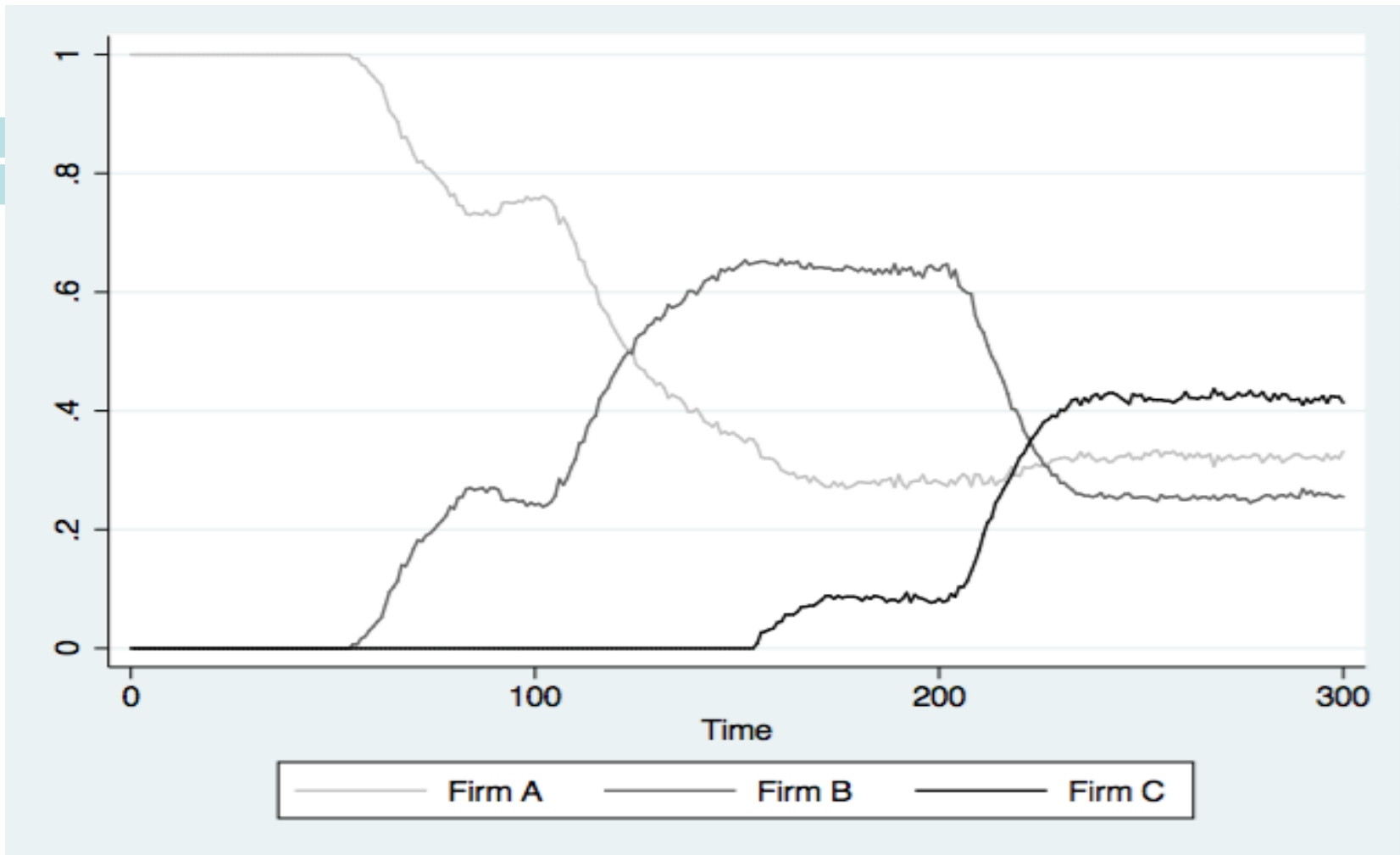
# Simulating catch-up cycles by 'history-friendly models'



# 'History-friendly' calibration: Bench Mark Case

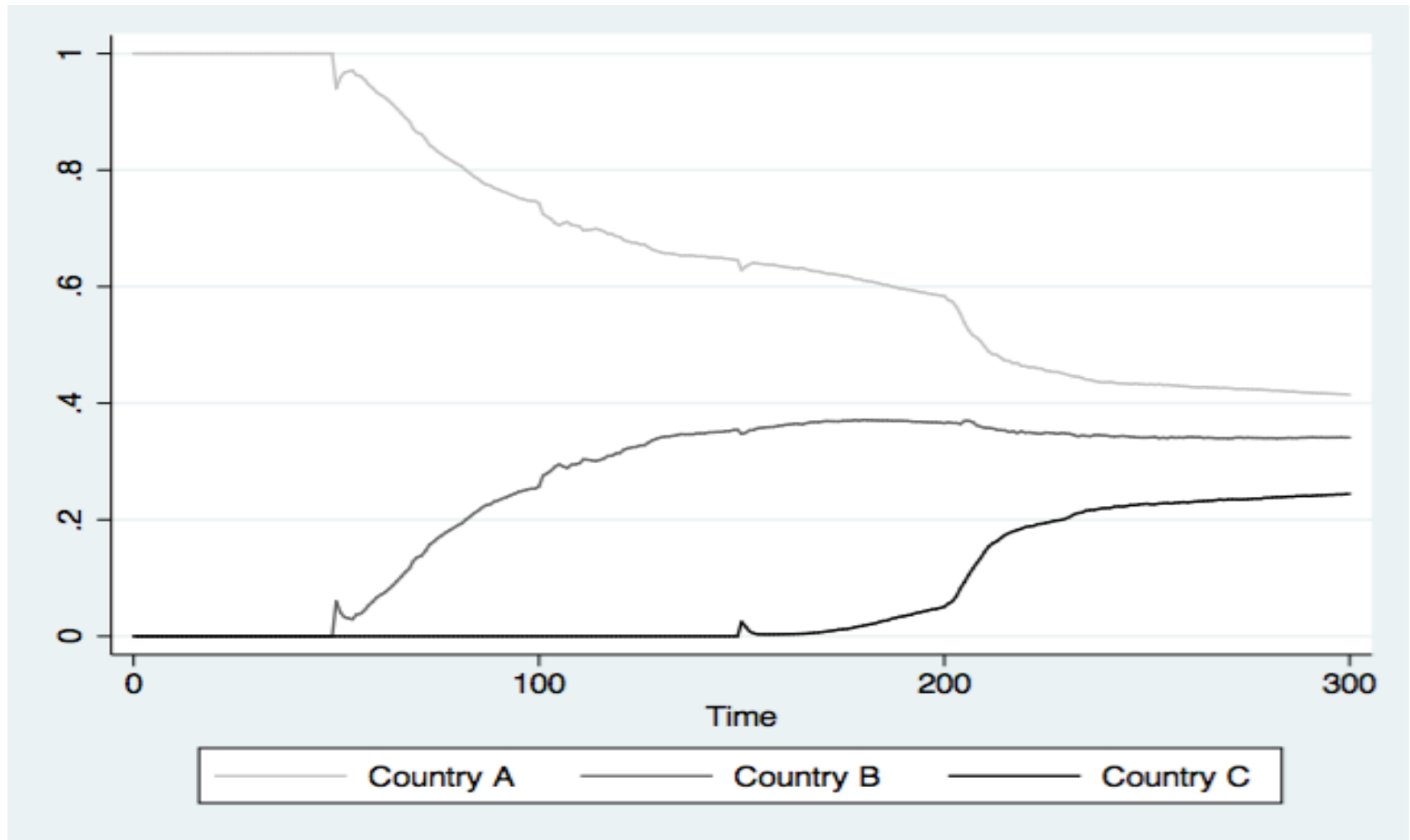
radical change in leadership after technology shocks

Evolution of total market shares: → immediate leadership changes



No Lock-in (no incumbent trap) Case:

→ No leadership change



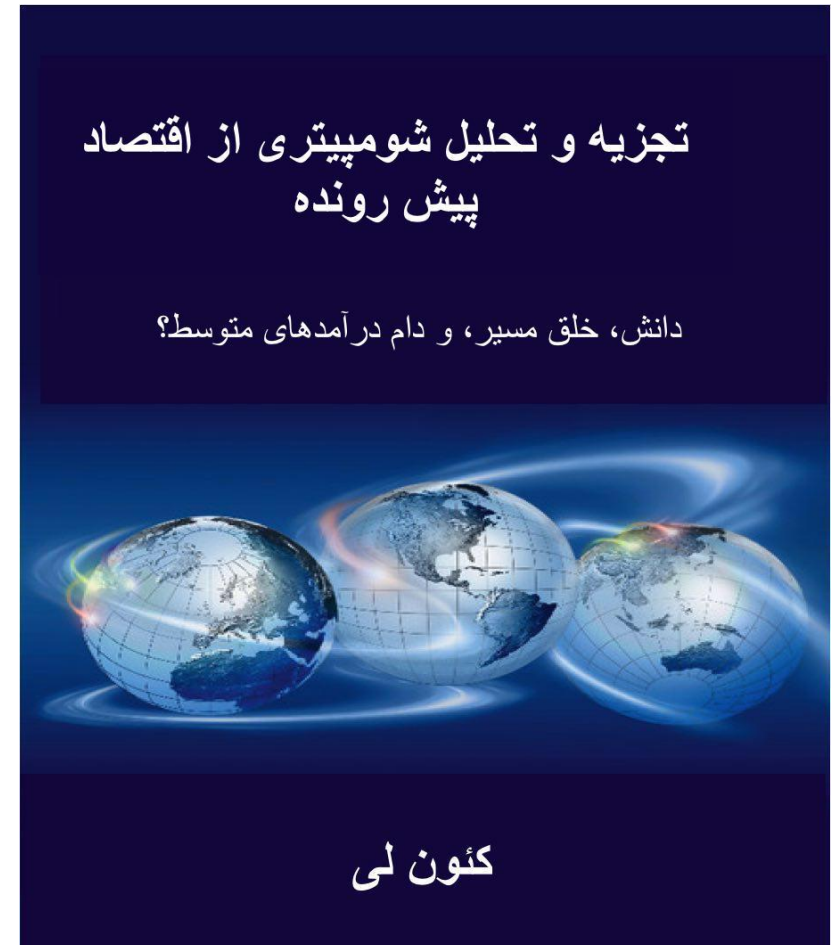
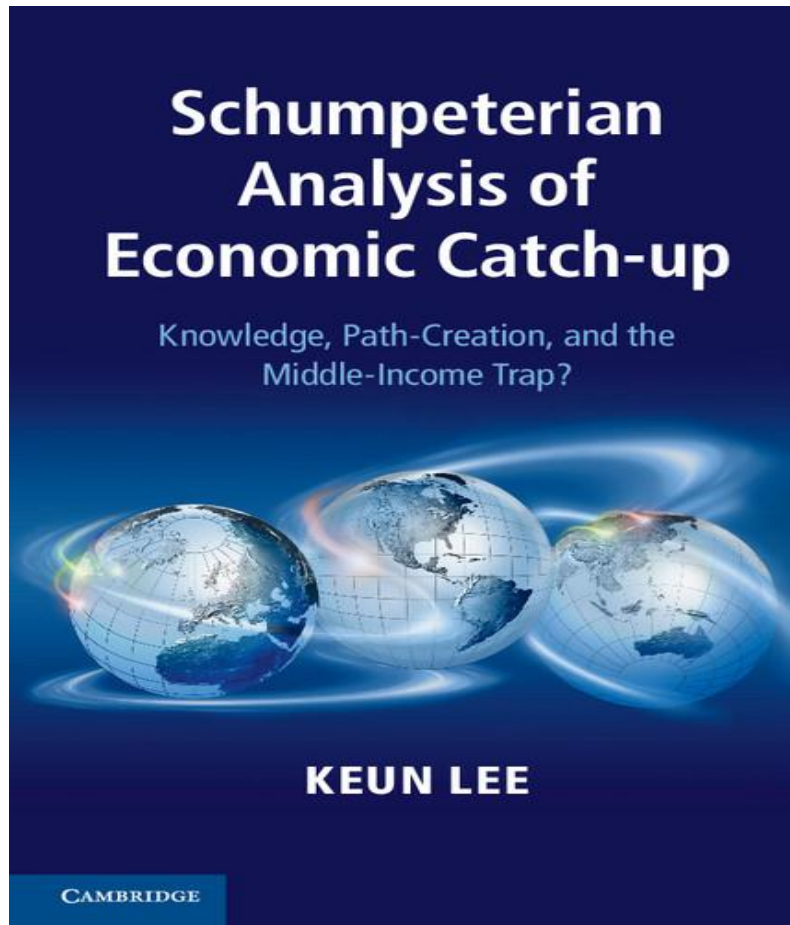
countries' market share for  $\rho = 0.6$ .

Theory: *Product–life cycle to Catch–up cycles*  
 Policy: *Trade– to Tech–based Specialization*

**From Trade Specialization to Technology Specialization**

Stages	Low or low middle income	Upper middle income To high income
Type of specialization	Trade-based specialization	Technology specialization
Source of specialization	Comparative advantages from resource endowment	Absorption/design capability from learning/R&D effort
Type of sector	Labor intensive/resource industries	Short cycle/emerging technologies
Background theory	Product life cycle (inheriting): Entry/gradual catch-up	Catch-up cycle (leapfrogging): Radical catch-up/reversal

Innovation system at 3 levels: firm, sector, & country  
=> 2014 Schumpeter Prize



سپاسگزارم

Danke shon!

ありがとう!

*Gracias!*

*Obrigado!*

*Thank you!*

謝謝大家

감사합니다

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