My Talk Today in 2 Parts

1) The Art of Economic Catch-up & Leapfrogging

2) Variety of NIS and their Evolution and Performance

Keun Lee

Professor of Economics, Seoul Nat'l University

Editor, Research Policy

Council Member, World Economic Forum

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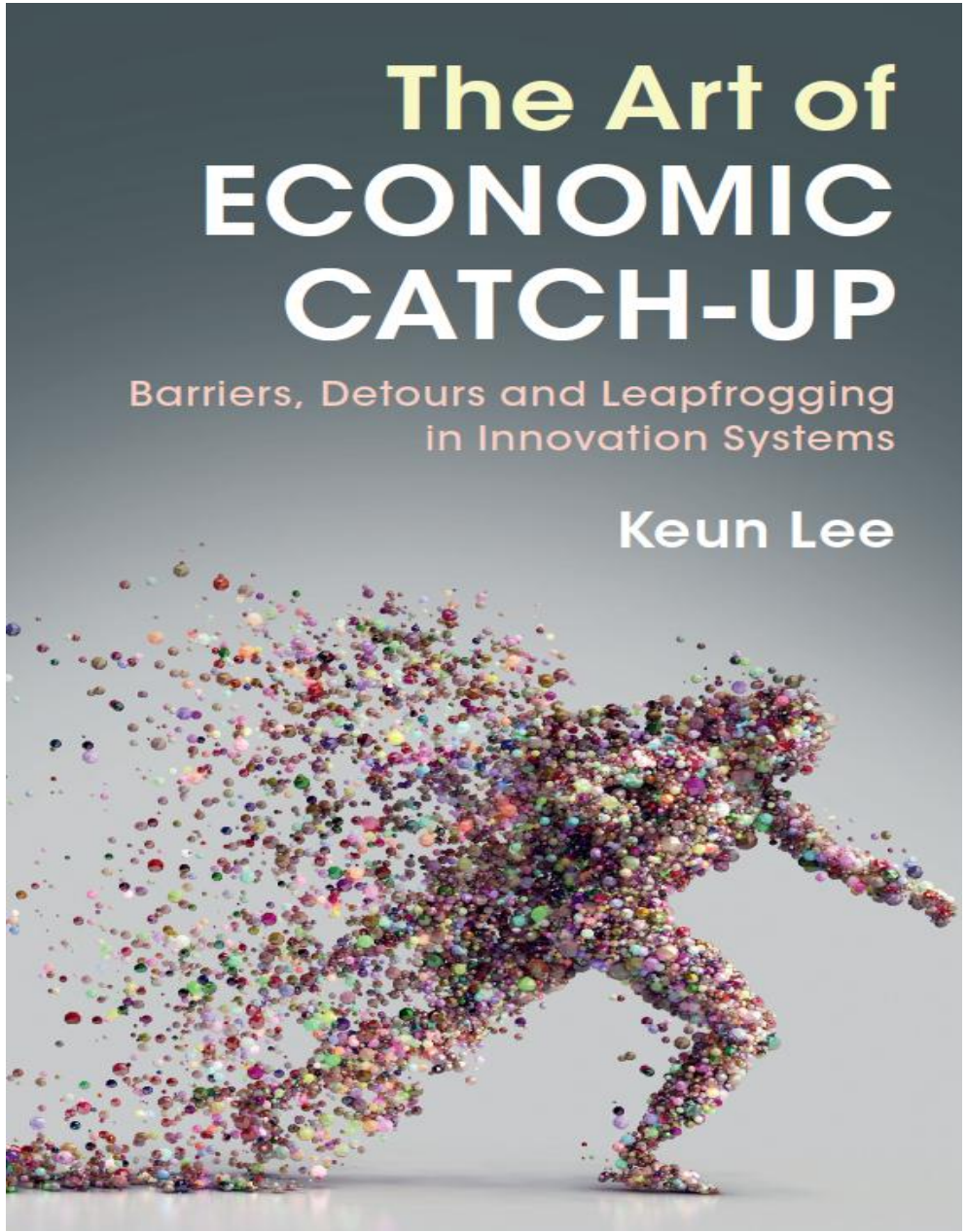


The Art of Economic Catch-up

="*Take a Detour and Fly on a Balloon when the Ladder is Kicked Away*"

Summary

Latecomers can still catch up with their forerunners
by taking detours (e.g., capability building)

and flying on a balloon (leapfrogging),
out of windows of opportunity,

even when the ladder to rich economy is kicked way,

What is catch-up, and how to achieve it?

"Catching up, forging ahead, and falling behind" (Abramovitz, 1986)

Catch-up = Closing the Gap in:

1) national level:
   per capita income, share in world GDP,
2) firm-level:
   market share, sales growth, productivity
   cf) technologies: patent counts, R&D/GDP, etc

=> **Catch-up is not cloning**

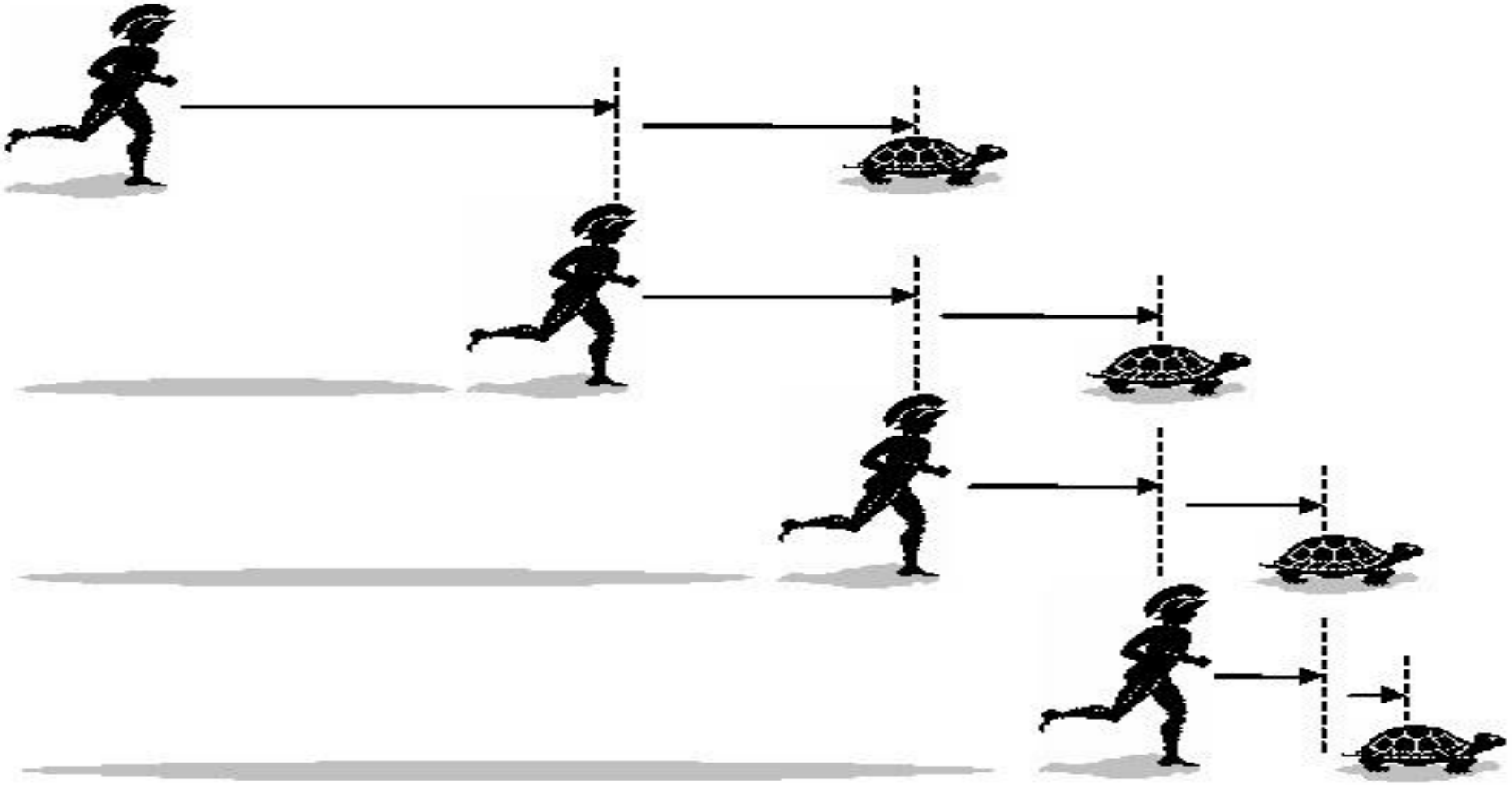
=> successful catch-up diverges from practices in forerunning countries/firms

=> can be achieved by **taking a different path (incl. detours)** from them **.**

Zenon's paradox :

Achilles will be not able to catch up with a turtle if the latter start 1k meter ahead

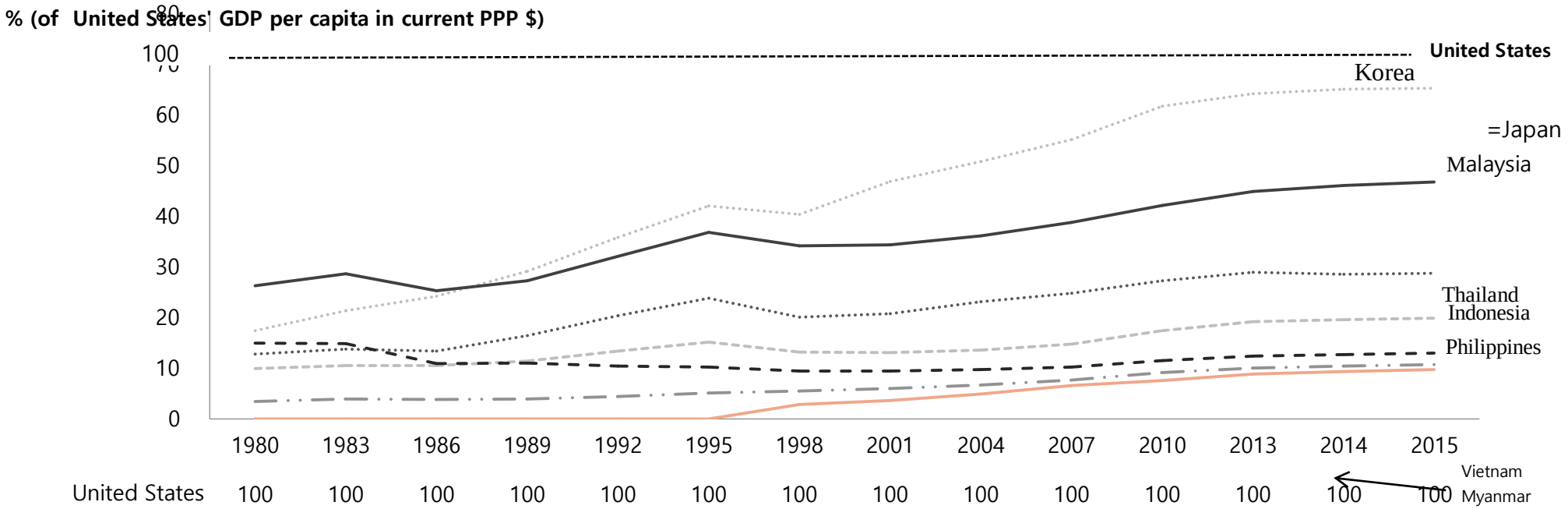
=> He has to leap over it



=> Catch-up Paradox One = To be similar, got to be different:

Korean Catch-up beyond the MIT (Middle income trap)

MIT = 20- 40% % of US GDP per capita (ppp $) for several decades: Thailand, Indonesia, Philippines, Vietnam, Myanmar

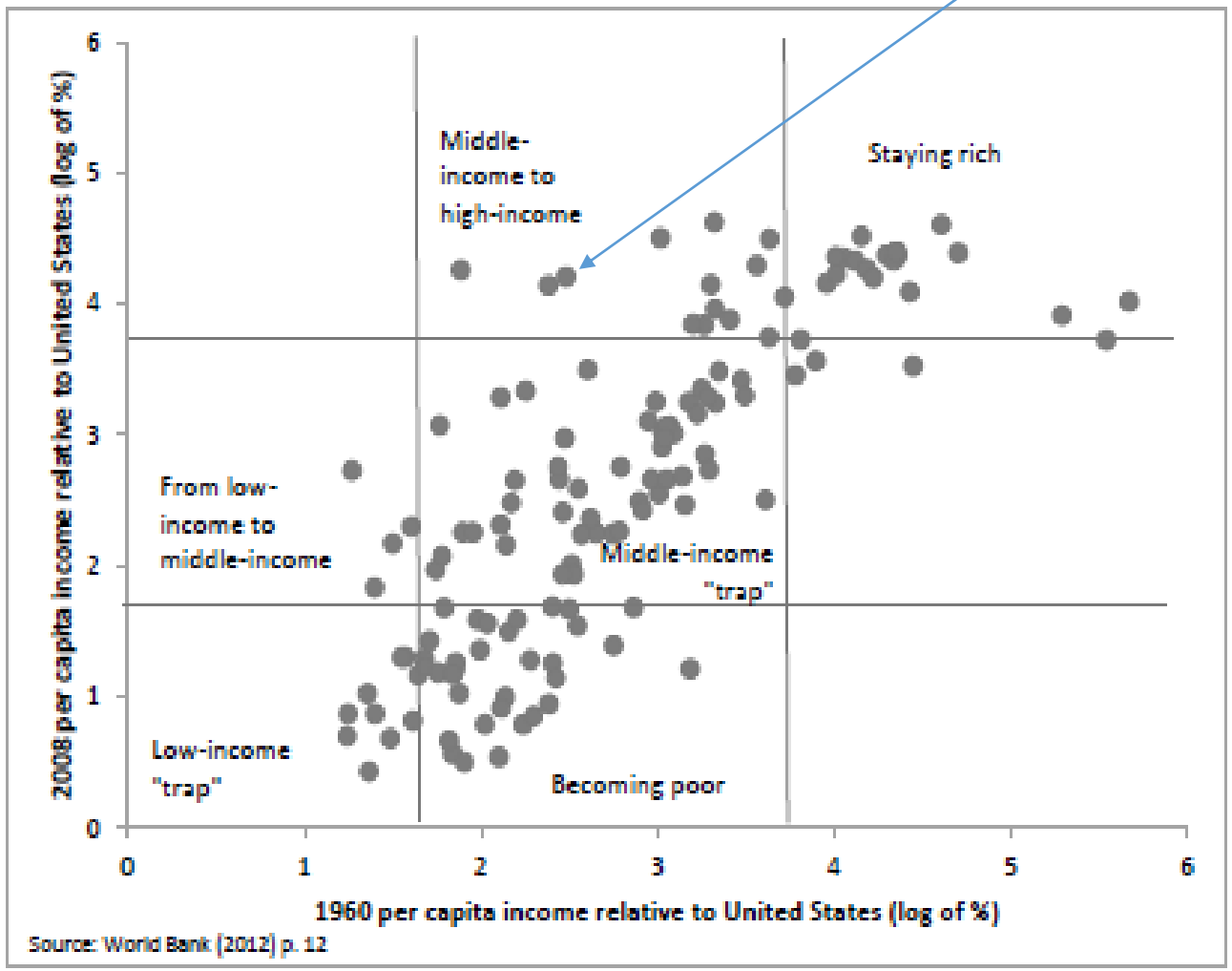


Middle income trap

	1980	1983	1986	1989	1992	1995	1998	2001	2004	2007	2010	2013	2014	2015
United States	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Korea	17,4	21,3	24,2	29,1	35,8	42,0	40,3	46,9	50,8	55,1	61,7	64,2	65,0	65,3
Malaysia	26,2	28,7	25,3	27,3	32,1	36,8	34,1	34,4	36,1	38,7	42,1	44,8	46,0	46,7
Thailand	12,8	13,8	13,4	16,4	20,4	23,8	20,0	20,7	23,1	24,8	27,3	28,9	28,6	28,8
Indonesia	9,9	10,5	10,5	11,4	13,4	15,2	13,1	13,0	13,6	14,7	17,5	19,2	19,6	19,9
Philippines	15,0	14,9	10,9	11,0	10,4	10,2	9,4	9,4	9,7	10,2	11,5	12,4	12,7	13,0
Vietnam	3,5	3,9	3,9	3,9	4,4	5,1	5,5	6,0	6,7	7,7	9,1	10,1	10,4	10,8
Myanmar	0,0	0,0	0,0	0,0	0,0	0,0	2,8	3,6	4,9	6,6	7,6	8,8	9,4	9,8

More MITs (middle income traps) than Poverty Traps

MIT
= per capita income within 20 to 40% range of the US level for couple of decades



Source: World Bank (2012) p. 12

Acemoglue and Robinson, Why Nations Fail ->b/c extractive vs inclusive institution

Bill Gates' book review; he was frustrated;
"this book never explain how to move to more "inclusive" institutions"

Inclusive vs. extractive :
-> relevant more in low income or pre-modern economy
b/c less difference among middle income countries

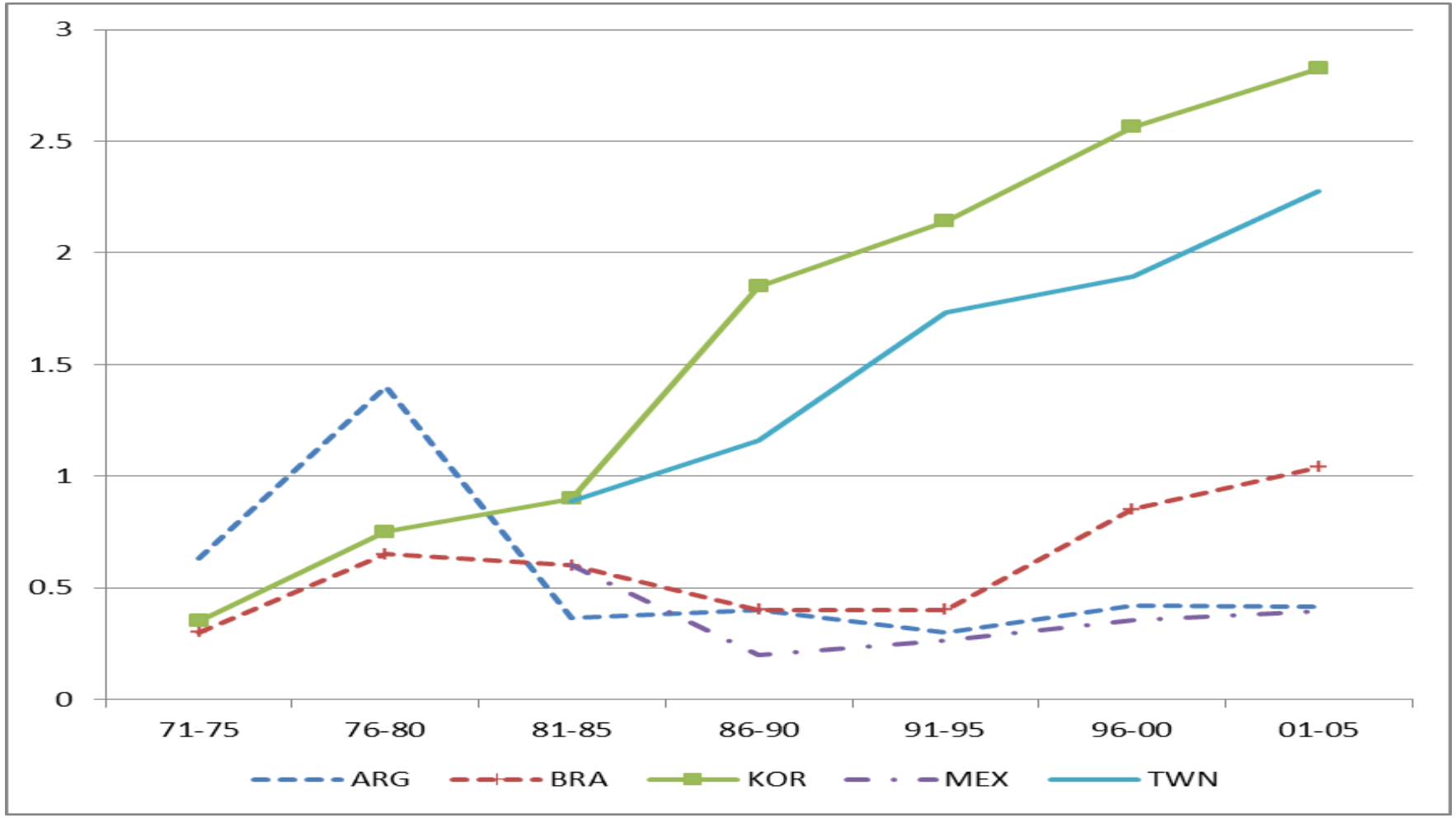
Q: Why Nations Fail at Middle Income Stage?
=> due to not-Innovative systems

Quality of Political Institutions (constraints on executives)

	1965	1980	2000
Korea	3	1	6
Taiwan	2	3	6
Philippines	5	1	6
Thailand	1	3	7
Malaysia	7	5	4
China	2	3	3
India	7	7	7
Brazil	1	1	6
Argentina	3	1	6
Chile	5	1	7
Mexico	3	3	6

Source: Polity IV Dataset; from Lee and Kim 2009 table 1

Similar **R&D/GDP in E Asia and L America in 80s' but changed later**



Lee, Keun & B. Kim (2009, World Development) : different growth at different stages

- Confirms importance of Innovation and high education for middle and higher income countries;

  cf) Institution and basic human capital matter for low and lower middle C's

- Next, beyond just patent counts (innovation measure)
  => details of the NIS (national innovation systems)

  1) Specialization into Short vs long Cycle Sectors
  2) Localization of Knowledge Creation

Neo-Schumpeterian Perspective: National Innovation systems (NIS) and capability building and learning

Nelson; Lundval (1992): defines NIS = elements and relationships

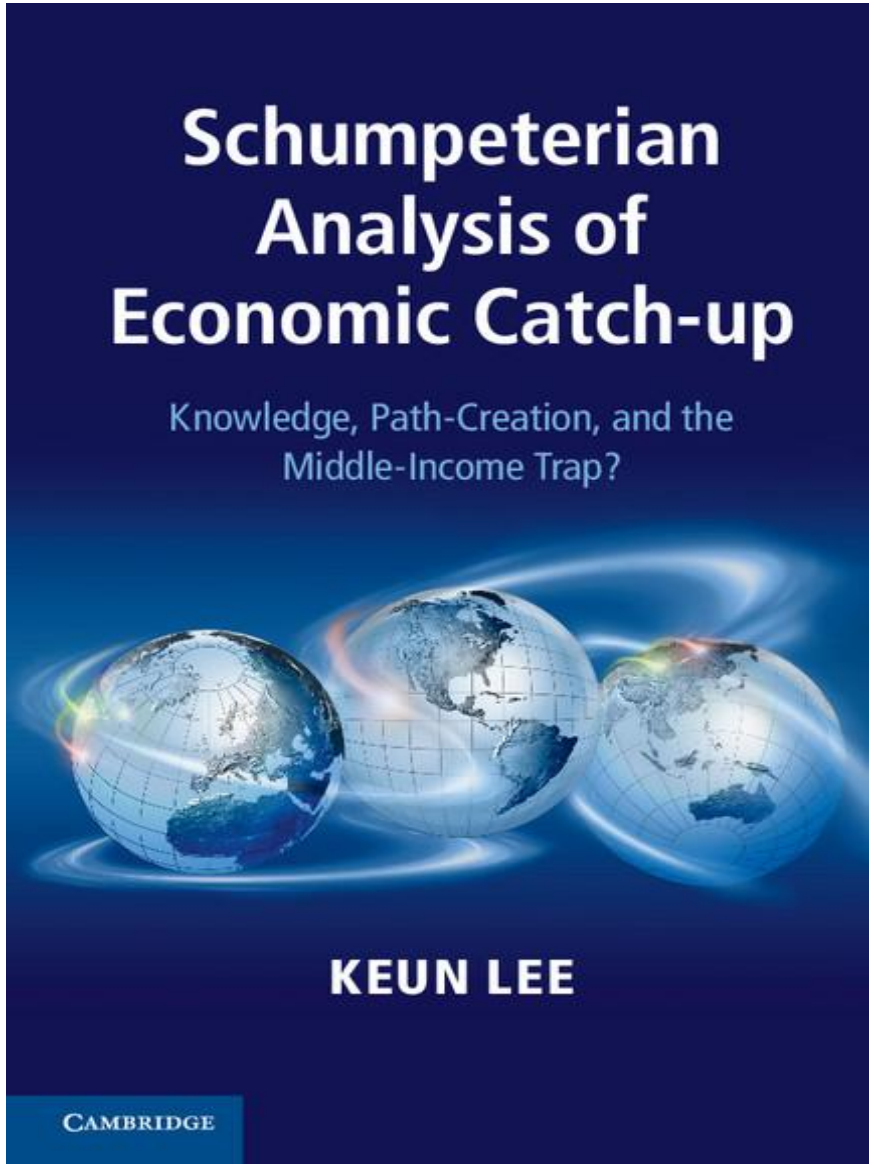
1) which interact in the production, diffusion and use of knowledge
2) rooted inside the borders of a nation state.'

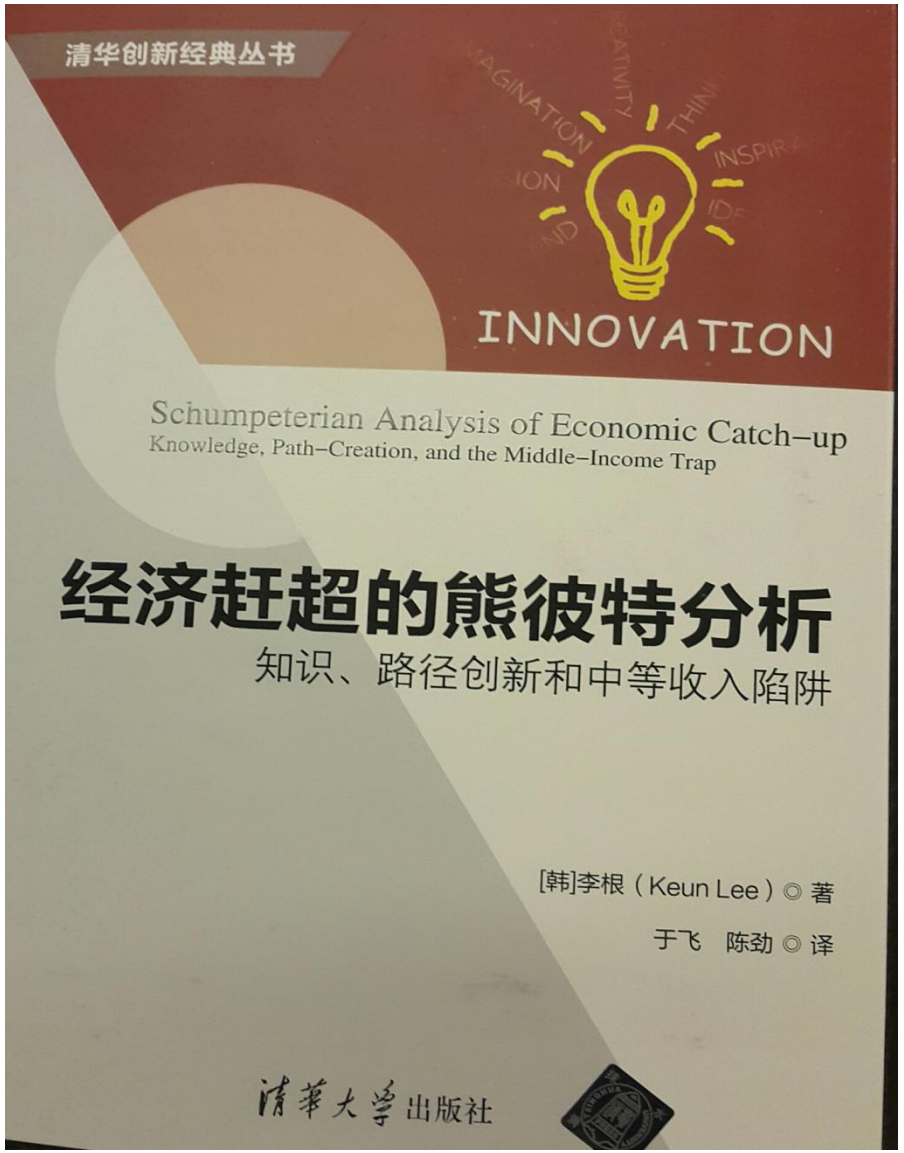
It is about efficiency
in acquisition, creation, diffusion, and utilization
of knowledge.

-> The differences in NIS
determines competitiveness of nations and their economic growth

Innovation systems at 3 Levels: country; Sector; firm

=> 2014 Schumpeter Prize





Thanks to Chen Jin

Different growth mechanisms of rich and poor nations,
and a very "narrow passage" in-between
-> If lost crossing the passage => middle-income trap (MIT)

- Several studies: Lee and Kim (2009); Bulman, Eden, and Nguyen (2014).

-- countries adopt different growth mechanisms at different stages;

- => different convergent paths:
  first path converging to a low-income steady state,
  second path converging to a middle-income steady state;
  third path converging to a high-income steady state .

- Then, what are the key transition variables and policy?
- This book: such transition, possible by taking detours & leapfrogging

Why Detour?
Due to Two failures (firm capability and size failures) and one barrier of IPR (intell. property rights) protection in the North

1) Firm capability failure = intrinsic difficulty of building innovation capabilities in the South.

   cf) radically differs from market failure.

2) Size failure = lack of big businesses in the South,

   that are filled with SMEs (insufficient to be a high income status).

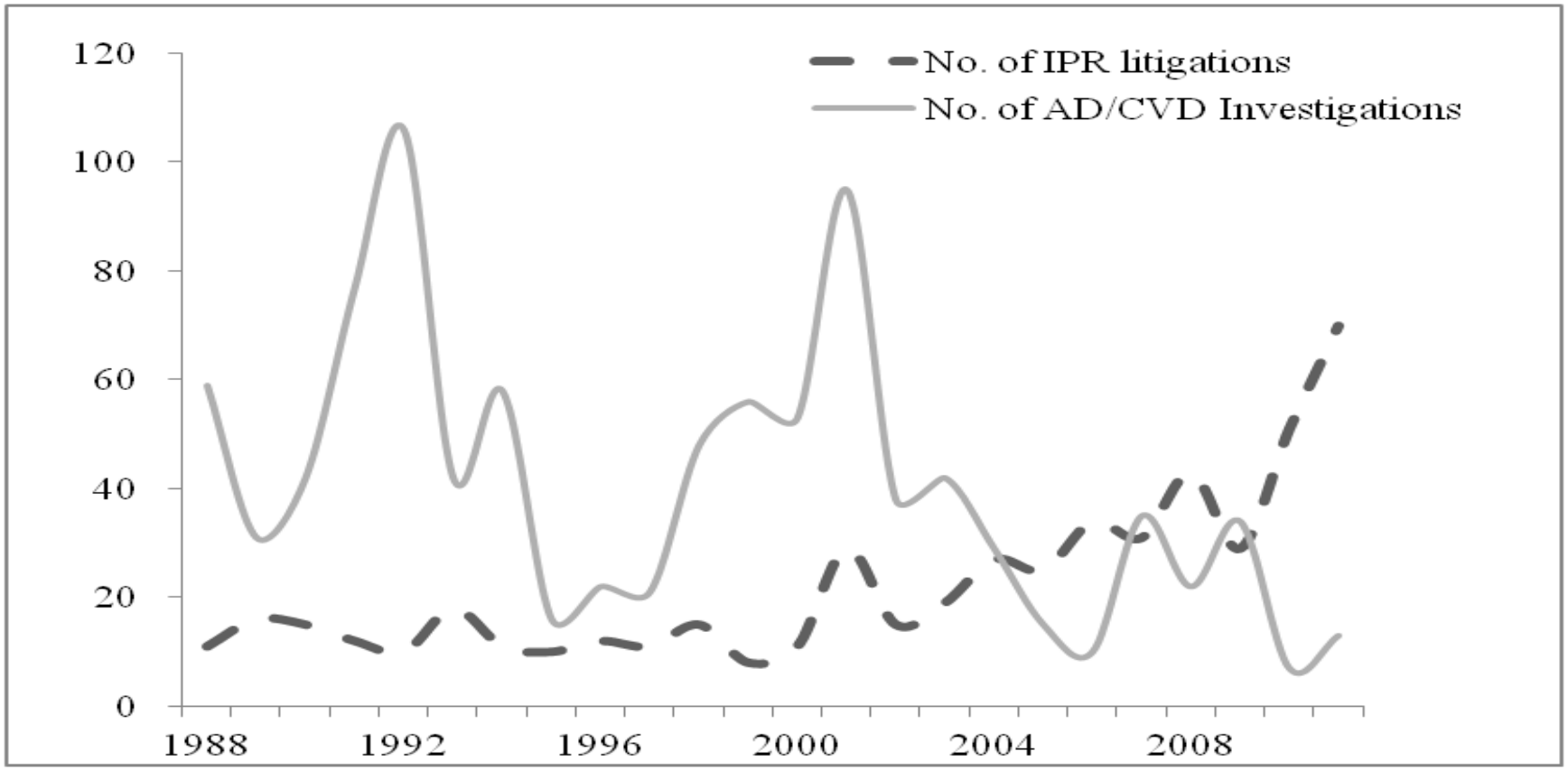
3) IPR in the North as Barrier to Catchup by the South;

   in addition to the ladder (industrial policy) kicked away)

Barrier : IPR in the North as the Barrier to Catch-up by the South

U.S. ITC filings on 'Unfair Imports':
➔ Increases in IPR-related Litigation than anti-dumping

Note: year are based on September year-end (by fiscal year)



An Example from Korea and China facing IPR Barrier

1) Samsung Electronics vs. Texas Instruments Inc. (1986)
2) Huawei vs Cisco in 2011

Texas Instruments Inc., a holder of patents for a "solid circuit" ,

filed a lawsuit in late 80s' against Samsung over a dispute about licensing agreement with TI.

→ ITC ruling: Put a ban on Samsung's memory chip export to the US

→ Samsung : settled with TI by a new patent licensing agreement ($1 billion)

2) Huawei from China; similar dispute with Cisco in 2011!

Huawei became weak in US markets;

went for EU and emerging country markets

Huawei = increasing target of IPR law suit (Haoyu Zhang 2016)

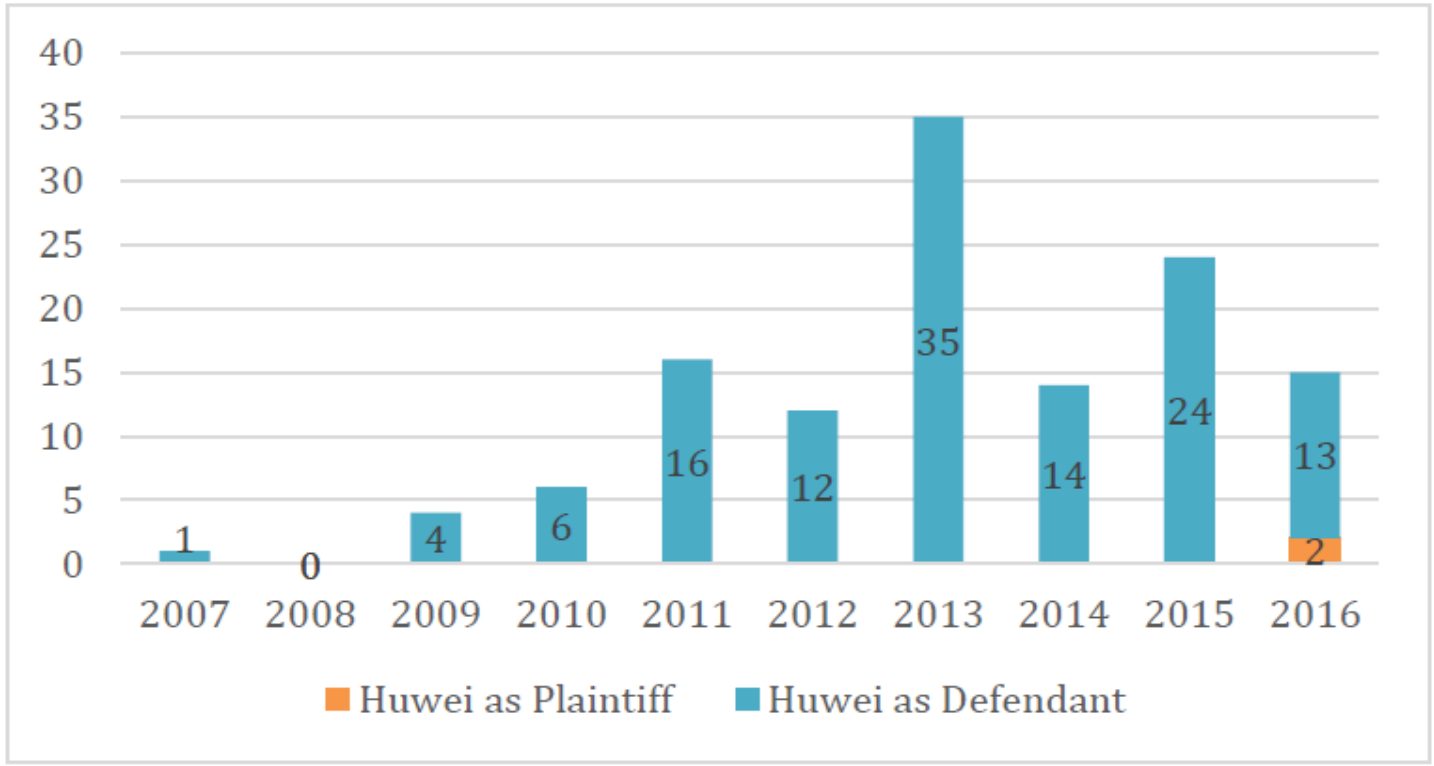
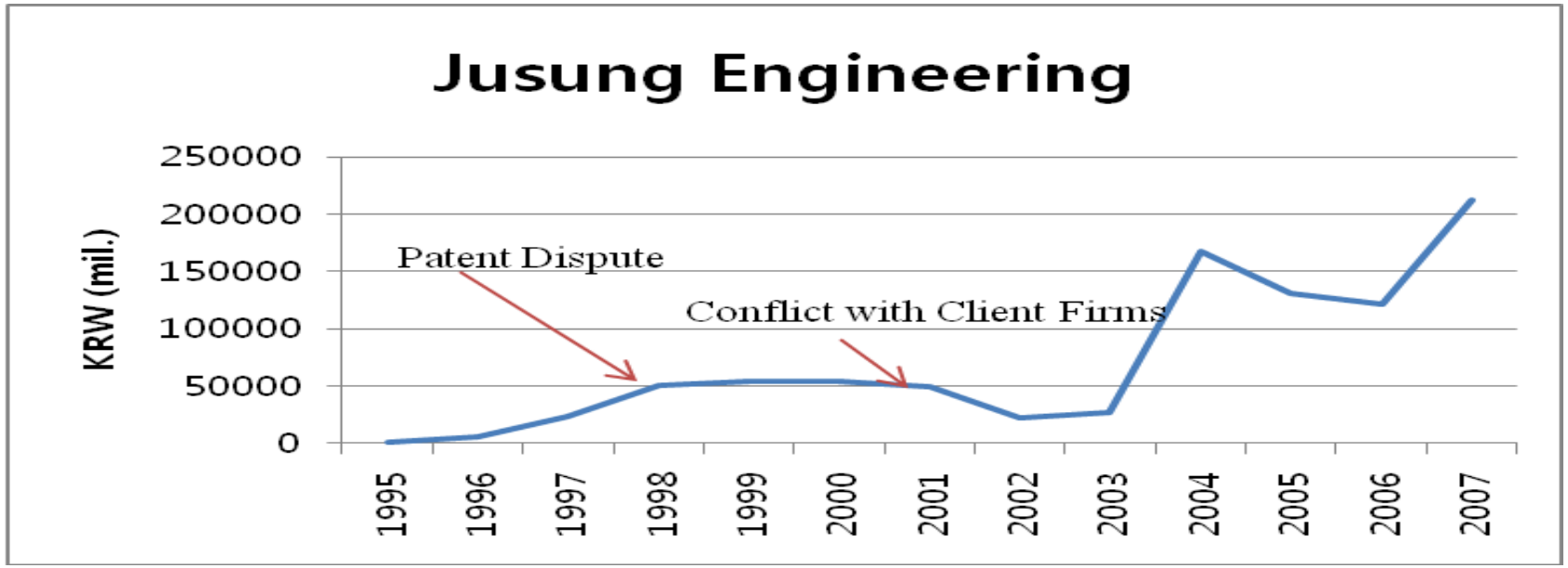
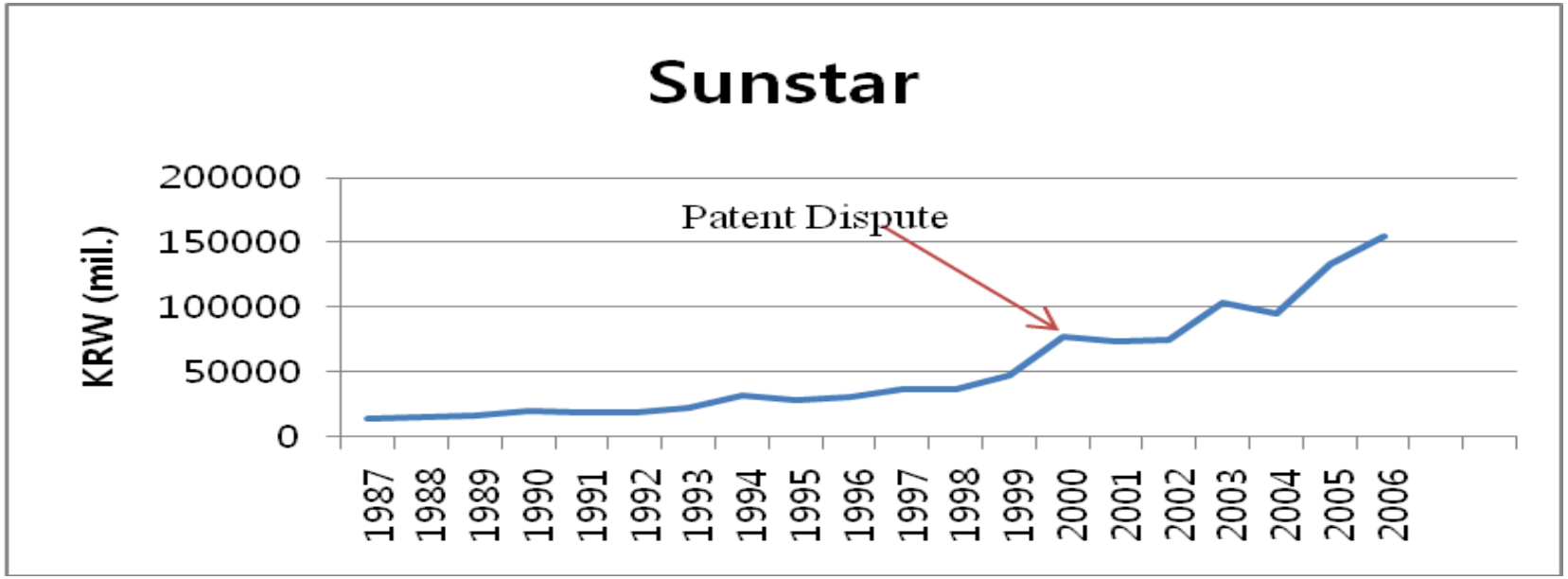


Figure 6: Number of Huawei-involved Intellectual Property Litigations

Two examples in Korean SME (Lee et al 2015 in Industry & innovation): Sales stagnated after IPR dispute with incumbent firms





Econometric proof of the IPR barriers:

Impacts of a (importing) country's IRP protection on other nation's exports to that country

: eg) US IPR on China's exports

(W. Shin, K. Lee, & Walter G. Park, World Economy, 2015)

"When an Importer's Protection of IPR Interacts with an Exporter's level of Technology: Comparing the Exports by the North and South"

Now
from Failures (capability & size) and IPR Barriers

to the 3 Detours:

1) from imitation to innovation,

2) from more GVC to less GVC (more Domestic VC) &more GVC again

3) from short to long cycle sectors

Why 1st detour from imitation to innovation?
Without capability, strong IPR -> nothing happen

1) General: Innovation vs. diffusion

=> strong IPR vs. weak IPR protection debate!

2) Development-specific perspective:

Early stage: tech imports/transfer (strong IPR) vs. imitative R&D (weak);

Later stage: local innovation (strong) vs. local diffusion (Weak)

3) different roles of several forms of IPRs:

Patents, petite patents (utility models), Trademarks.

Petite Patents (=UM: utility models)" = German invention as a latecomer against UK

= recognition of minor, adaptive innovation with less duration

Utility Models (petit Patents) vs. (regular) Patents

Utility Models	(regular) Invention Patents
Second-tier protection for minor inventions; The inventive step required is small; a practical or functional advantage over existing prior art	Granted for inventions that are novel, non-obvious, and have industrial applicability
Processes or methods of production are typically excluded	Cover products and processes,
Typically 6 – 10 years duration of protection	20 years duration from the date of application
Less expensive to apply for and do not require substantive examination	Undergo substantive examination, and are costly to obtain (filing fees, search and examination fees, attorney costs, and translation fees, where applicable)
Eg) Germany, Japan, Korea, China, Adopted in countries with continental law tradition; cf)Thailand in 1999	Practiced in UK, USA, India under Anglo-Saxon Legal tradition

Cross-country panel analysis
with patent rights index & petit Patent (UM utility model) dummy

Kim YK, Keun Lee, Walter Park (Research Policy 2012), "Appropriate Intellectual Property Protection and Economic Growth in Countries at Different Levels of Development,"

- Innovation (US patents) on:
- 'G-Park' Patent Right index and cross terms with a low/middle income country dummy (or high income dummy)

- utility model (UM) dummy for countries that adopted the UM system and its cross term with a low/mid income country dummy

- => Patent rights not significant for lower income groups,
  but significant at upper middle and higher income C's;

- while UM country dummy, positive and significant for lower group, but not significant for higher groups.

Detour 2: for domestic value chains
More GVC->Less GVC for more DVC-> More GVC again

What matter is not more participation at GVC (Gloval Value Chain)
but creating more domestic value-added
based on learning from the GVC, (otherwise, stuck in low-ends; OEM)
and that is the way out of the middle income trap (to ODM, OBM)

after some domestic value-chains, you can be more global again as you send your factories abroad due to rising wages rates

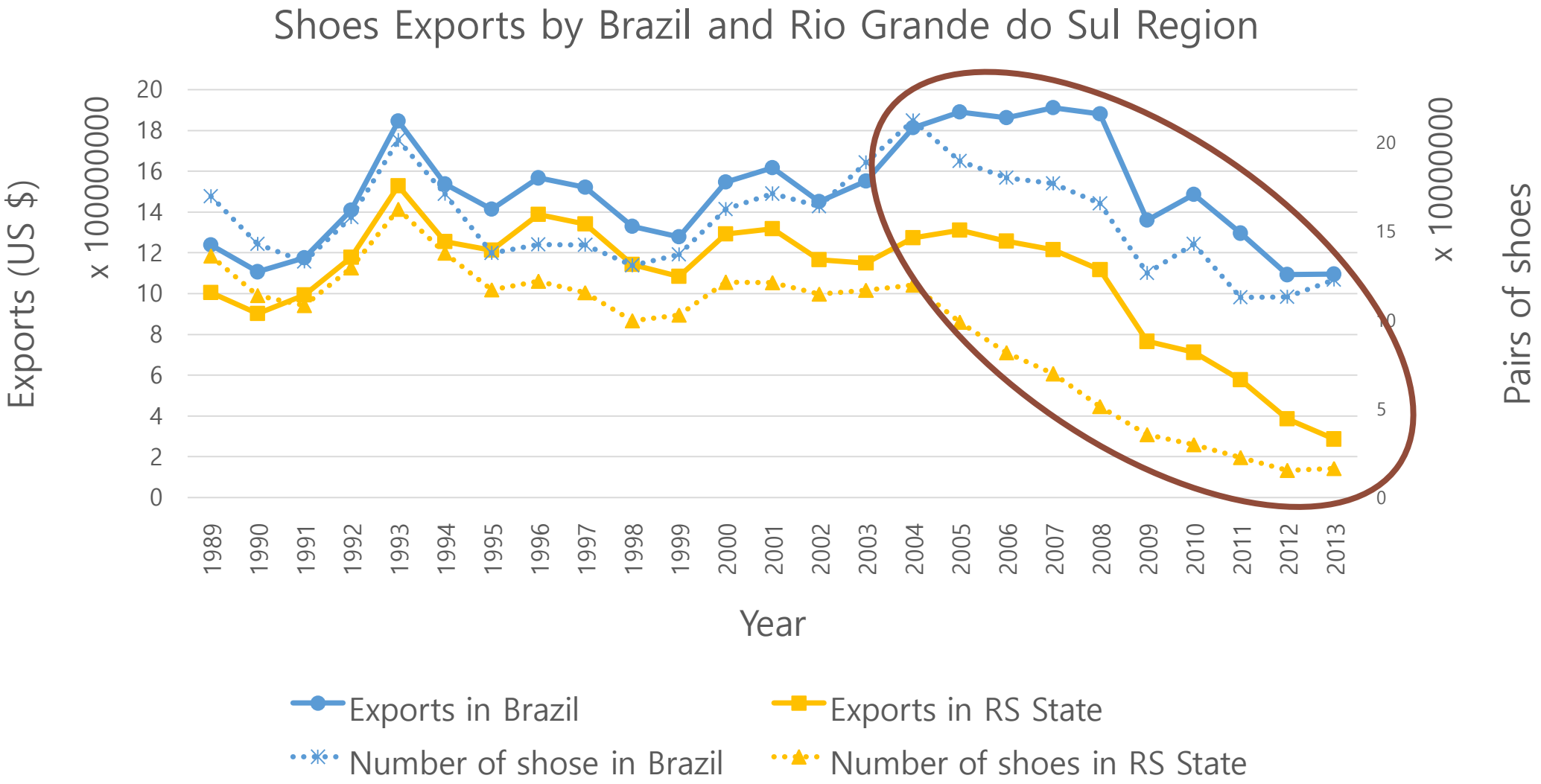
Alternative to the linear view on GVC (the more the better)

My view: Non-linearity:
=> more GVC-> stage of less GVC (creating domestic V-add) -> again more GVC (internationalization of production).

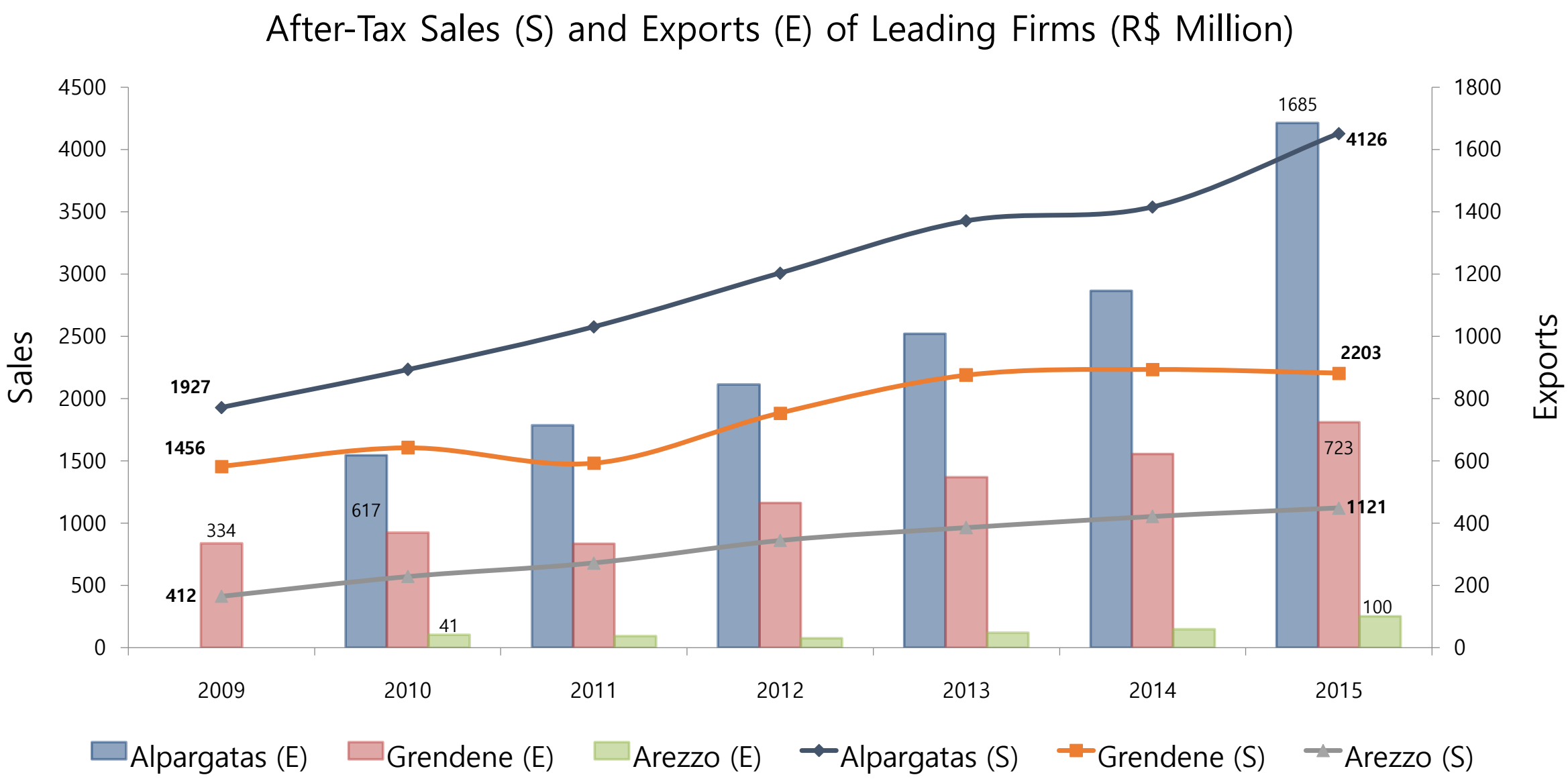
=> Lee et al, 2017, ***European J of Development Research,*** **" From the GVC (Gloval Value Chain) to Innovation Systems for Local Value Chains and Knowledge**

Shoes Exports by Brazil & Rio Grande do Sul Region: 1989 to 2013:

-> decline since the early-mid 2000s with rise of China



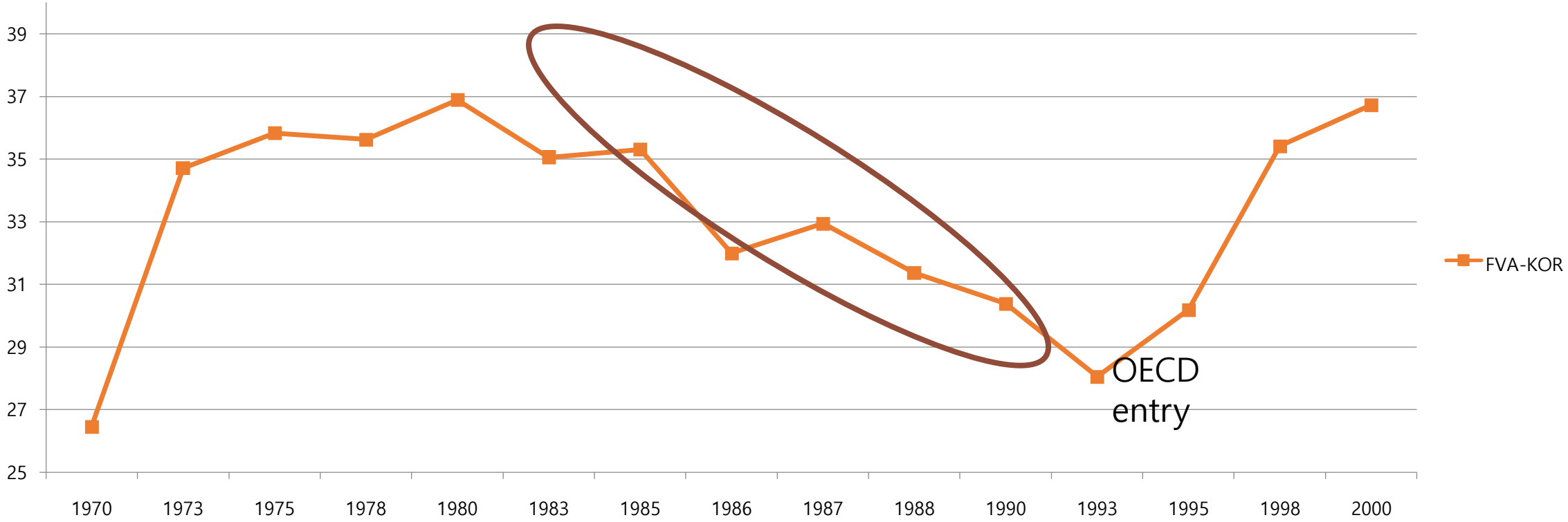
Continued Expansion of several leading firms: on independent upgrading road



Trend of GVC participation in Korea:
"more-less-more again"
about 10 years of Less: from 35% in 1980 to 28% in 1993

Measured by FVA = share of foreign value-added in gross exports

Korea FVA Hummels, Ishil and Yi (2001)

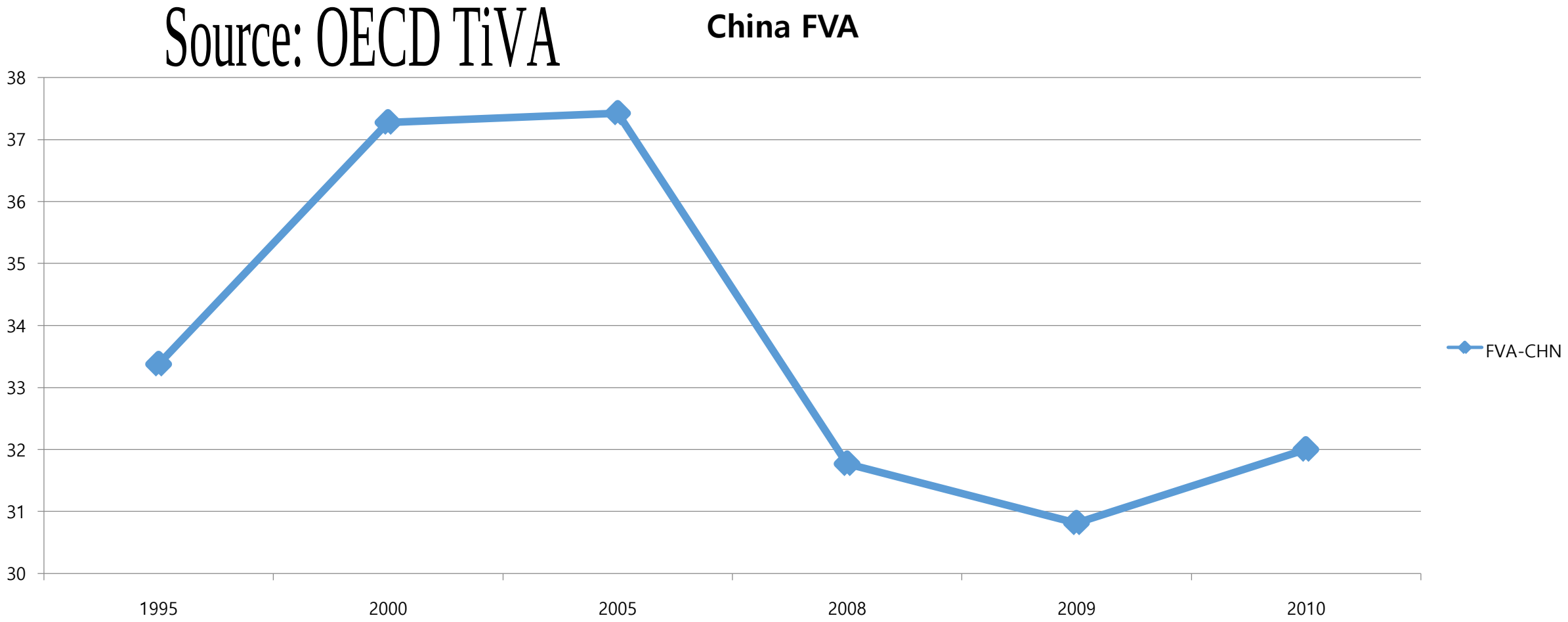


Trend in China: similar but bottom at later than Korea:

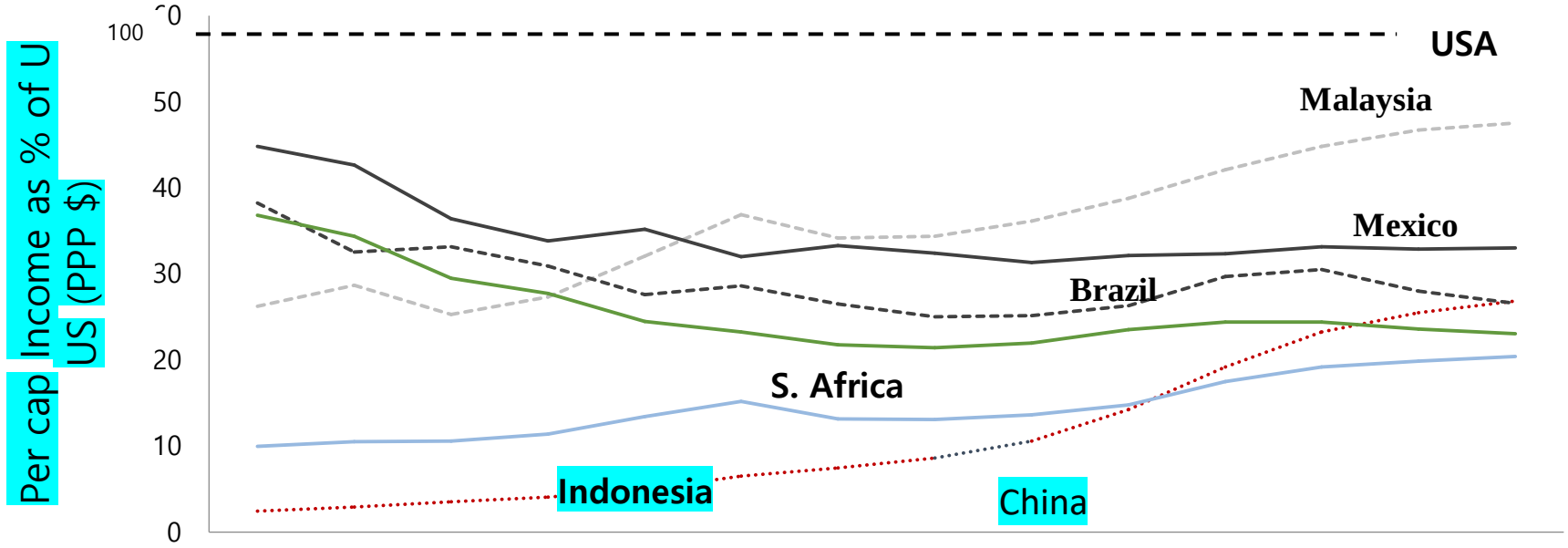
Peak at 37% in early 2000s to 31% In late 2000s

Taiwan (‘86) ->Korea (‘93)->China (2009)

Source: OECD TiVA



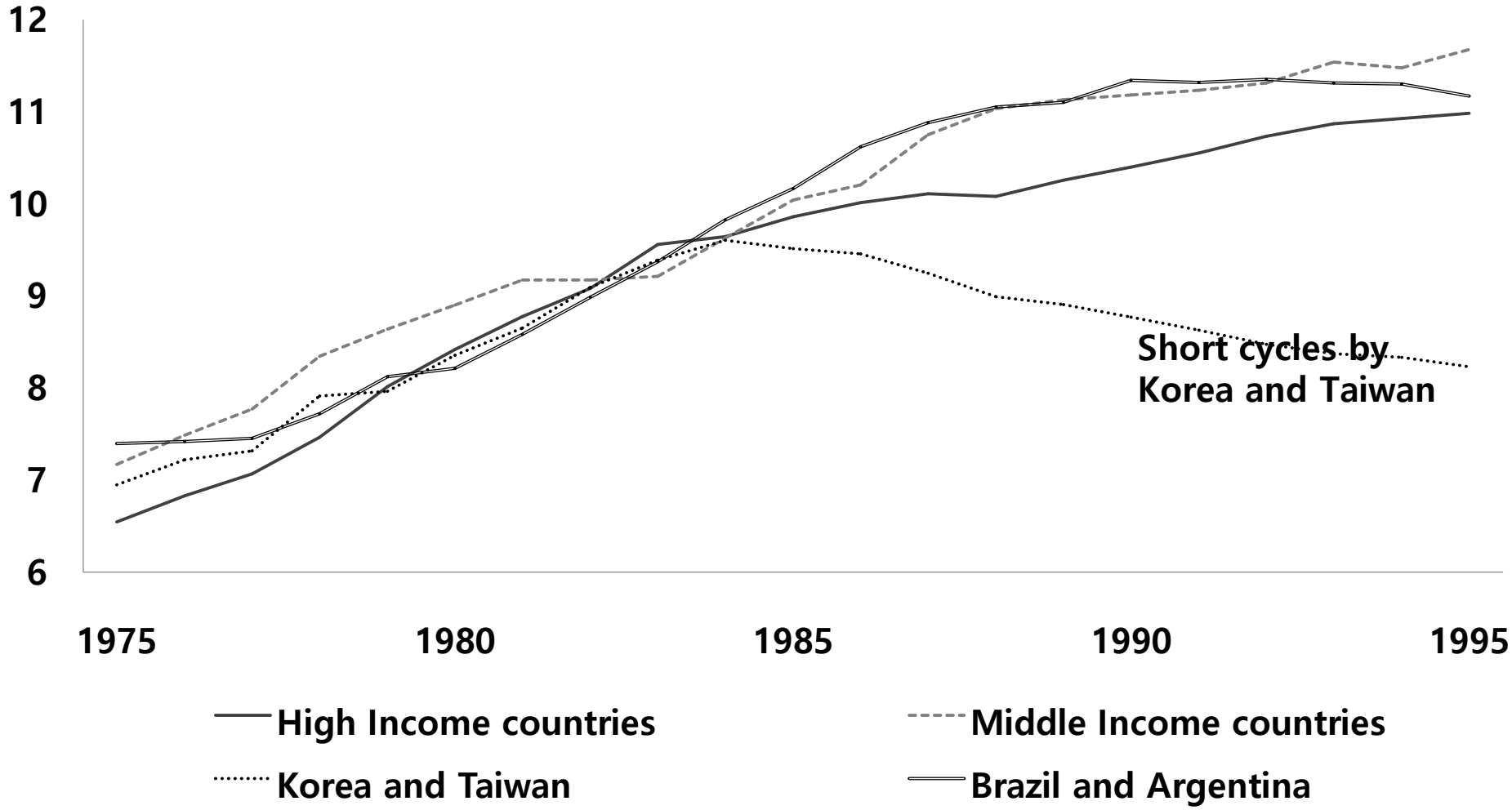
Weak NIS -> Middle income Trap (MIT) in many E. Economies
Mexico =keep falling despite NAFTA: 45->33%;
China beyond MIT? 2010 China = 20% of USA Level; now 27% Keep catching-up



	1980	1983	1986	1989	1992	1995	1998	2001	2004	2007	2010	2013	2015	2016
미국	100	100	100	100	100	100	100	100	100	100	100	100	100	100
말레이시아	26,2	28,7	25,3	27,3	32,1	36,8	34,1	34,4	36,1	38,7	42,1	44,8	46,7	47,5
멕시코	44,8	42,6	36,4	33,8	35,1	32,0	33,3	32,4	31,3	32,1	32,4	33,1	32,9	33,0
중국	2,5	2,9	3,5	4,0	5,0	6,5	7,4	8,6	10,6	14,2	19,2	23,3	25,5	26,8
브라질	38,2	32,5	33,2	30,9	27,6	28,6	26,5	25,0	25,1	26,3	29,7	30,5	28,0	26,5
남아공	36,8	34,3	29,5	27,7	24,5	23,3	21,8	21,4	21,9	23,5	24,4	24,4	23,6	23,0
인도네시아	9,9	10,5	10,5	11,4	13,4	15,2	13,1	13,0	13,6	14,7	17,5	19,2	19,9	20,4

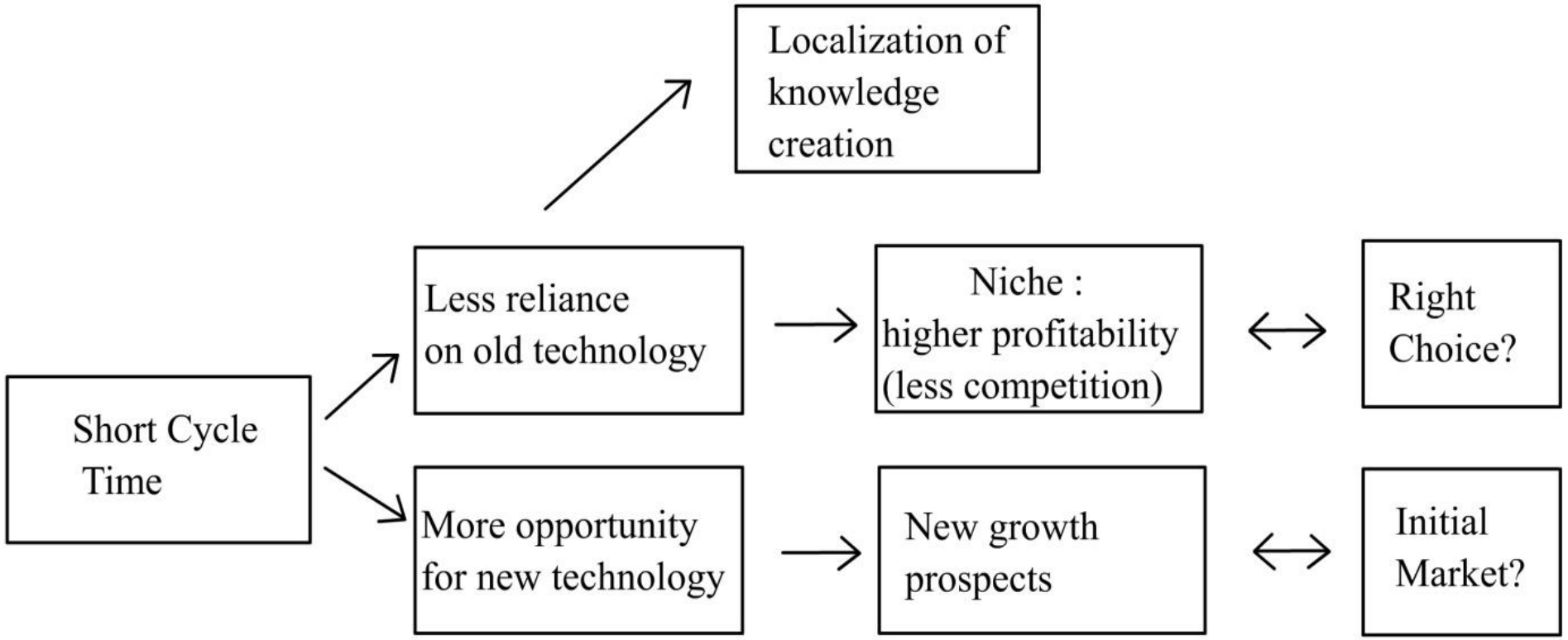
Detour 3: From Short to Long Cycle Technologies

Specializing in terms of Cycle Time of Technologies



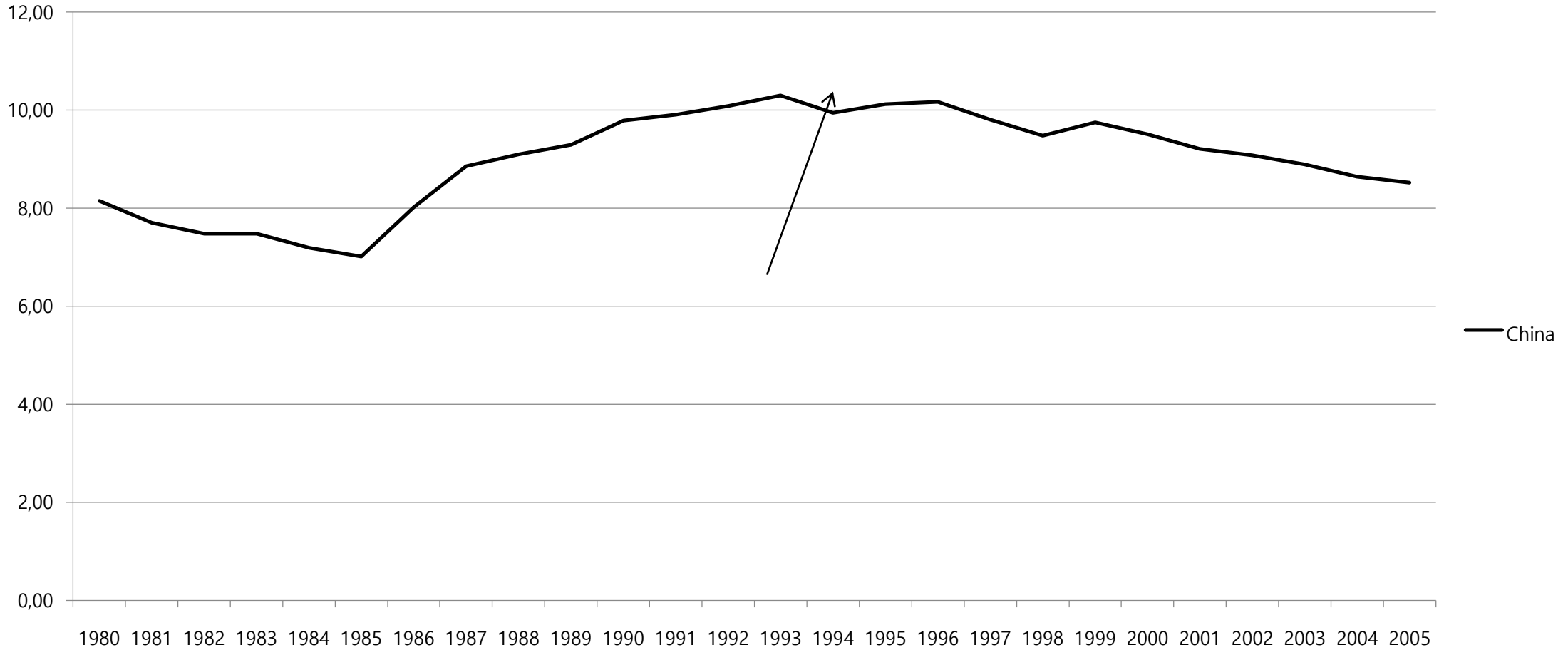
Why Getting into Short cycles matters: Less entry barrier and better growth prospects

Figure 6-2 : Criterion of Technological Specialization - Why the Sectors of Short Cycle Matter



Proxy variable | Criterion of specialization | Advantages | Risks

Lee's Turning Point & Middle income trap in China



Top 10 Classes of G5 vs Korea-Taiwan ->no overlap

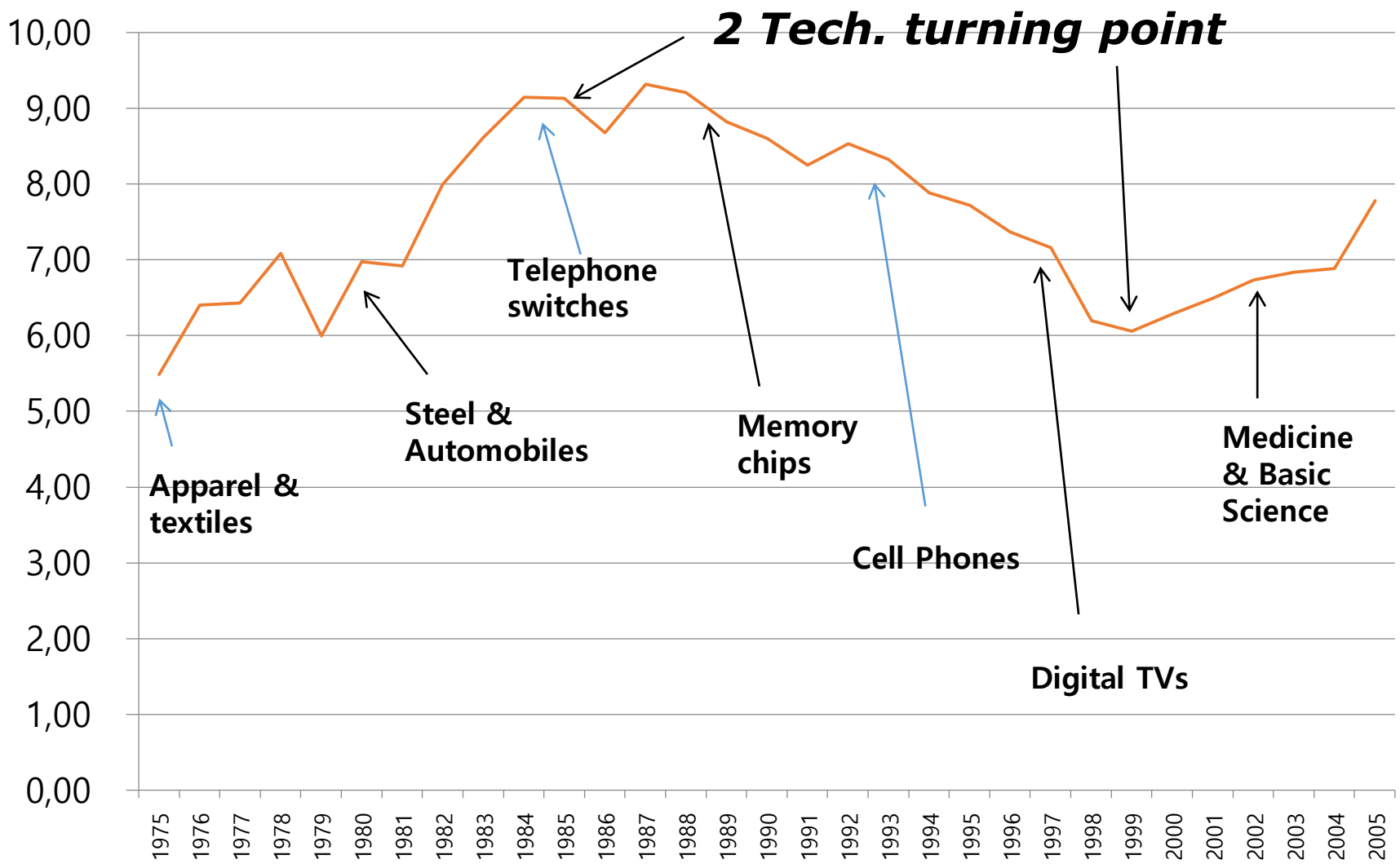
G5	Class	Class Name	Patent count
1	514	Drug, Bio-Affecting and Body Treating Compositions	10349
2	428	Stock Material or Miscellaneous Articles	3883
3	73	Measuring and Testing	3789
4	123	Internal-Combustion Engines	3479
5	424	Drug, Bio-Affecting and Body Treating Compositions	3389
6	210	Liquid Purification or Separation	2853
7	435	Chemistry: Molecular Biology and Microbiology	2852
8	250	Radiant Energy	2639
9	264	Plastic & Nonmetallic Article Shaping or Treating	2349
10	324	Electricity: Measuring and Testing	2325

Korea-Taiwan	Class	Class Name	Patent count
1	438	Semiconductor Device Manufacturing: Process	1189
2	348	Television	712
3	439	Electrical Connectors	408
4	257	Active Solid-State Devices (Transistors, Solid-State Diodes)	374
5	362	Illumination	374
6	280	Land Vehicles	355
7	365	Static Information Storage and Retrieval	346
8	70	Locks	340
9	360	Dynamic Magnetic Information Storage or Retrieval	313
10	482	Exercise Devices	311

Korean Detour from Short to long cycle technologies

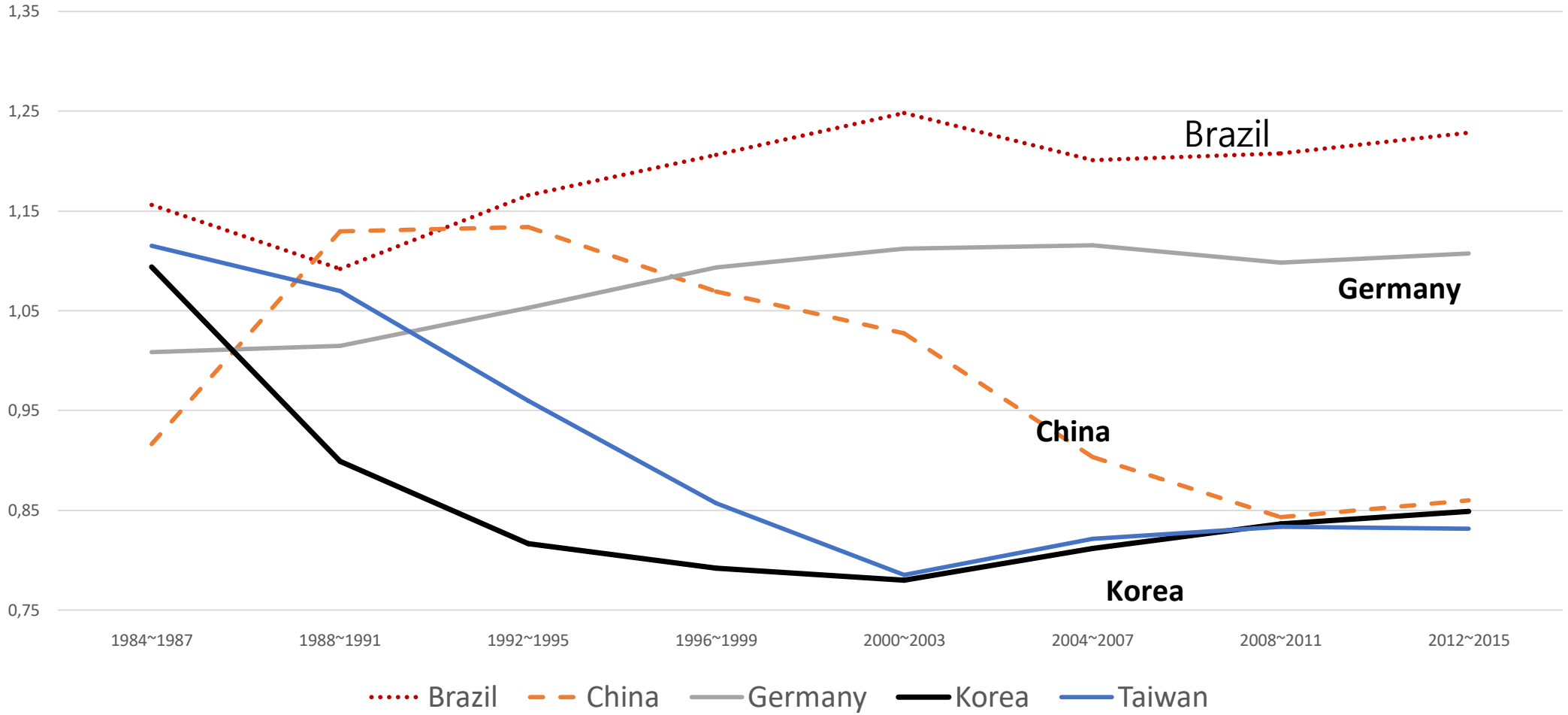
1st in the mid 80s: to short cycle sectors

2nd in the 2000s: to long cycle sectors; ex. Samsung's biosimilar



(Normalized) Average Cycle Time of Technologies: mid 1980s to 2010s

Table 3-1 Period average cycle time of technologies in selected economies



From detours to Leapfrogging at the final stage

= ‘flying on a balloon
when the ladder to catch-up is kicked away.”

From detours to Leapfrogging at the final stage

Leapfrogging = latecomers doing something new ahead of the forerunners and thereby leap over the incumbent.

- Why need it? Because detour may not be sufficient;
- Also, as you get closer to frontier, difficult to expect tech. transfer from the incumbent

- **2 benefits from Leapfrogging**

1) A way to overcome IPR barriers,
 - no need to rely on IPR held by the incumbents
 - IPR tend to reside in public domains (academia) during the transition period ; or no dominant IPR holders
2) A way to avoid direct competition with incumbent
 by entering new markets ahead of incumbents

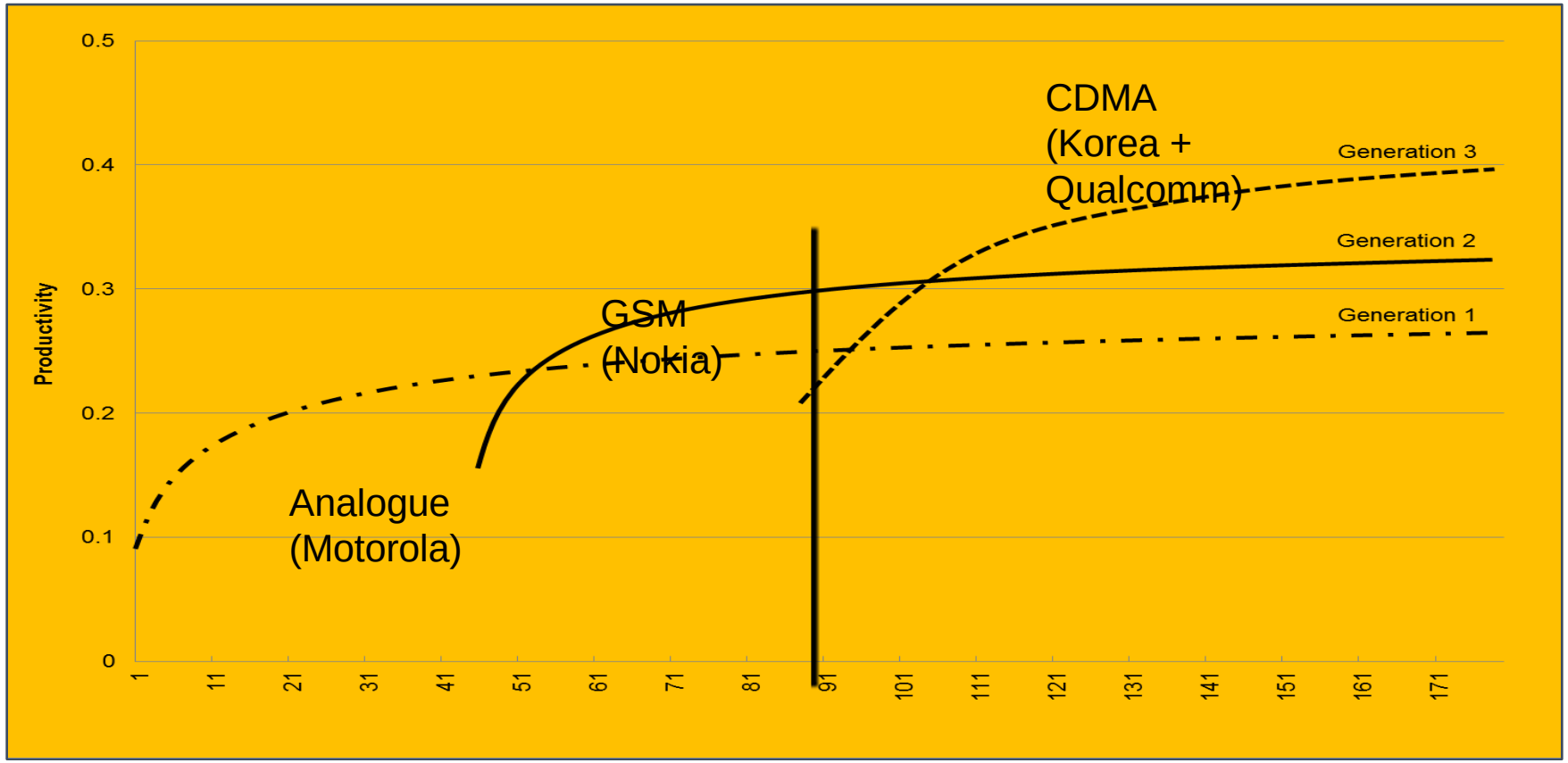
Risk and Potentials of Leapfrogging (intra-sector & inter-generation):

1) Path-following = entry with oldest generation tech (1G)

2) Stage-skipping = entry by up-to-date generation 2 Tech

3) Path-creating /leapfrogging = entry by generation 3 technology;

eg) Samsung skipped generation 1 and 2 but jumped generation 3 using Public-private joint R&D to share risks



Variations of Economic Leapfrogging

1) Compared with the Path of the Incumbent (Lee and Lim 2001): path-following

- a) Stage-skipping in a given trajectory
- b) Path-creating into a new trajectory

2) Two variations of Path-creating Leapfrogging (Lee and Ki 2017)

- a) Follow-on Innovation-based Leapfrogging
- b) Radical innovation-based Leapfrogging

3) Inter- vs. Intra-sectoral leapfrogging (Lee 2019)

- **a) Intra-sector (across generations of tech; less risky)**
- **b) Inter-sector (cf. Long jump across prod space in Hidalgo; more risky)**

4) Leapfrogging in GVC: OEM to OBM (skipping ODM)

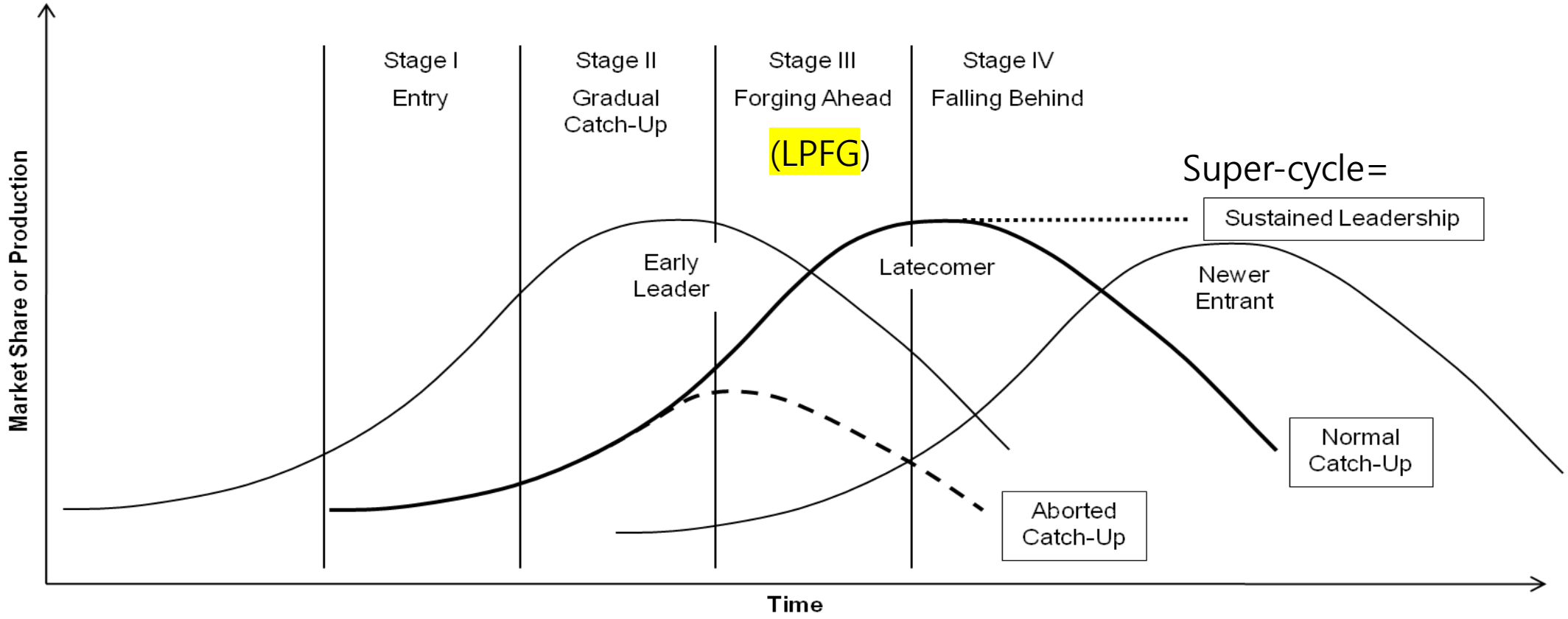
5) Macro (Country) vs Micro (Firm)-Level LPFG:

India: Agriculture to Services (skipping Manufacturing)

WIPRO: Palm oil -> (PC making) -> IT service

Leapfrogging in Catch-Up Cycle (Lee & Malerba 2017)

3 Windows of Opportunity, 3 strategies, 3 Cycles



Each cycle is that of a leading firm or a collection of firms in a nation; -> a new cycle replacing an old cycle

Catch-up Cycles & Leadership changes in 6 sectors (Lee and Malerba 2017)

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

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

Leapfrogging/stage-skipping in all 11 cases of leadership change;
=> not sufficient but necessary condition for leadership change

1) stage-skipping (3 cases):

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

2) Leapfrogging 1= radical, endogenous innovations

5 cases: cell phones in Nokia vs. Motorola;
mirrorless camera in 2000s;
Jets in Canada/Brazil; Wines by new worlds

3**) Leapfrogging 2: adoption and follow on innovations**:

3 cases; steel in Japan (BOF method) vs. US steel
Samsung to adopt Android vs. Nokia
Camera in Japan to adopt SLR & improve vs. German

leapfrogging = 'flying on a balloon =>need to wait for good weather (window of opportunity)

- As we cannot fly balloons everyday; have to wait for a good weather
  => 3 windows of opportunity
  (technological; . Demand window; gov't regulation/Ind policy);

Q: When best chance for success?
  => some incumbent fall into the trap /lock-in with current technologies

So, best chance for success is:
  disruptive innovations + incumbent traps

Pre-conditions and Risks for Leapfrogging:

1) Leapfrogging similar/Different from Long jump ;

-- intra- and inter-sector leapfrogging

the latter (intra-sector) leapfrogging is a jump not to different sectors/spaces but to different generations of technologies within the same sectors;

- So, less difficult than long jumps to different, unrelated sectors

  But need to have built up, sector-specific capabilities

  In other words, You got to have strong "Wings" to fly

  ; otherwise, you might fall through the 'windows', rather than fly.

Leapfrogging =another way of avoiding competition with incumbent

cf) Product space literature: less concern for entry barrier and competition upon entry: not all the neighboring spaces are feasible to enter; => entry possibility: short cycle matter

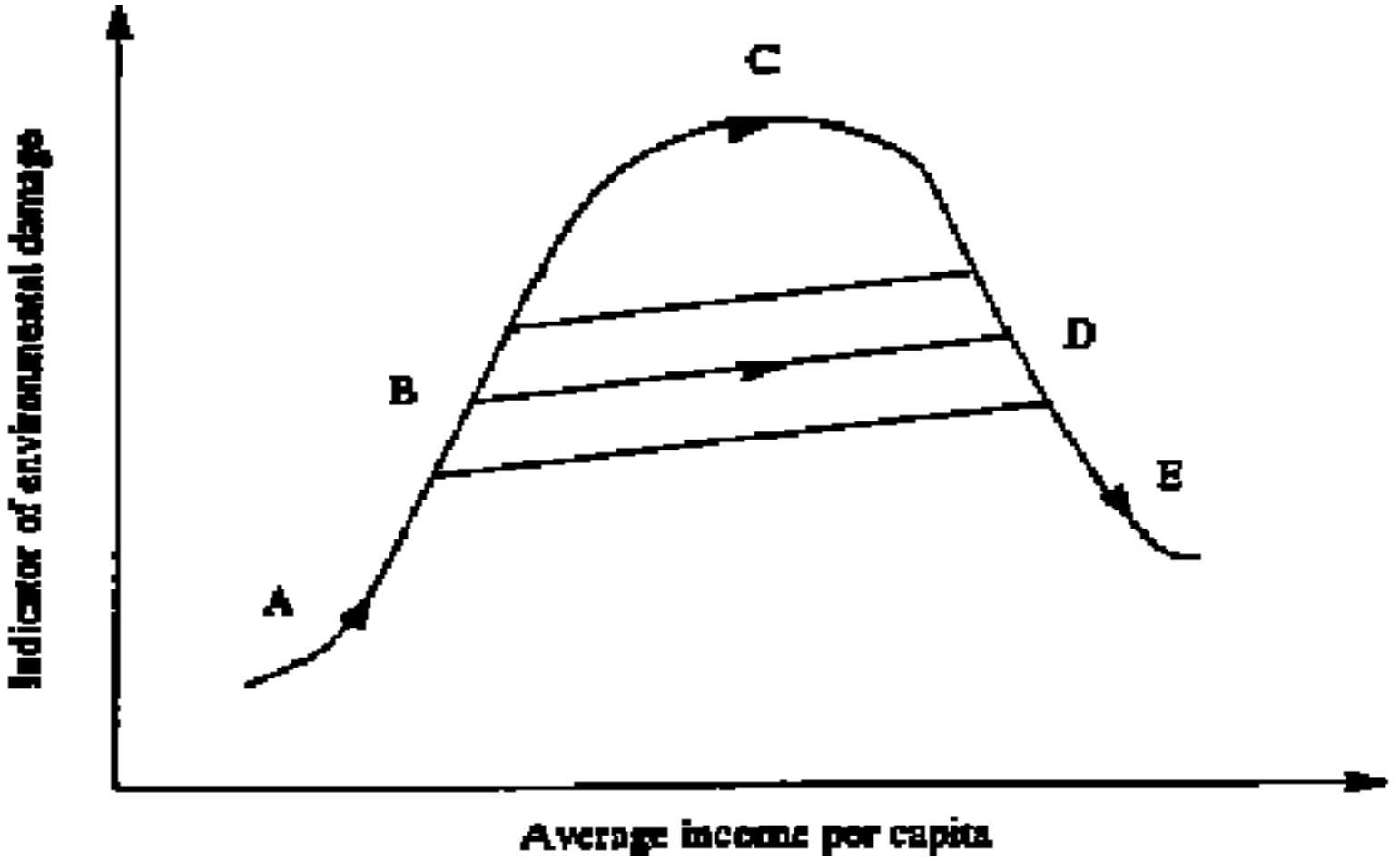
2) Need to take care of the 2 Risks (Lee et al 2005).

A) risk of choice among alternative technologies;

B) existence of initial markets

=> government activism is called for, unless you have patient capital (Mazukato)

Stage-skipping and Leapfrogging in the Environmental Kuznets Curve



Source: adapted from Assefa (2011)

Now Another Paradigm Shift = Best Time for Leapfrogging

1) New Energy Revolution (Renewable Energies)
to replace fossil-fuel
2) 4th Industrial Revolution =Fusion of Technologies (IT, BT, NT,)

-> already happening;
"former latecomers are no more latecomers"

1) E-fishing in Indonesia: Using IoT to provide efficient feeding of fishes

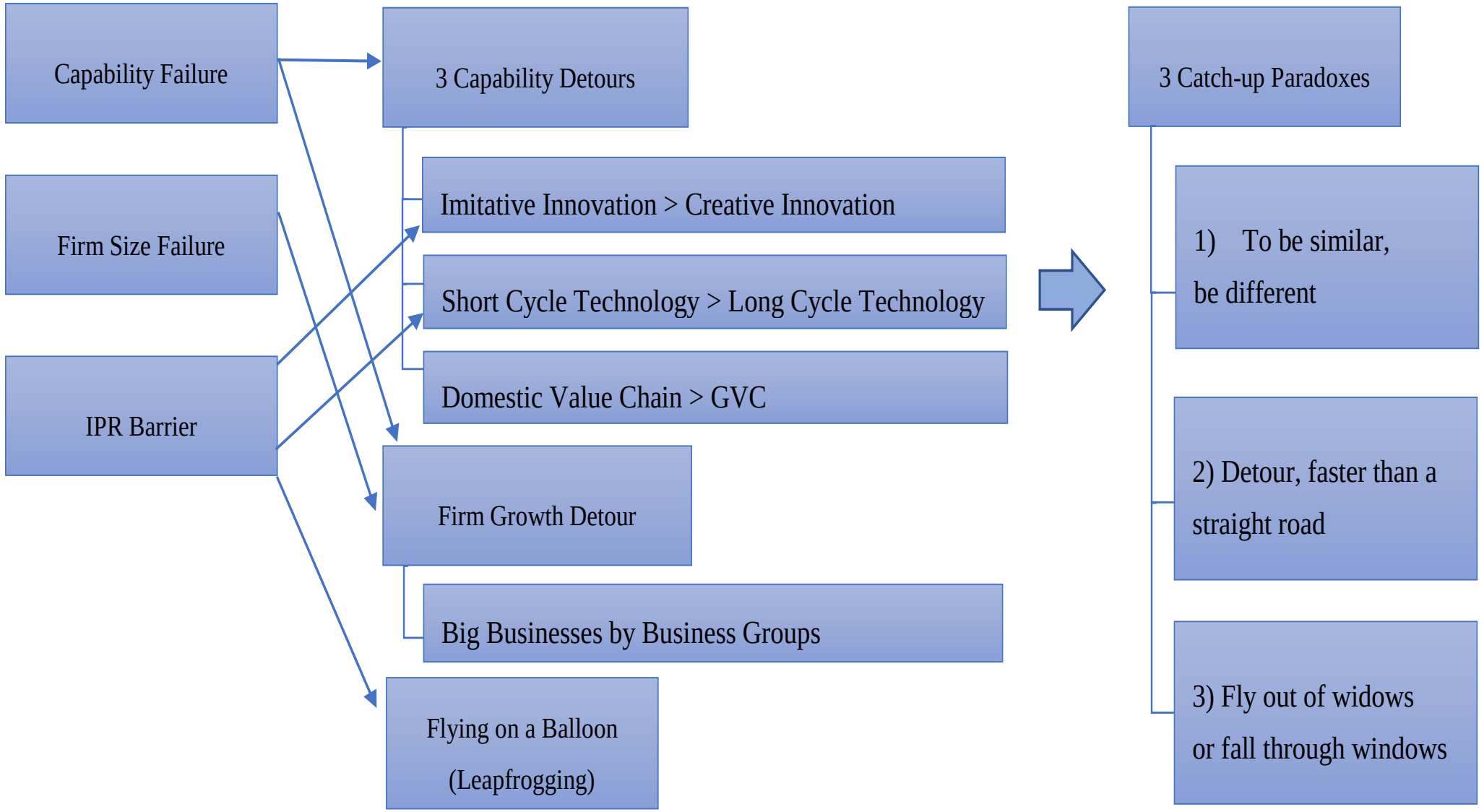
2) Solar thermal heating in China
- Rural area bypassed the stage of gas or electricity based heating but solar thermal heating.

3) Bio-Ethanol and Bio-Diesel in Brazil
(EMBRAPA: soils suitable for sugar cane cultivation

4) Burkina Faso: developed insect-resistant GM cotton that has significant reduced the amount of insecticides; skipped the first generation of GM cotton for second generation

4) Keyna: M-Pesa (mobile banking); M-copa (Solar energy for rural)

Figure 1-3. Art and Paradox of Economic Catch-up => **A Comprehensive Theory of Catch-up (Lee 2019)**



Just Online: *Journal of Evolutionary Economics*

National innovation systems, Economic complexity and Economic growth:

Keun Lee (Seoul National University)
With Jongho Lee

5 Variables to measure the NIS (Lee 2013): Basis for a composite index of NIS

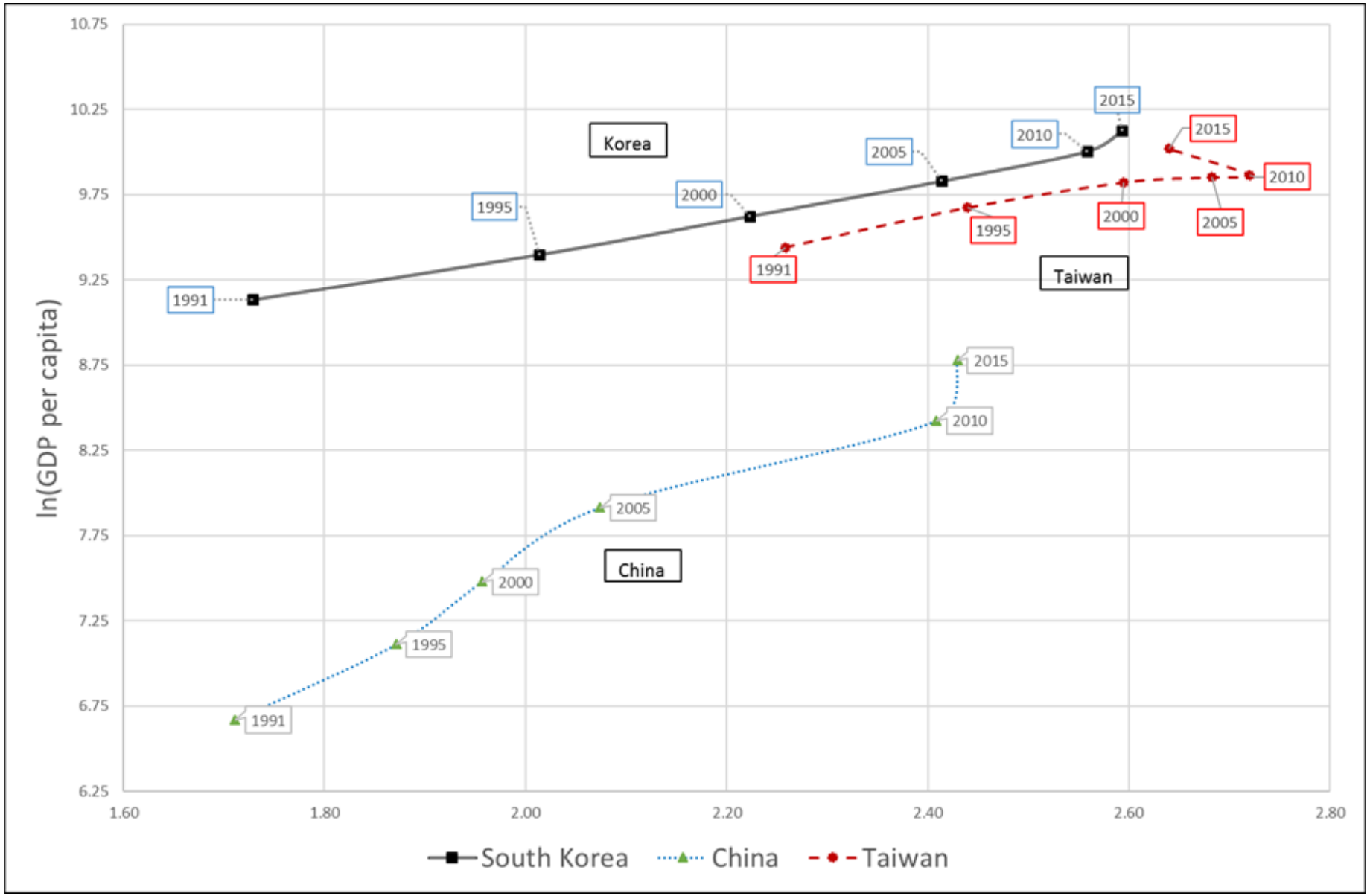
Localization(Intra-national creation and diffusion) of Knowledge (vs. reliance on foreign sources)
Dispersed vs. Concentration = 1-HHI of knowledge creation (by assignees)
Short vs. long cycle technologies Specialization
Originality (high if citing and combining widely) (= Technological Convergence /combination)
Technological Diversification (Wide vs. Deep in patent portfolio)

NIS Index of 45 economies, 2011~2015: top 21

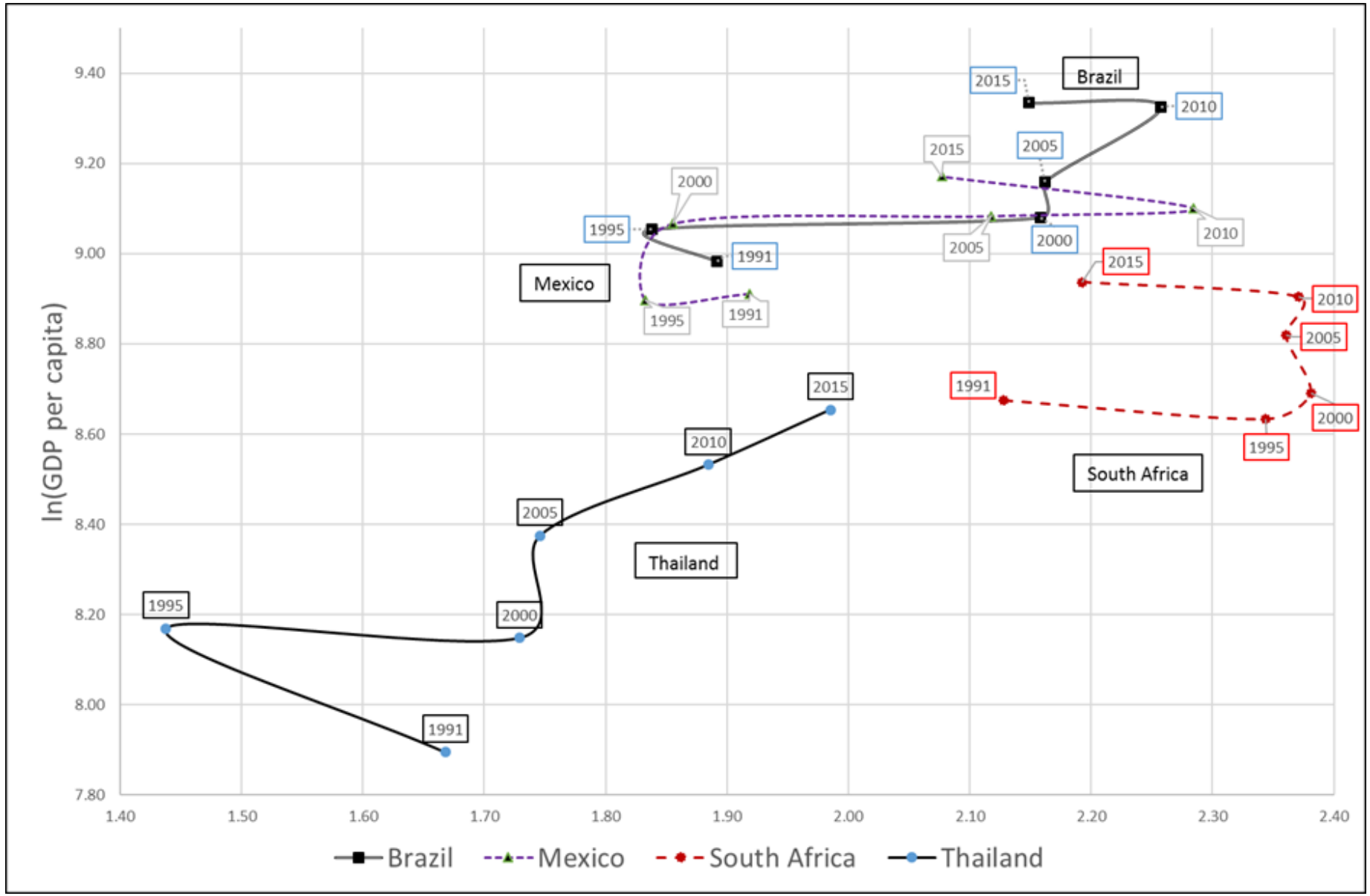
Country	Localization	Tech Diversif'n	Originality	Relative cycle time	Decentral'n 1-HHI	Index of NIS-5	Rank of NIS5
Japan	0.407	0.866	0.354	0.942	0.980	3.566	1
United States	0.246	0.937	0.503	1.005	0.994	3.495	2
Germany	0.140	0.844	0.455	1.106	0.984	3.147	3
France	0.111	0.735	0.402	1.083	0.975	2.873	4
United Kingdom	0.070	0.687	0.450	1.157	0.993	2.855	5
Italy	0.090	0.611	0.408	1.163	0.981	2.763	6
Australia	0.134	0.469	0.466	1.176	0.923	2.742	7
Switzerland	0.042	0.657	0.434	1.159	0.984	2.730	8
Canada	0.065	0.671	0.486	1.014	0.935	2.709	9
Taiwan	0.129	0.674	0.331	0.828	0.971	2.575	10
Netherlands	0.075	0.582	0.434	1.041	0.903	2.564	11
Israel	0.066	0.431	0.498	1.044	0.990	2.551	12
South Korea	0.137	0.705	0.339	0.846	0.854	2.533	13
Denmark	0.081	0.374	0.429	1.169	0.971	2.516	14
Norway	0.080	0.268	0.482	1.200	0.985	2.503	15
Austria	0.076	0.405	0.422	1.133	0.967	2.496	16
Sweden	0.098	0.568	0.390	0.992	0.824	2.435	17
Belgium	0.065	0.378	0.418	1.130	0.955	2.421	18
China	0.048	0.643	0.332	0.854	0.944	2.343	19
New Zealand	0.043	0.172	0.481	1.251	0.976	2.341	20
Spain	0.044	0.324	0.400	1.107	0.986	2.308	21

Country	Localization	Diversification	Originality	Relative cycle time	1-HHI	NIS5	Rank of NIS5
Finland	0.095	0.418	0.426	0.976	0.770	2.249	22
South Africa	0.072	0.116	0.424	1.231	0.959	2.249	23
Brazil	0.022	0.158	0.390	1.237	0.957	2.134	24
Mexico	0.014	0.096	0.485	1.216	0.933	2.129	25
Hong Kong	0.037	0.289	0.388	0.978	0.965	2.126	26
Ireland	0.023	0.241	0.465	0.993	0.929	2.109	27
Singapore	0.037	0.323	0.437	0.889	0.915	2.106	28
India	0.028	0.243	0.371	1.057	0.969	2.097	29
Luxembourg	0.007	0.221	0.472	1.032	0.928	2.088	30
Poland	0.069	0.074	0.369	1.156	0.952	2.072	31
Saudi Arabia	0.020	0.191	0.467	1.130	0.774	1.999	32
Malaysia	0.035	0.084	0.399	1.129	0.917	1.982	33
Chile	0.014	0.042	0.426	1.175	0.939	1.976	34
Portugal	0.032	0.045	0.418	1.106	0.932	1.956	35
Hungary	0.033	0.049	0.384	1.116	0.939	1.934	36
Argentina	0.041	0.028	0.392	1.135	0.909	1.926	37
Russia	0.039	0.102	0.423	0.934	0.889	1.871	38
Czech Republic	0.018	0.056	0.332	1.110	0.945	1.845	39
Thailand	0.009	0.031	0.467	1.107	0.824	1.837	40
Slovenia	0.014	0.038	0.335	1.272	0.831	1.822	41
Greece	0.016	0.031	0.327	1.179	0.870	1.781	42
Iceland	0.039	0.038	0.420	1.300	0.563	1.735	43

Trends of NIS5 in China, Korea, and Taiwan



Trends in Brazil, Mexico, Thailand, and South Africa



Composite NIS index (vs. Complexity index)

- We applied 4 different method on generating a composite index
  - Principal Component Analysis(PCA)
  - Data Envelopment Analysis(DEA)
  - Benefit of the doubt(BOD)
  - Equal-weighting method (after normalized) => our Choice!

  - 6 Different Indies tried for regressions (robustness and power)

1) NIS3a = S_Originality + S_Relative cycle time + S_Diversification
2) NIS3b = S_Originality + S_Relative cycle time + S_1 – HHI
3) NIS3c = S_Relative cycle time + S_1-HHI + S_ Localization
4) NIS4a = S_Originality + S_Relative cycle time + S_ 1 – HHI + S_Diversification
5) NIS4b = S_Originality + S_Relative cycle time + S_1 – HHI + S_Localization
6) NIS5 = S_Originality + S_Rel. cycle time + S_1 – HHI + S_Diversification + S_Localization

NIS and Complexity(ECI) on Growth (Lee & Lee 2019 JEE)

	1990/2015						
	(1) Base	(2) NIS3a	(3) NIS3b	(4) NIS3c	(5) NIS4a	(6) NIS4b	(7) NIS5
Ln(InitialGDP)	-0.046***	-0.057***	-0.049***	-0.046***	-0.056***	-0.051***	-0.057***
	(-6.48)	(-7.83)	(-7.22)	(-6.47)	(-7.25)	(-6.93)	(-6.60)
POP growth Rate	-1.66***	-1.57***	-1.71***	-1.66***	-1.61***	-1.68***	-1.58***
	(-2.81)	(-2.76)	(-2.99)	(-2.87)	(-2.83)	(-2.98)	(-2.82)
Fixed Investment Rate	0.30***	0.29***	0.32***	0.31***	0.31***	0.32***	0.32***
	(5.52)	(5.61)	(6.09)	(5.66)	(6.12)	(6.16)	(6.15)
Enrollment Rate Secondary	-0.0034	0.0047	-0.0048	-0.0051	-0.0045	-0.0024	-0.0014
	(-0.23)	(0.31)	(-0.32)	(-0.34)	(-0.30)	(-0.15)	(-0.095)
Democracy	0.0018	0.0016	0.0015	0.0018	0.0015	0.0016	0.0016
	(0.95)	(0.85)	(0.81)	(0.92)	(0.84)	(0.89)	(0.93)
Openness	0.045**	0.035**	0.040**	0.047***	0.036**	0.044**	0.043**
	(2.71)	(2.09)	(2.35)	(2.81)	(2.13)	(2.60)	(2.44)
ECI	0.017**	0.017**	0.018**	0.017**	0.017**	0.017**	0.015**
	(2.32)	(2.54)	(2.54)	(2.21)	(2.52)	(2.43)	(2.32)
NIS3a		0.045***					
		(3.23)					
NIS3b			0.027**				
			(2.06)				
NIS3c				0.016			
				(1.35)			
NIS4a					0.036**		
					(2.66)		
NIS4a						0.026*	
						(1.84)	
NIS5							0.033**
							(2.15)
adj. R-sq	0.29	0.32	0.30	0.29	0.32	0.30	0.32
상수항, 관측치, 하우스만 테스트 결과는 생략함							

ECI loses significance when terms of trade added

	1990/2015					
	(1) NIS3a	(2) NIS3b	(3) NIS3c	(4) NIS4a	(5) NIS4b	(6) NIS5
ln(Initial GDP)	-0.050***	-0.045***	-0.044***	-0.049***	-0.046***	-0.050***
	(-6.34)	(-6.61)	(-6.27)	(-6.41)	(-6.76)	(-6.47)
POP growth Rate	-1.71**	-1.81**	-1.75**	-1.73**	-1.77**	-1.70**
	(-2.42)	(-2.56)	(-2.46)	(-2.44)	(-2.48)	(-2.37)
Fixed Investment Rate	0.25***	0.28***	0.28***	0.27***	0.28***	0.27***
	(5.11)	(5.49)	(5.28)	(5.46)	(5.42)	(5.42)
Enrollment Rate Secondary	0.016	0.011	0.0074	0.010	0.012	0.012
	(1.06)	(0.79)	(0.58)	(0.76)	(0.88)	(0.87)
Democracy	-0.00041	-0.00037	-0.00026	-0.00034	-0.00027	-0.00025
	(-0.44)	(-0.37)	(-0.28)	(-0.33)	(-0.28)	(-0.25)
Openness	0.014	0.017	0.024	0.016	0.020	0.019
	(0.94)	(1.18)	(1.56)	(1.03)	(1.38)	(1.28)
Government Expenditure	-0.29**	-0.30**	-0.27**	-0.28**	-0.29**	-0.27**
	(-2.46)	(-2.48)	(-2.38)	(-2.45)	(-2.39)	(-2.35)
Terms of Trade	0.0014	-0.0036	-0.00092	-0.0013	-0.0025	-0.00051
	(0.23)	(-0.62)	(-0.16)	(-0.23)	(-0.43)	(-0.088)
ECI	0.010	0.012	0.012	0.011	0.012	0.011
	(1.45)	(1.65)	(1.58)	(1.52)	(1.65)	(1.53)
NIS3a	0.037**					
	(2.27)					
NIS3b		0.023*				
		(1.76)				
NIS3c			0.026**			
			(2.13)			
NIS4a				0.025**		
				(2.23)		
NIS4a					0.019	
					(1.67)	
NIS5						0.020**
						(2.06)
adj. R-sq	0.47	0.46	0.45	0.46	0.45	0.46
상수항, 관측치, 하우스만 테스트 결과는 생략함						

NIS3a, NIS4a, NIS 5 most robust: GMM:

Dep: ln(per capita GDP)	1990/2015					
	(1) NIS3a	(2) NIS4a	(3) NIS5	(4) ECI & NIS3a	(5) ECI & NIS4a	(6) ECI & NIS5
L.ln(per capita GDP)	0.78***	0.80***	0.79***	0.80***	0.81***	0.82***
	(12.8)	(14.0)	(13.6)	(11.9)	(12.5)	(12.7)
POP growth Rate	-3.61*	-3.92*	-3.60*	-2.78	-3.00	-2.69
	(-1.75)	(-1.90)	(-1.83)	(-1.47)	(-1.57)	(-1.35)
Fixed Investment Rate	1.59***	1.67***	1.71***	1.48***	1.60***	1.60***
	(4.07)	(4.25)	(4.43)	(4.27)	(4.53)	(4.47)
Enrollment Rate Secondary	-0.037	-0.066	-0.066	-0.036	-0.068	-0.086
	(-0.40)	(-0.72)	(-0.75)	(-0.36)	(-0.72)	(-0.93)
Democracy	-0.0014	-0.00062	-0.00035	-0.0036	-0.0017	-0.0016
	(-0.13)	(-0.063)	(-0.037)	(-0.35)	(-0.18)	(-0.17)
Openness	0.076	0.079	0.11	0.074	0.085	0.11
	(0.95)	(0.96)	(1.42)	(0.95)	(1.08)	(1.41)
Government Expenditure	-0.85	-0.85	-0.68	-0.87	-0.85	-0.70
	(-1.37)	(-1.64)	(-1.41)	(-1.29)	(-1.53)	(-1.31)
Terms of Trade	0.011	-0.0089	-0.0030	0.037	0.018	0.033
	(0.25)	(-0.21)	(-0.069)	(0.68)	(0.36)	(0.69)
ECI				0.049	0.056	0.069*
					(1.44)	(1.75)
NIS3a	0.30***			0.32***		
	(4.20)			(3.82)		
NIS4a		0.24***			0.24***	
		(4.47)			(3.21)	
NIS5			0.22***			0.20***
			(4.06)			(3.07)
AR(2) z-statistics	-2.12	-2.25	-1.90	-1.64	-1.94	-2.11
(p-value)	(0.034)	(0.024)	(0.057)	(0.100)	(0.053)	(0.035)
Hansen x^2 statistics	6.22	5.56	6.18	4.50	4.60	4.97
(p-value)	(0.286)	(0.351)	(0.290)	(0.480)	(0.466)	(0.419)
N	124	124	124	118	118	118

Concluding remarks

1) Robust impact of NIS3a, NIS4a, and NIS5 on economic growth.

- common component vars = originality, cycle time, & tech. diversification.
- a low correlation with ECI; originality (0.05); cycle time (–0.31).

2) NIS3 = most parsimonious and powerful NIS index

---- it has the largest coefficient among others in all the regression results.

-- R^2 with NIS3 = higher than, or similar to, other indices

3) NIS3a has the lowest correlation (0.46) with ECI;

cf) NIS4a (0.54) and NIS5 (0.59)

4) But, NIS5 is still useful

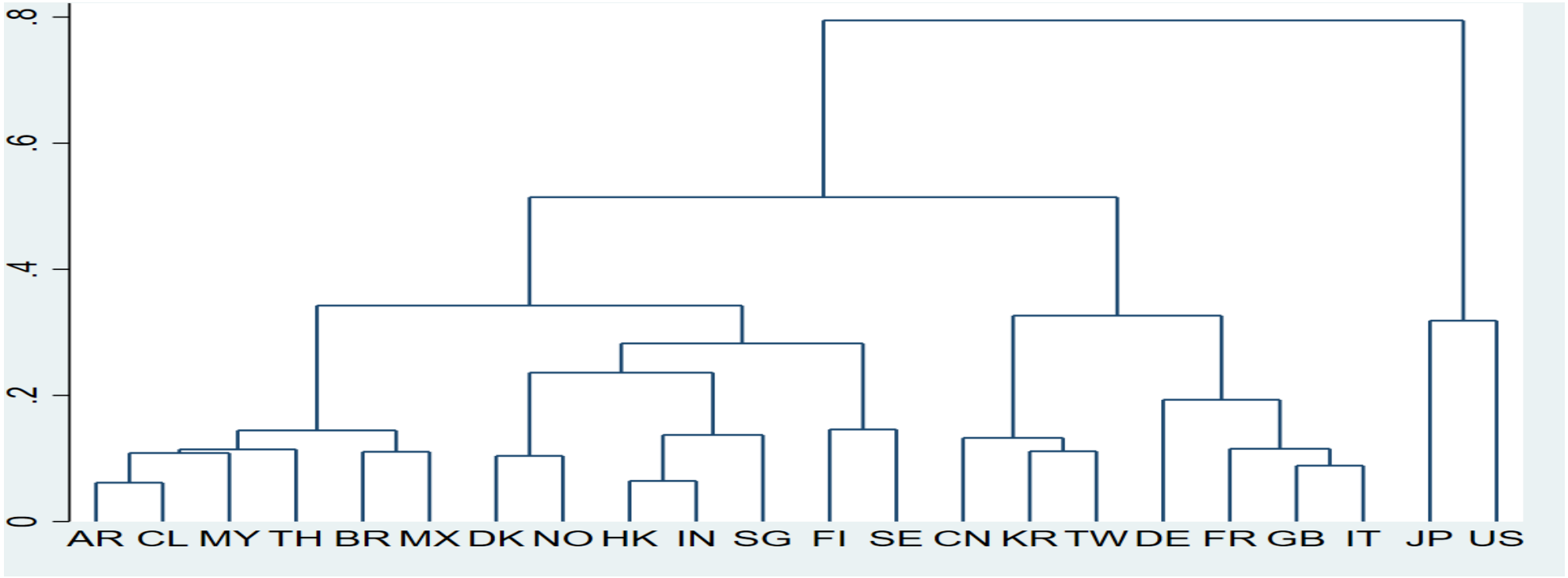
to show more diverse aspects and more stable in rankings across nations

Variety of National Innovation Systems around the world and their dynamic evolution and economic performance:

To show the ‘detour’ with the catching-up NIS,

cf) Trapped NIS

Cluster Analysis with 5 NIS variable of 22 C's: 2010-2017



1) Balanced and large NIS: Germany (DE), France (FR), Italy (IT), and the United Kingdom (GB).
2) Imbalanced but caching up NIS: China (CN), Korea (KR), and Taiwan (TW).
3) Imbalanced and Trapped NIS: Argentina (AR), Brazil (BR), Chile (CL), Malaysia (MY), Mexico (MX), Thailand (TH).
4) Balanced & Small NIS: Denmark (DK), Finland (FI), Hong Kong (HK), India (IN), Norway (NO), Singapore (SG), Sweden (SE).

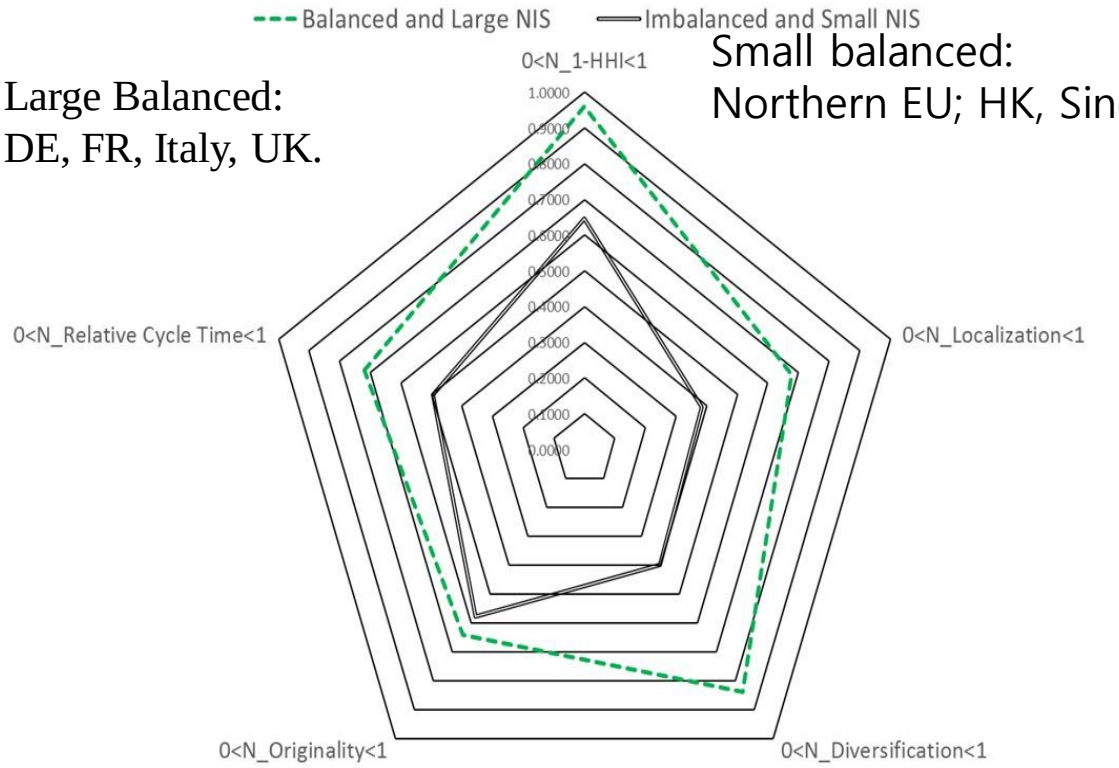
Clustering of NIS by 5 variables (normalized, 2010-2017):
4 Clusters and 2 outliers (US, Japan)

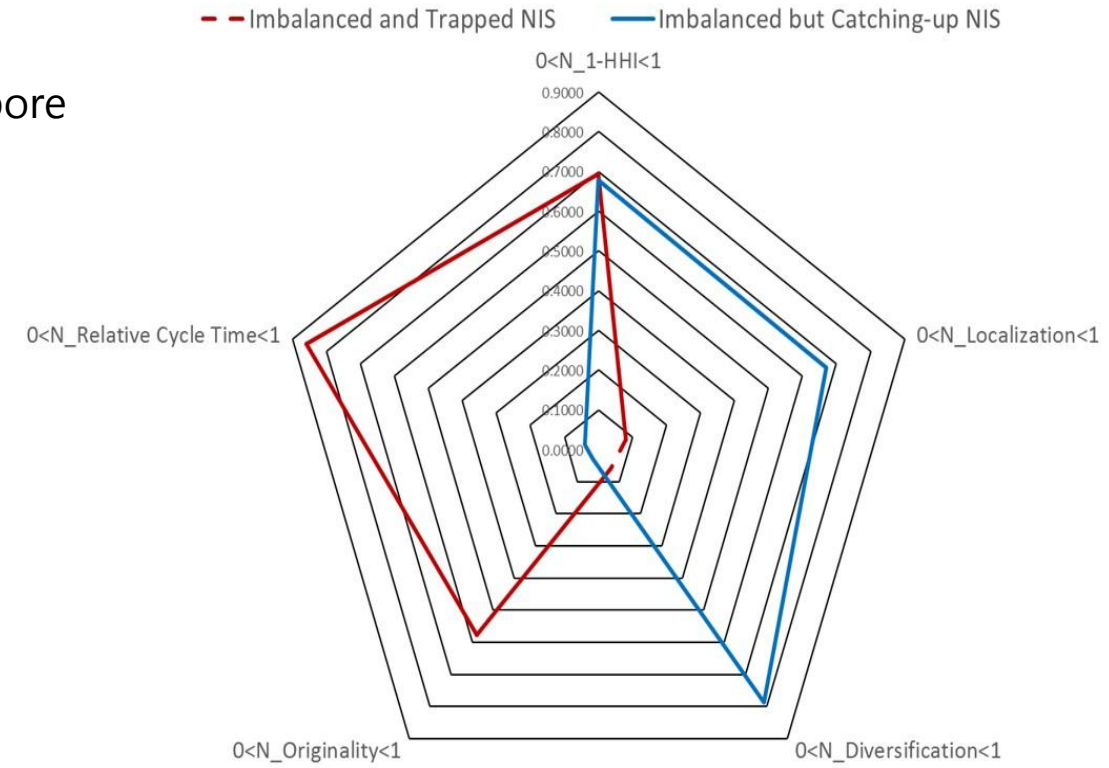
NIS Group	Economies	1-HHI	Localiz'n	Diversif'n	Originality	Rel. Cycle time	Avg. No patents per year	GDP p. c (PPP $)	Growth of p. c GDP %
Balanced & Large NIS	Germany, UK France, Italy	0.9849	0.1204	0.6864	0.4388	1.1273	6,144	38,185	0.82
Balanced & Small NIS	Denmark, Norway, Finland, H. Kong, Singapore Sweden (India)	0.9184	0.0720	0.3436	0.4289	1.0344	1,085	46,581	2.19
Imbalanced caching-up NIS	S. Korea, Taiwan China	0.9255	0.1195	0.6469	0.3428	0.8472	10,481	29,752	4.95
Imbalanced & Trapped NIS	Argentina, Brazil Chile, Mexico, Malaysia, Thailand	0.9284	0.0220	0.0781	0.4288	1.1841	64	18,283	2.16

Balanced vs. Imbalanced NIS:
Imbalanced & Trapped vs Imbalanced but catching-up NIS

Large Balanced:
DE, FR, Italy, UK.

Small balanced:
Northern EU; HK, Singapore





- ❖ Balanced NIS = Equally high/med scores; eg) large and small HICs
- ❖ Trapped = long cycle, but very low localization/diversification
- ❖ Catching up NIS = short cycle but high localization/diversification

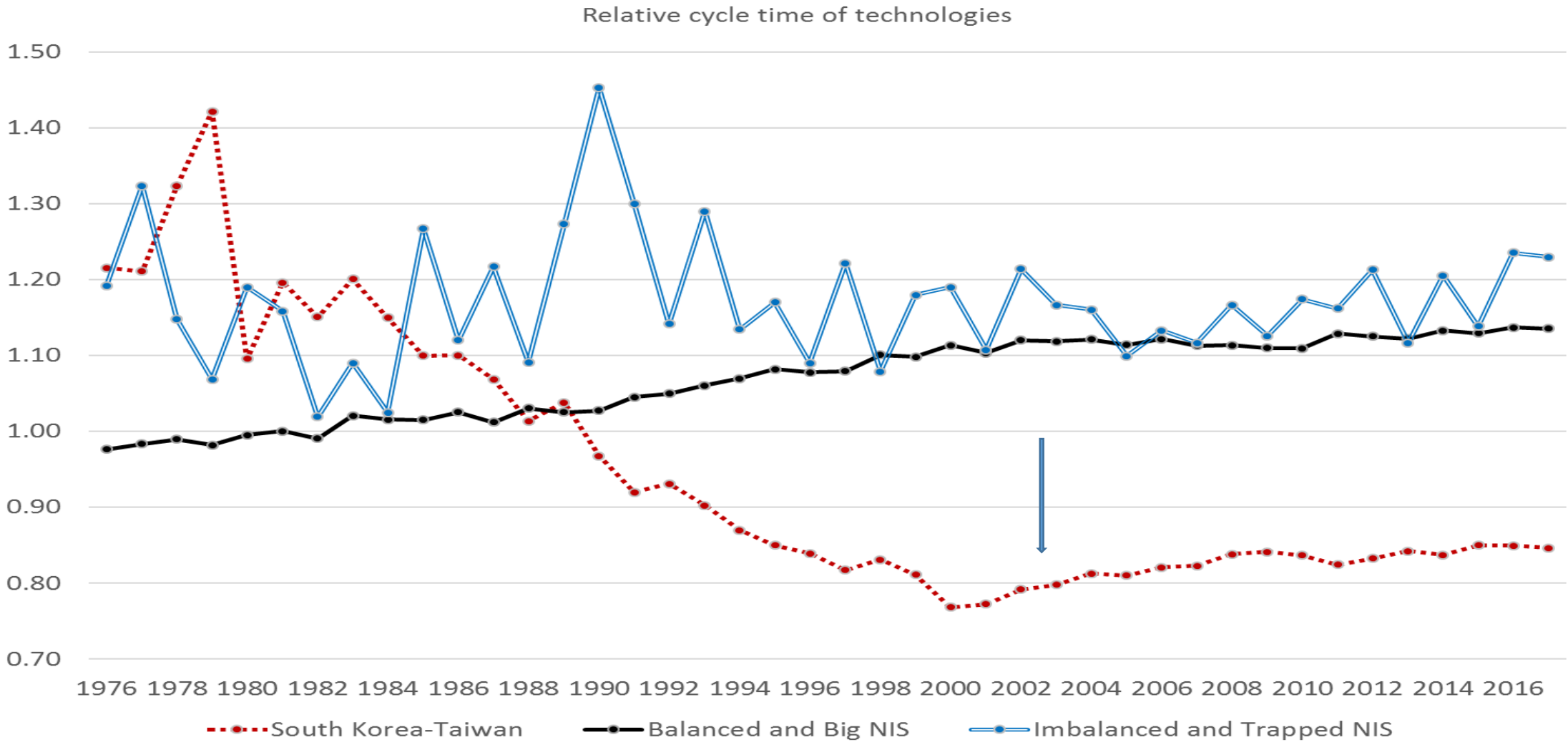
From NIS Types to Economic Growth: catching up vs trapped NIS

Dependent var.: average growth rates of GDP per capita	Using per capita GDP in constant 2010 $							
	LSDV Estimation				Pooled estimation with dummies			
	Model (1) 1983-2015		Model (2) 1991-2015		Model (3) 1983-2015		Model (4) 1991-2015	
	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value	Coeff.	t-value
Ln (InitialGDP)	-0.0096***	(-2.93)	-0.0089***	(-2.97)	-0.0096***	(-2.93)	-0.0089***	(-2.97)
Population growth Rate	0.11	(0.26)	-0.21	(-0.48)	0.11	(0.26)	-0.21	(-0.48)
Fixed Investment Rate	0.12*	(1.97)	0.13**	(2.49)	0.12*	(1.97)	0.13**	(2.49)
Secondary school Enrollment Rate	0.013	(0.73)	0.0018	(0.10)	0.013	(0.73)	0.0018	(0.10)
Imbalanced & Trapped NIS	0.073***	(2.68)	0.078***	(3.06)				
Balanced and Small NIS	0.080***	(2.70)	0.085***	(3.18)	0.0068	(1.19)	0.0066	(1.21)
Imbalanced but caching up NIS	0.11***	(3.34)	0.10***	(3.43)	0.039***	(2.83)	0.025**	(2.07)
Balanced and large NIS	0.077***	(2.62)	0.078***	(2.95)	0.0041	(0.68)	-0.00033	(-0.057)
Constant					0.073***	(2.68)	0.078***	(3.06)
Observations	153		117		153		117	
Adjusted R-squared	0.71		0.72		0.45		0.46	

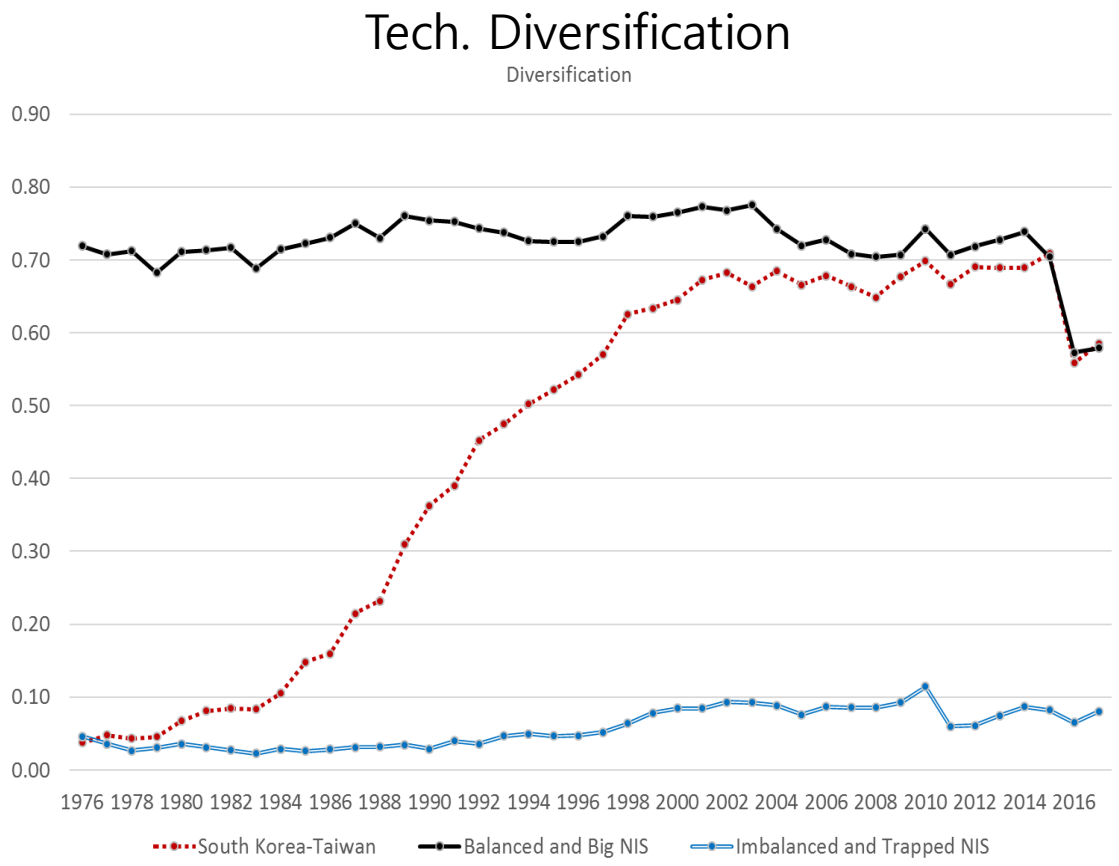
Dynamic Evolution of the NIS over time (Cluster Analysis) why the detour makes sense; emergence of the Catching-up NIS:

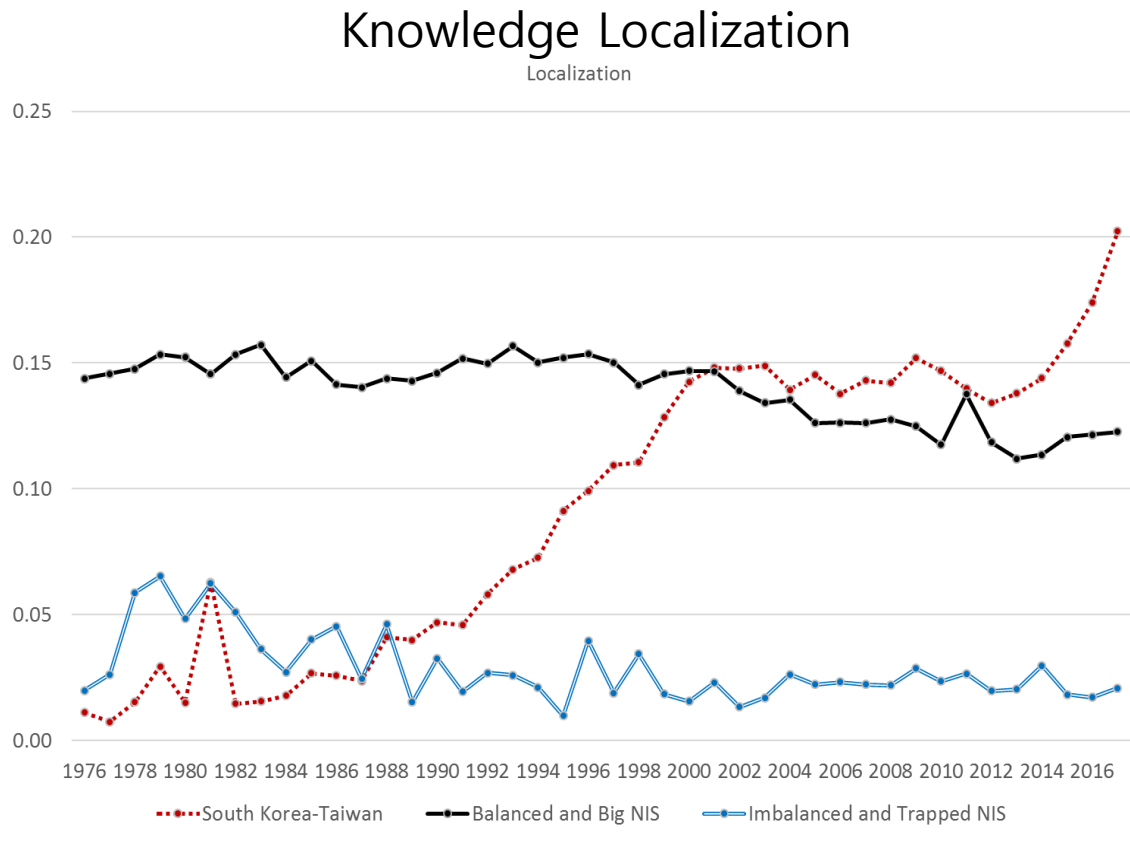
Period	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8
1984-91	Argentina, Brazil, Mexico, Norway, Hong Kong, India, Singapore, South Korea, China, Malaysia, Denmark, Finland, Taiwan	Chile	Thailand			Germany, France, United Kingdom, Italy, Sweden	Japan	USA
1992-99	Argentina, Brazil, Mexico, Norway, Hong Kong, India, Singapore, China, Malaysia, Denmark, Chile, Thailand			Finland	South Korea, Taiwan	Germany, France, United Kingdom, Italy, Sweden	Japan	USA
2000-07	Argentina, Brazil, Mexico, Norway, Hong Kong, India, Singapore, Malaysia, Denmark, Chile, Thailand			Finland	South Korea, Taiwan, China	Germany, France, UK, Italy, Sweden	Japan	USA
2008-15	Argentina, Brazil, Mexico, Chile, Malaysia, Thailand			Denmark, Finland, Hong Kong, India, Norway, Sweden, Singapore	South Korea, Taiwan, China	Germany, France, UK, Italy	Japan	USA

Trend : Relative Cycle Time of Technologies: How to get out of the Trap: from short to long in Korea, Taiwan, China



Tech. Diversification and Knowledge Localization:
Quick increase in catching up NIS vs No change in Trapped NIS





1) Getting into short cycles -> help to increase localization (less need to rely on incumbents)
-> tech. diversification by keep entering newly emerging classes
2) Linear approach like indexing cannot explain the detour: the more of index, always the better?
eg) if you go to long cycle first, that is a trap, leading to stagnation in catch up

Thank you!

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"Take a Detour and then Fly on a Balloon when the Ladder is Kicked Away"