Global Knowledge Networks, Competitiveness and Heavy Manufacturing

The Case of Flat Panel Displays

Research Institute of Economy, Trade and Industry (RIETI)
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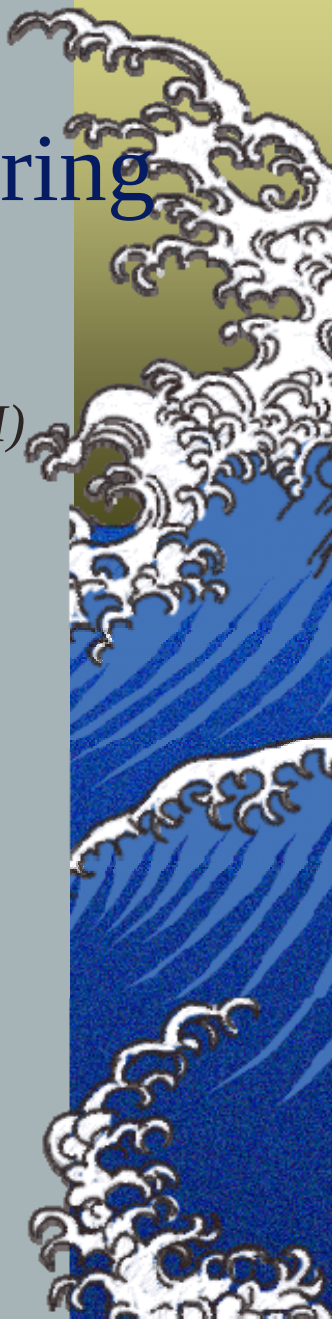
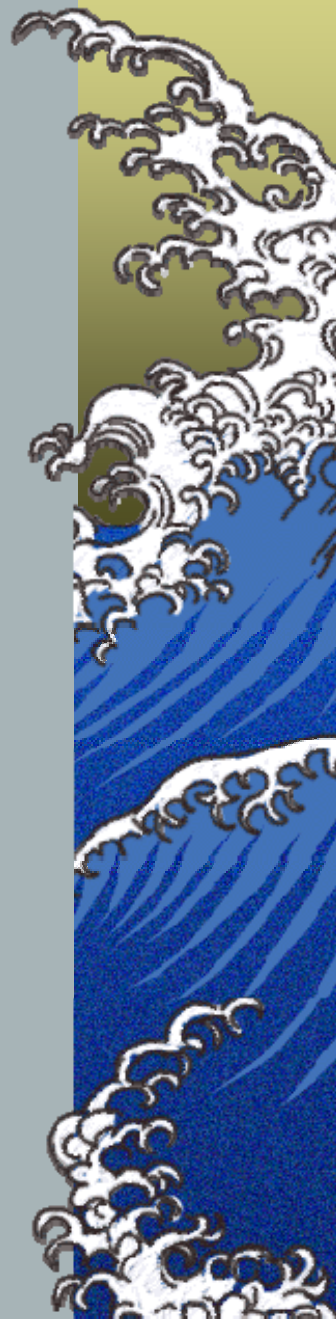


The future belongs to those enterprises that most successfully build obstacle-free networks between themselves and others. . . the locus of competition is shifting from individual enterprises to companies linked in networks.

Akemi Yoshitake
Global Marketing, AKT Inc.
An Applied Materials Company



Research Sponsored by the Alfred P. Sloan Foundation

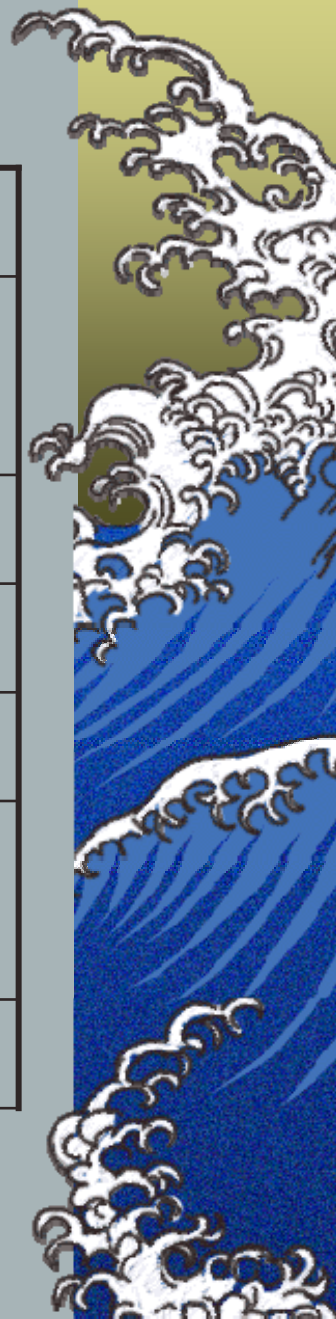
- *Sloan Foundation Industry Studies Program sponsors Research Centers and Projects on over 25 industries in U.S. Universities.*
- *FPDs: One of 7 industry projects linked into the Sloan Industry Globalization Research Program (Phase II).*
- *Program Title:"Industries as Global Knowledge Networks."*

Sloan Industry Centers and Projects

- *Flat Panel Displays*
- *Financial Institutions*
- *Motor Vehicles*
- *Trucking*
- *Airlines*
- *Managed Care*
- *Pharmaceuticals*
- *Steel*
- *Powder Metallurgy*
- *Industry Studies*
- *Industrial Performance*
- *Food Retailing*
- *Textile & Apparel*
- *Paper*
- *Printing*
- *Cross Industry Studies*
- *Software*
- *Information Storage*
- *Semiconductors*
- *Tele-information*
- *Electricity*
- *Construction*

Projects

Flat Panel Displays	*Minnesota*
Contract Manufacturing	*MIT*
Semiconductors	*UC Berkeley*
Personal Computers	*UC Irvine*
Venture Capital	*UC Davis/BRIE*
Business Process Outsourcing	*Stanford/UC Davis*
Direction:	*Minnesota/U Pittsburgh*



Industries as Global Knowledge Networks

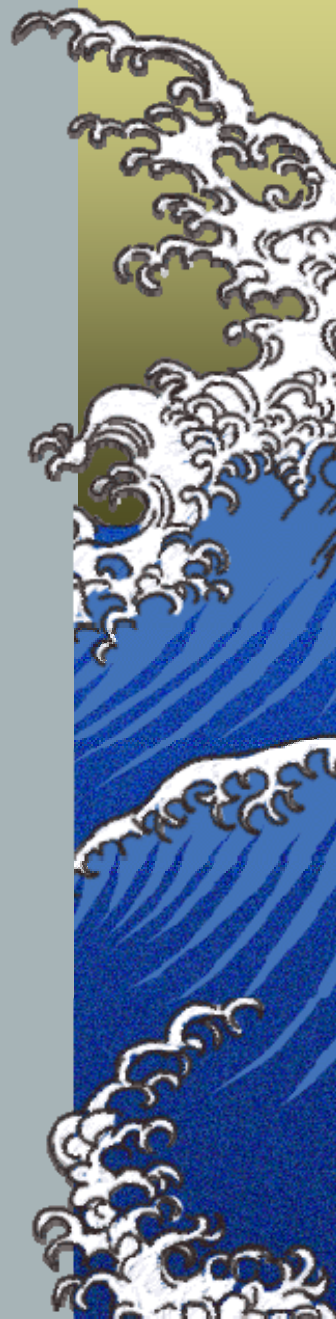
- *Technology complexity, scale, specialization, capital requirements and global workforce upgrading have increased opportunities and challenges of collaboration for innovation.*
- *Industries, countries and firms must adjust to greater knowledge interdependence with customers, suppliers, alliance partners and competitors, at home and offshore.*
- *Foreign affiliates' R&D matters more and more to companies' global competitiveness.*

New Research Issues

- *Competitive implications of deverticalization for countries and companies.*
- *Competitive and welfare implications of global workforce upgrading.*
- *Managing dispersed people, processes and assets, with increased competitive pace.*
- *Balancing IP protection and knowledge co-creation with suppliers, partners, competitors.*
- *Small enterprises' growing roles in the global knowledge economy.*

Phenomena

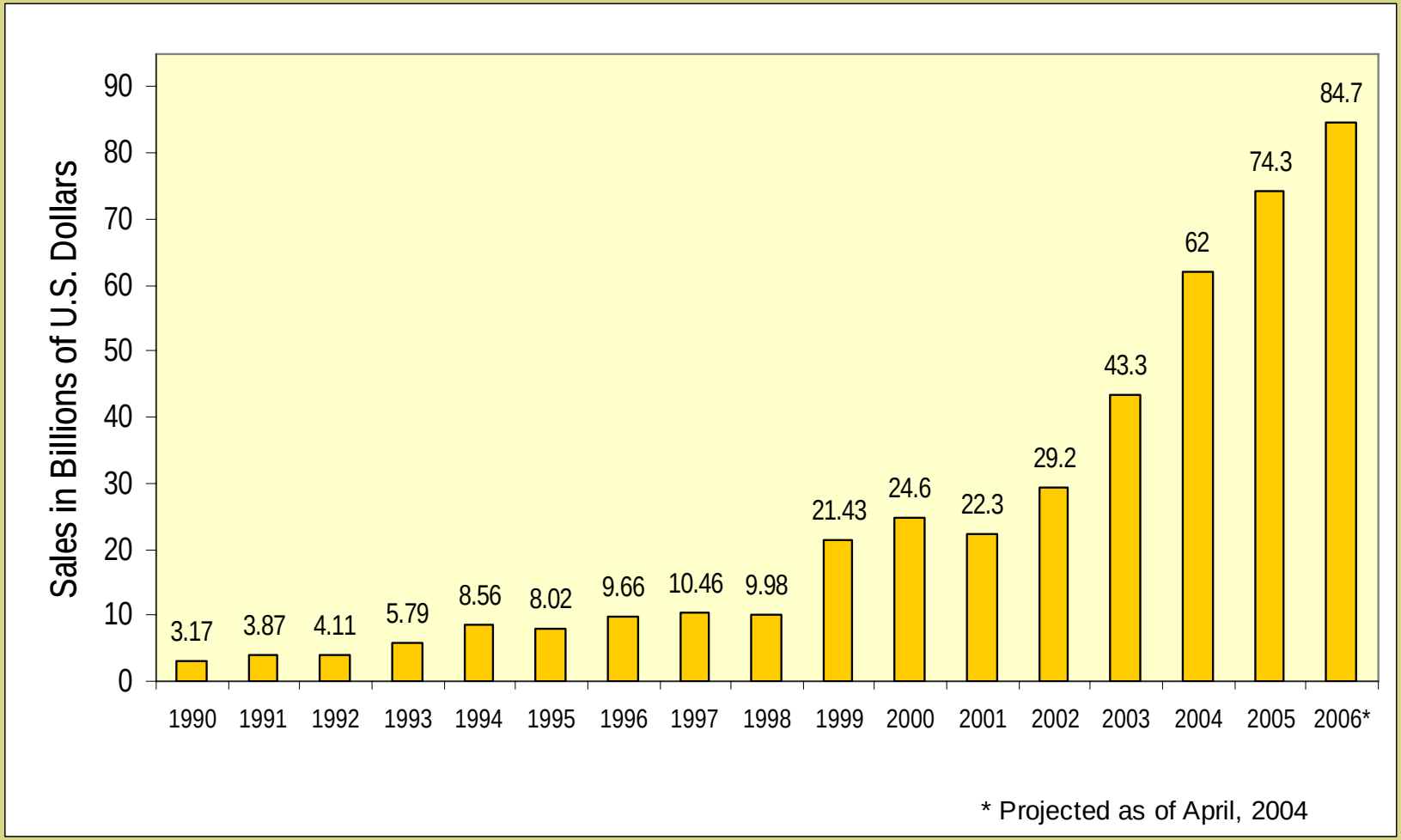
- *Fabless Semiconductor firms*
- *Semiconductor foundries*
- *Manufacturers that manufacture without factories (AKT)*
- *VCs as knowledge agents*
- *Manufacturers* sans *manufacturing (HP)*
- *Total Mfg. Service providers (Flextronics)*
- *Business process outsourcing (India)*
- *Pervasive modularization (PCs)*



A picture of a new global industry in 1995.

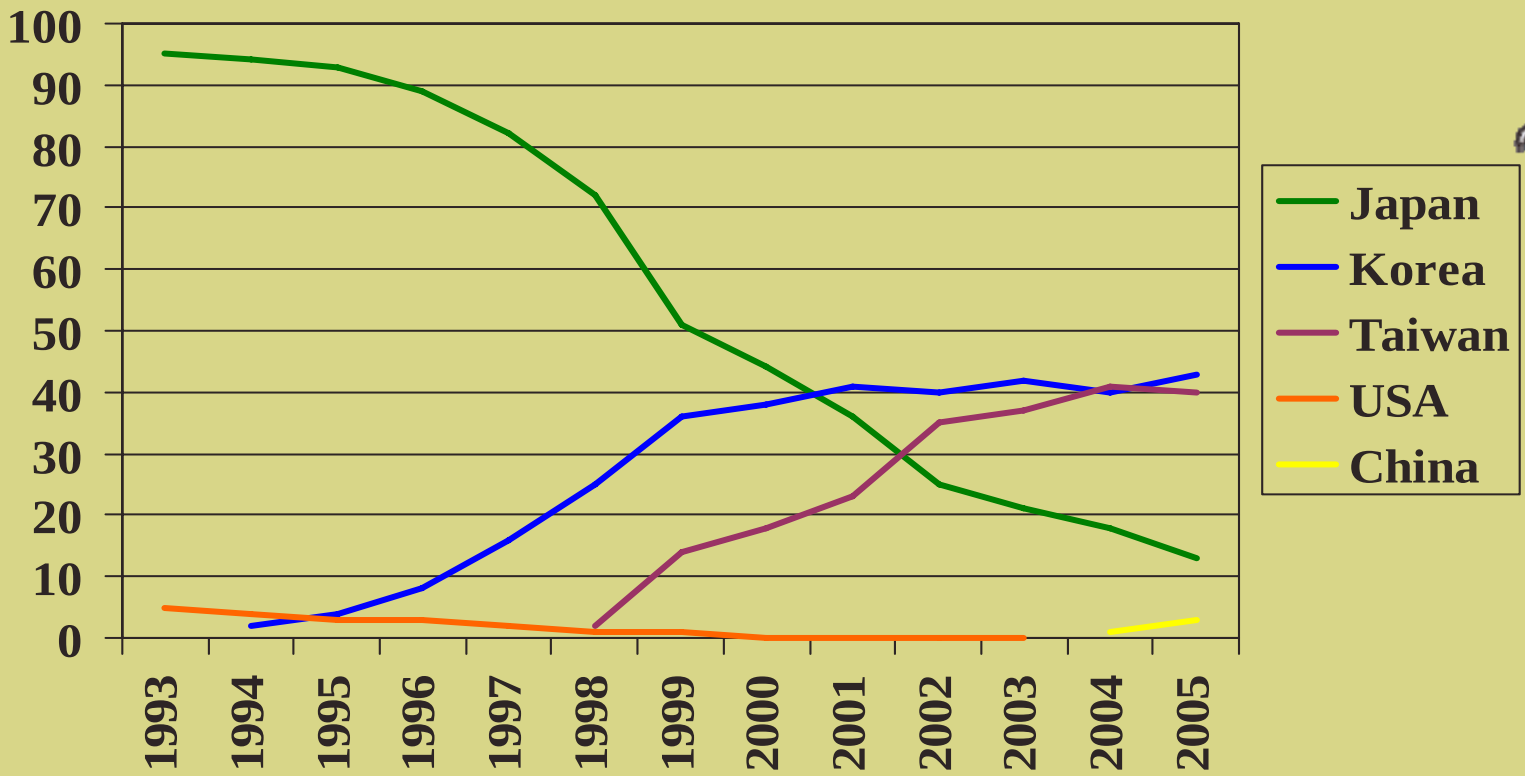
Source: SEMI JAPAN

FPD World Sales Volume: 1990-2006



Source: DisplaySearch

Share of Global Markets for Territorially-Based FPD Production, by Country



National Shares of Global Markets for FPDs Produced within Country, 1993-2005*

	93	94	95	96	97	98	99	00	01	02	03	04	05
Japan	95%	94%	93%	89%	82%	72%	51%	44%	36%	25%	21%	18%	13%
Korea		2%	4%	8%	16%	25%	36%	38%	41%	40%	42%	40%	43%
Taiwan						2%	14%	18%	23%	35%	37%	41%	40%
U.S.	5%	4%	3%	3%	2%	1%	1%	0%	0%	0%	0%		
China												1%	3%

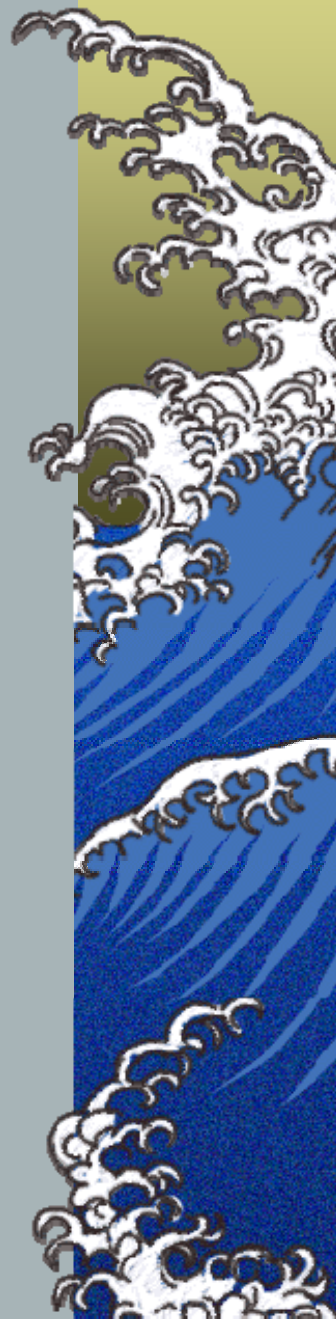
***In terms of authors' estimates of market value based on various sources.**

1996 – 2005 Rank Order of Large Format (g.t. 10.4-inch) TFT LCD Market Share Leaders

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
DTI	DTI	DTI/ Samsung	Sam-sung	Sam-sung	Sam-sung	Sam-sung	LPL	Sam-sung	LPL
Sharp	Sharp	Sharp	LPL	LPL	LPL	LPL	Sam-sung	LPL	Sam-sung
NEC	NEC	NEC	DTI	Hitachi	AUO	AUO	AUO	AUO	AUO
Hitachi	Hitachi	LG	Sharp	DTI	Sharp	Sharp and CPT	Sharp	Sharp	CMO
	Sam-sung	Hitachi	Hitachi	Sharp	Hitachi	CMO			
			NEC	NEC					

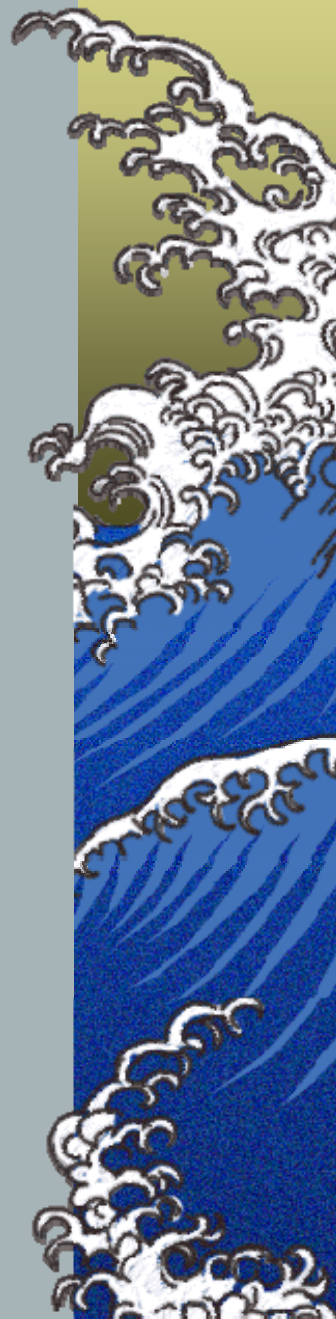
The Great Questions:

- *Why did the high volume FPD industry emerge with its geographic center in Japan?*
- *Why did industry diffuse from Japan to other countries in Asia?*
- *What role should Japan play in technology progress today (black box vs. open innovation)?*
- *Why has the industry grown in Asia, but not the U.S. or Europe?*



Methodology

- *Semi-structured interviews with over 200 senior managers, engineers and scientists since 1996.*
- *Comprehensive archival documentation of trade and business media.*
- *Company, industry and government documents.*
- *Site visits to all major FPD producers in U.S., Japan, Taiwan, Korea, Europe between 1996 and 2004, often multiple over time.*
- *Trade shows and industry conference attendance and presentations of findings.*
- *Acquisition and analysis of data from leading industry market research firms.*



Site Visits: U.S.: 1996-2002

- OIS
- ImageQuest Technologies
- dpiX, A Xerox Company
- IBM
- Planar Inc.
- Plasmaco
- Candescent Technology Corporation
- FED Corp.
- PixTech
- Motorola
- Raytheon
- Display Technology Systems
- Applied Komatsu Technologies
- Applied Materials, Inc.
- MRS Technology, Inc.
- Photon Dynamics
- Lam Research
- Corning Inc.
- 3M
- Honeywell
- Compaq
- Lucent Technologies
- United States Display Consortium
- Technical Visions
- InFocus
- Sharp, U.S.A.
- Department of Defense
- DARPA
- National Economic Council

Site Visits, Japan: 1996-2002

- IBM Japan
- Toshiba
- DTI
- NEC
- Hitachi
- Hosiden
- Philips Hosiden Flat Panel Co.
- Seiko Epson
- Sharp
- Matsushita Electric
- Sumitomo 3M
- MITI/METI
- SEMI
- U.S. Embassy, Japan
- Corning, Japan KK
- Corning Advanced Display Products
- Applied Komatsu Technologies
- Canon
- Futaba
- Asian Technology Information Program (DARPA/USDC)

Site Visits, Korea and Taiwan: 1996-2002

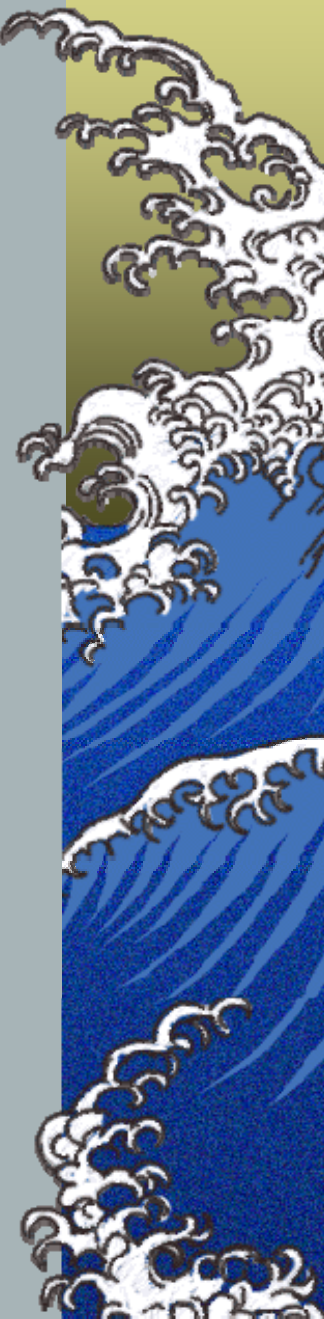
- Samsung Display Devices
- Samsung Electronics
- Samsung Corning
- LG Electronics
- LG.Philips
- Hyundai
- Daewoo
- EDIRAK
- Korean Ministry of Science and Technology
- Korean Ministry of Trade, Industry and Energy
- Nan Ya Plastics
- First International Computer
- Prime View
- ITRI
- Unipac
- Chunghwa Picture Tubes

Site Visits: Europe: 1996-2002

- Philips
- LG.Philips
- PixTech

Site Visits, Field Work: 2003-2006

- *Sony (Tokyo) (x2)*
- *Corning Advanced Display Products World Headquarters (Tokyo)*
- *Applied Materials Japan (Tokyo)*
- *AKT/Applied Materials (Santa Clara, California)*
- *IDTech/CMO (Yasu, Japan)*
- *Matsushita Electronics (Osaka)*
- *DisplaySearch U.S. Display Forum, 2003, 2004, 2005 (San Diego)*
- *Society for Information Display Annual Meeting, 2004 (Seattle)*
- *Photon Dynamics (San Jose, California)*
- *FPD International, Yokohama*
- *Sharp (Kameyama)*
- *LG Electronics (Gumi, S. Korea)*
- *LG.Philips (Seoul)*
- *Philips Electronics (Amsterdam)(x3)*
- *Samsung-Corning Precision Glass (Gumi, S. Korea)*
- *Corning Display Technologies, Taiwan (Taipei)*
- *Center for Innovation, Kyungpook University (Daegu, S. Korea)*
- *European Display Forum (Den Hague)*
- *LUMILEDS (San Jose, California)*
- *Merck KGaA (Darmstadt, Germany)*
- *CPT (Taiwan)*
- *AUO (Taiwan)*
- *AMTC (Taiwan)*
- *ITRI (Taiwan)*
- *DisplaySearch Taiwan (Taipei)*
- *AKT Taiwan (Hsinchu)*
- *Kaiyuan Security Investment Consultants Co. Ltd. (Taipei)*
- *National Chiao Tung University Display Institute (Hsinchu, Taiwan)*
- *CMO (Taiwan)*
- *Unaxis Taiwan*
- *Toppoly (Taiwan)*
- *Canon*
- *Nikon*
- *RIETI*



Success factors for leading high tech industry emergence:

- ***CONTINUITY***
- ***LEARNING***
- ***KNOWLEDGE NETWORK ACCESS***
- ***SPEED***

For successful followers add:

- ***STEPPING BACK TO LEARN TO STEP FORWARD***

FPD Industry Timeline: Some Key Events

1968 *RCA demonstrates first LCD*

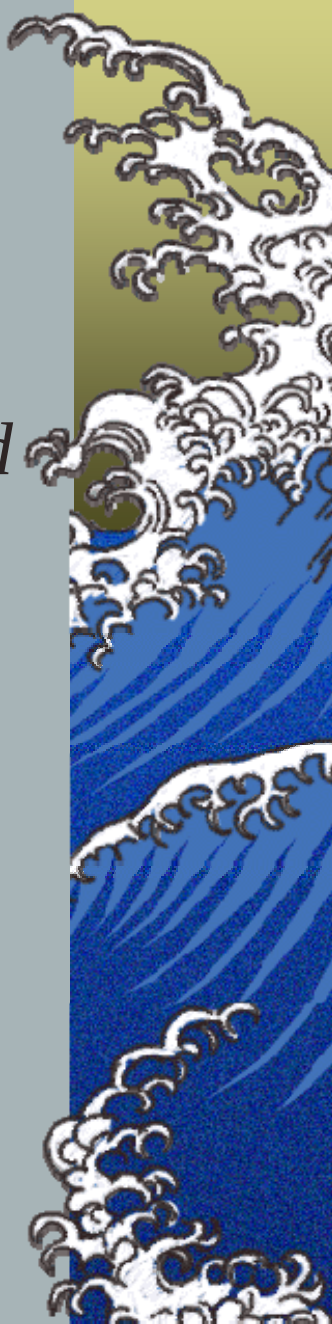
1973 *First LCD calculators, watches (Sharp and Seiko)*

1973 *IBM builds plasma display plant*

1983 *Seiko demonstrates LCD color TV*

1986 *IBM stops PDP R&D, starts large-format LCD R&D with Toshiba*

1986 *Sharp starts up large-format LCD R&D*



FPD Industry Timeline: Some Key Events

1988 *Sharp, IBM/Toshiba announce 14-inch LCD prototypes*

1989 *IBM/Toshiba form DTI production JV*

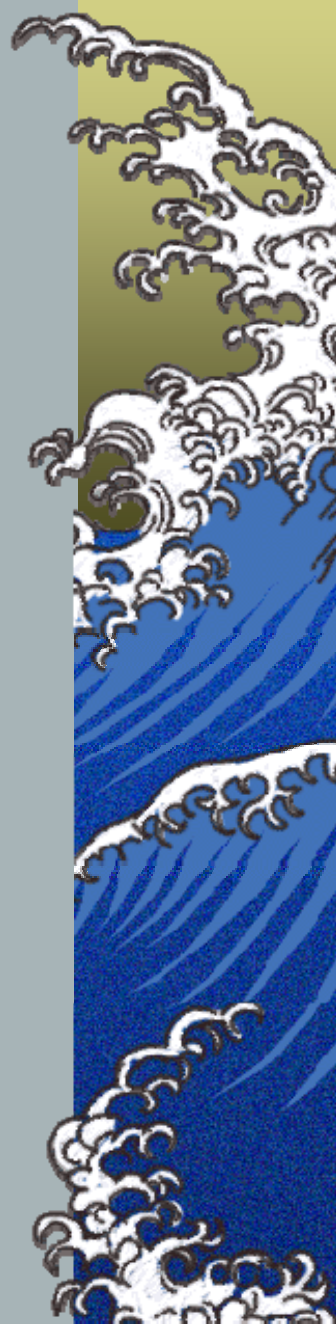
1991 *Sharp, DTI start production*

1994 *First Gen 2 lines with AKT CVD*

1995 *Sharp, then DTI start up Gen 3 lines*

1996 *Samsung becomes third company to start up Gen 3 fab*

1997 *Samsung shares lg. format lead with DTI*



FPD Industry Timeline: Some Key Events

1999 *(May-July) First Gen 3-plus fabs start up in Taiwan (CPT, ADT), with collaboration of Japanese producers.*

2001 *Merged AUO #3 in global share.*

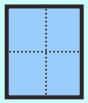
2003 *FPDS eclipse CRTs in share of world market value; Samsung, Sony form production alliance*

2004 *Taiwan vies with Korea for global market share leadership.*

2005 *China production gains significance*

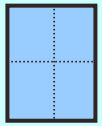
Glass substrate size comparison

Gen. 1
300x 400mm



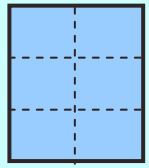
8.4“x 4

Gen. 2
370x 470mm



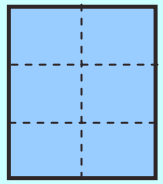
10.4“x 4

Gen. 3
550x 650mm



12.1“x 6

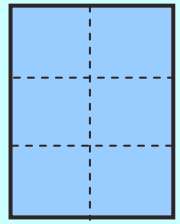
Gen. 3.5
600x 720mm



13.3“x 6

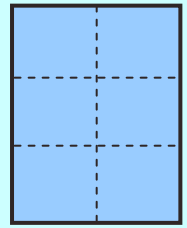
Gen. 4

680x 880mm



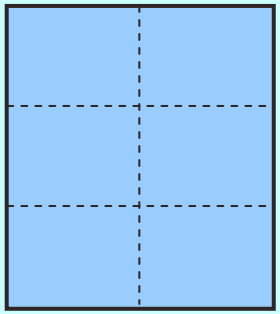
13.3“x 9
15” x 6
20” x 4

730x 920mm



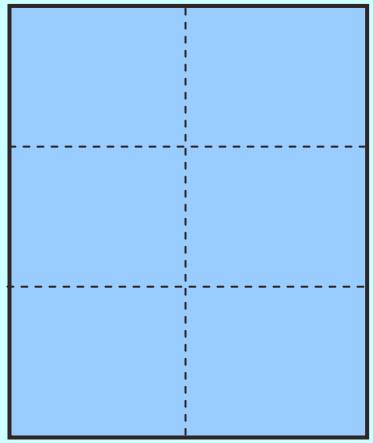
14“ x 9
17” x 6

Gen. 5
1100x 1250mm



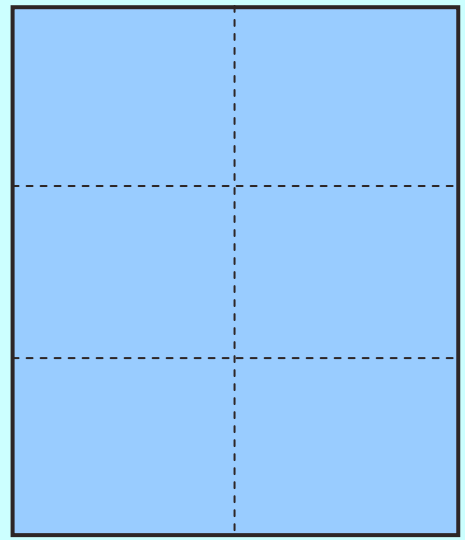
32“ x 8
37” x 6
42” x 3

Gen. 6
1500x 1800mm



32“ x 8
37” x 6
42” x 3

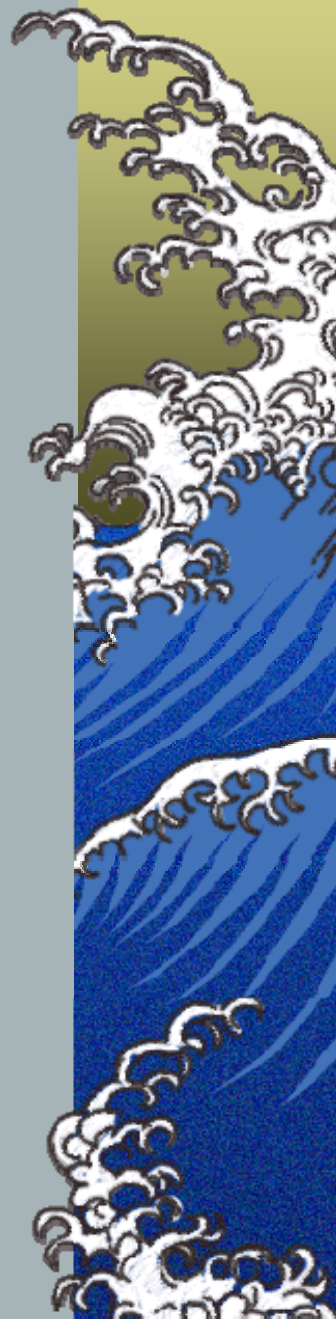
Gen. 7
1870x 2200mm



32“ x 10
42” x 6

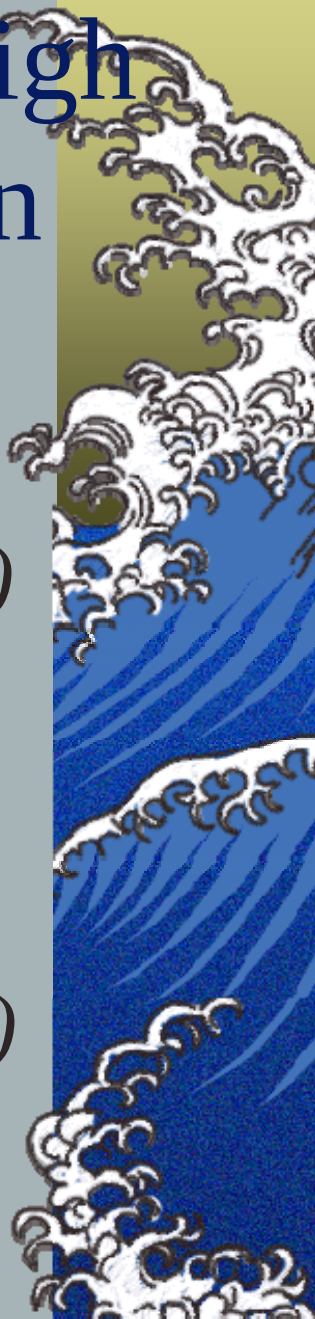
FPDs as a Knowledge-Driven Industry

- *Dominant TFT LCD mfg. paradigm emerged mid-1990s through competition and collaboration among global firms with organizational capabilities in Japan.*
- *Intense interpersonal contact among and within companies remains critical, in part because rapid technology evolution creates a knowledge codification backlog.*



Non-Japanese Contributors to High Volume FPD Industry Creation

- *Corning, glass substrates*
- *Applied Materials, CVD tools*
- *IBM, large format LCDs (prior to 2001)*
- *3M, brightness enhancement film*
- *Photon Dynamics, test equipment*
- *Merck KGaA, liquid crystal*
- *Philips, large format LCDs (since 1999)*



Rapid Evolution of Fab Generations: Consequences

- *Knowledge enters new generations before it can be written or sometimes even verbalized.*
- *Successful Gen transitions require scientists, engineers and operators to migrate forward.*
- *High capital costs create incentives for partnerships, alliances and industry-wide tools and solutions.*
- *All panel makers seek differentiation.*
- *Suppliers' knowledge is critical to progress.*

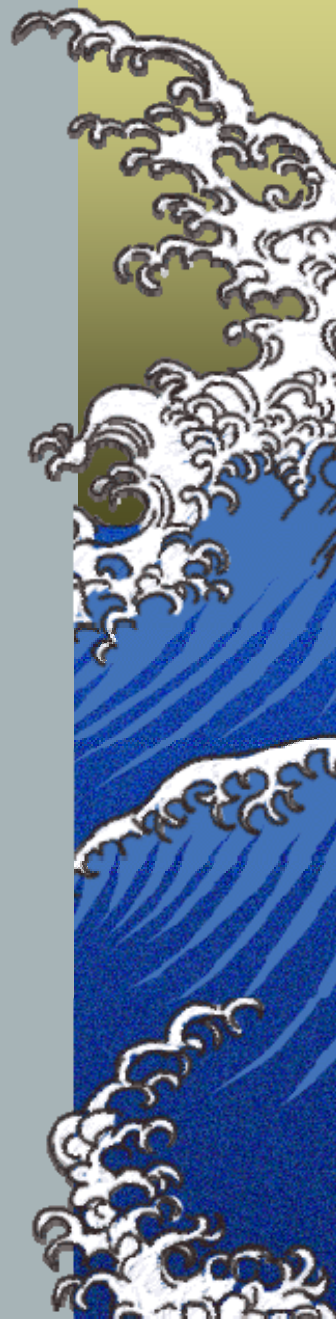
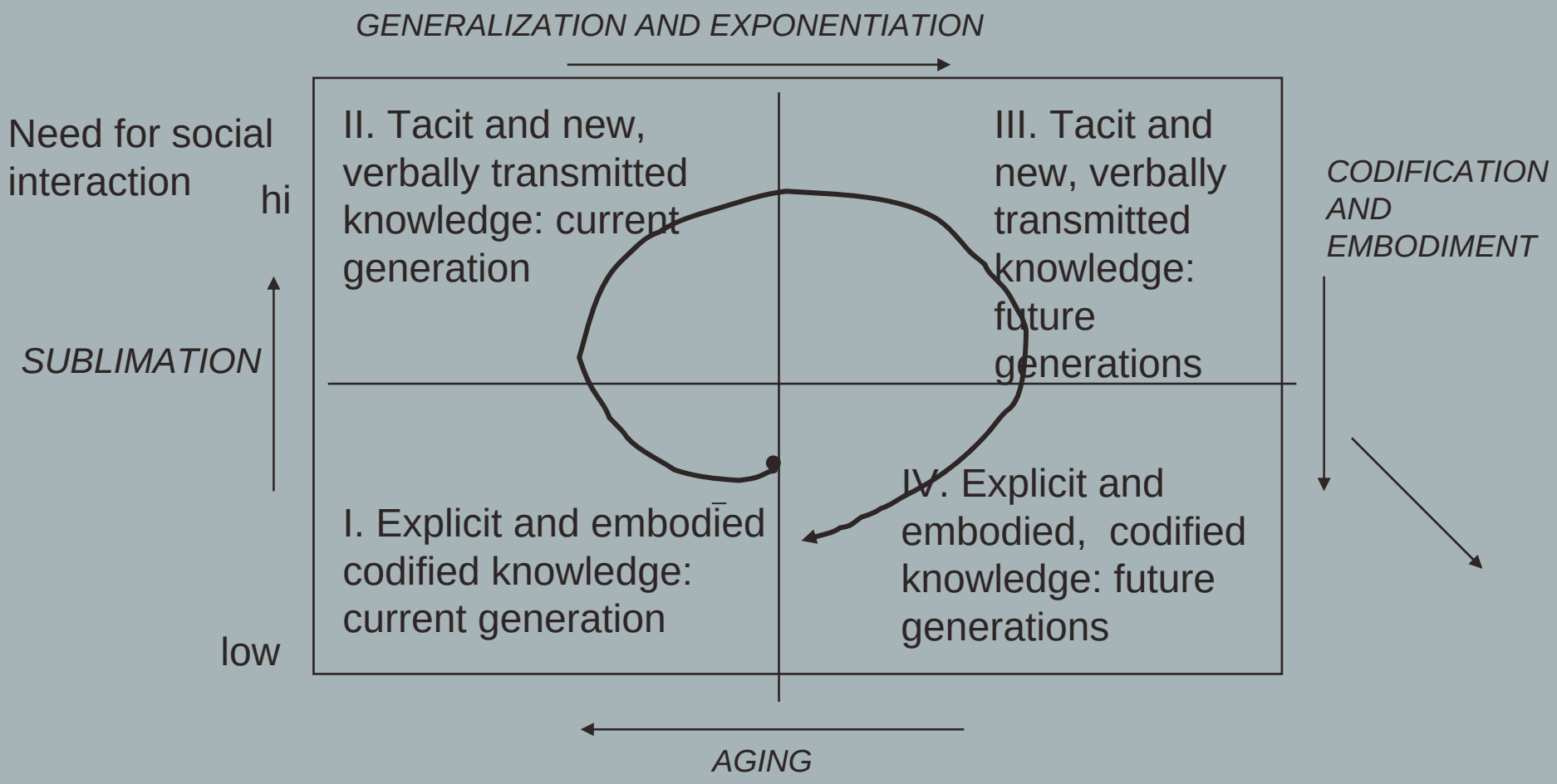
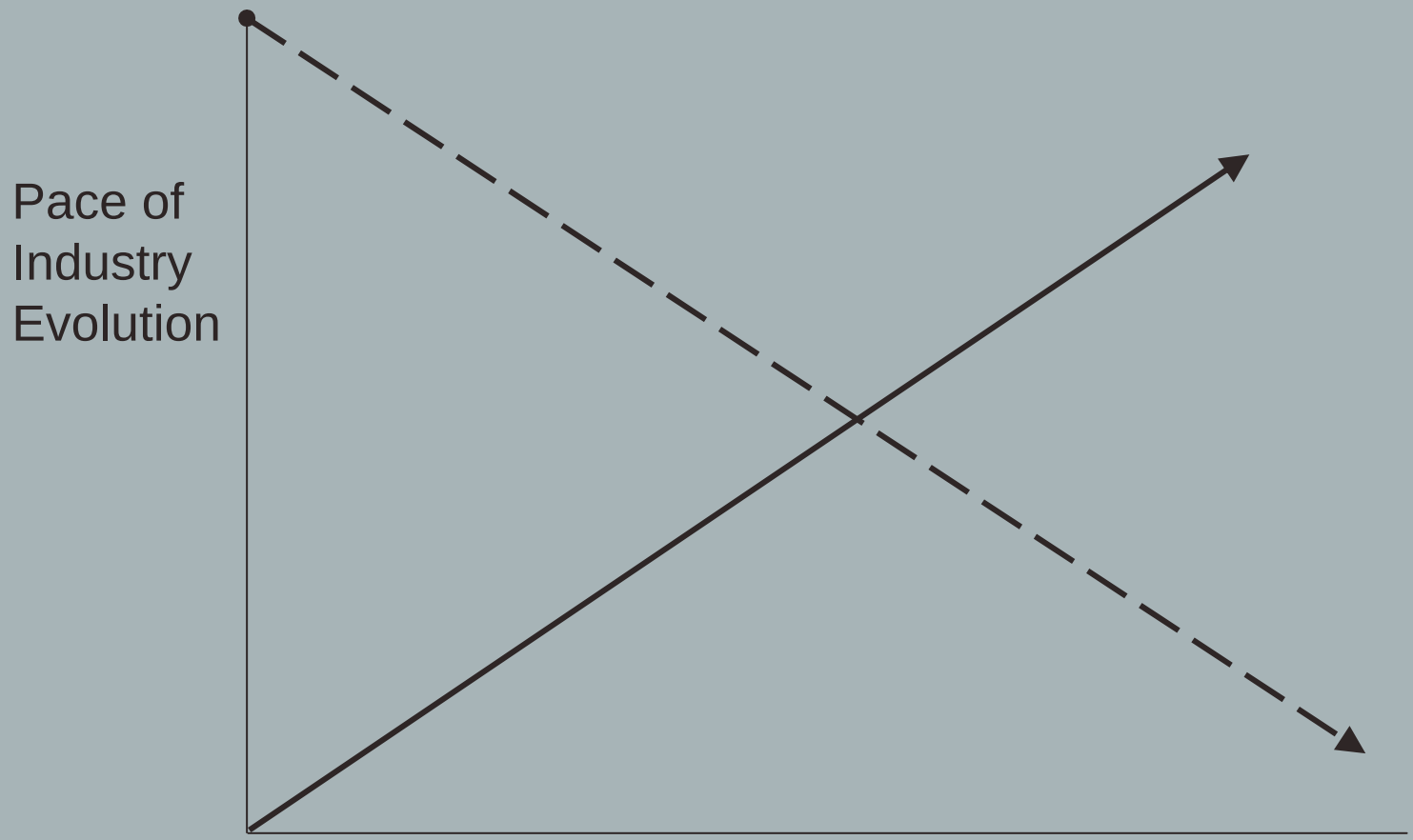


Figure 7-4: Evolutionary Spiral: New Industry Creation as Cross-Generational Knowledge Formation

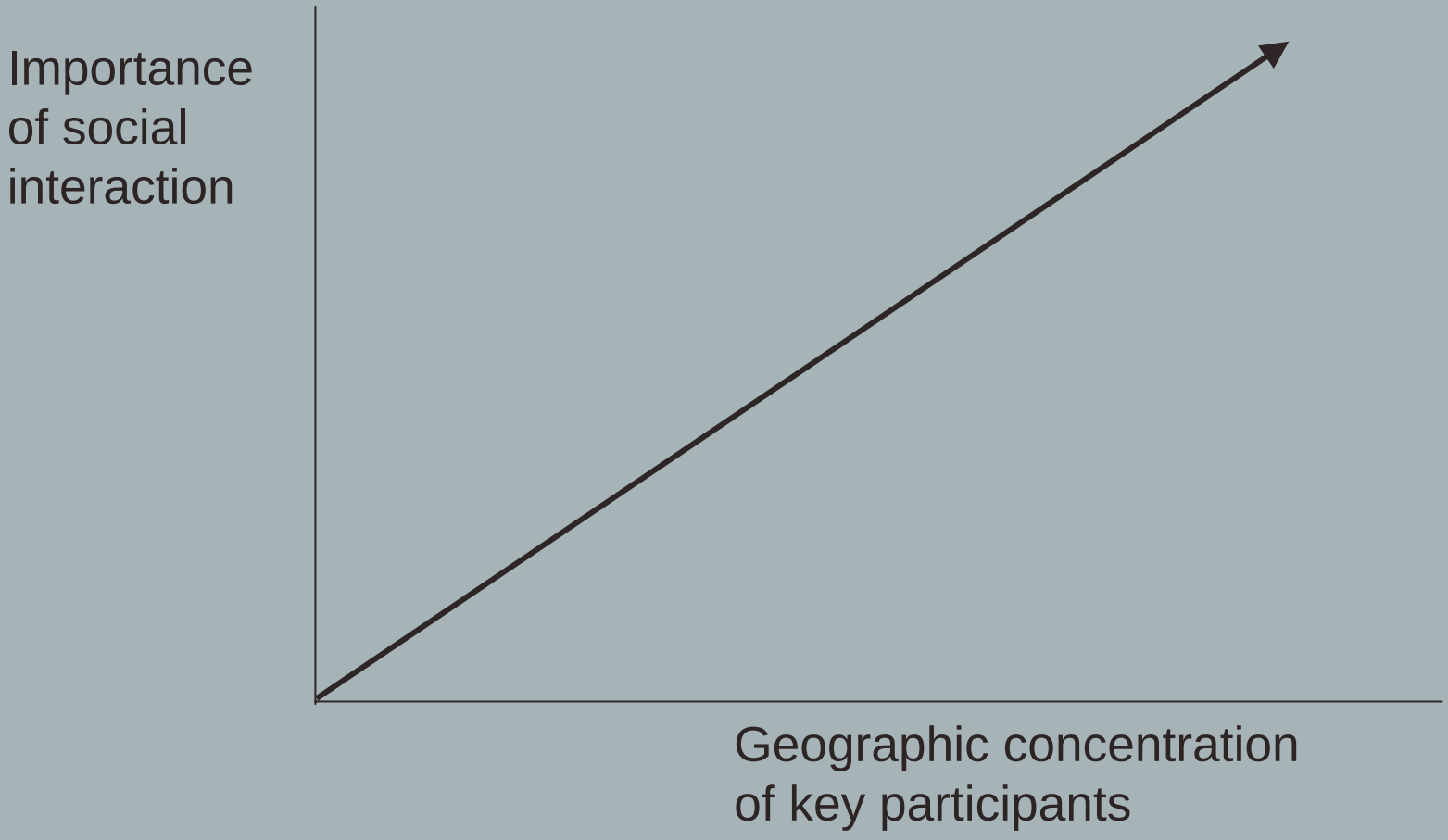


Pace of Industry Evolution, Codification of Knowledge and the Importance of Social Interaction for Knowledge Creation

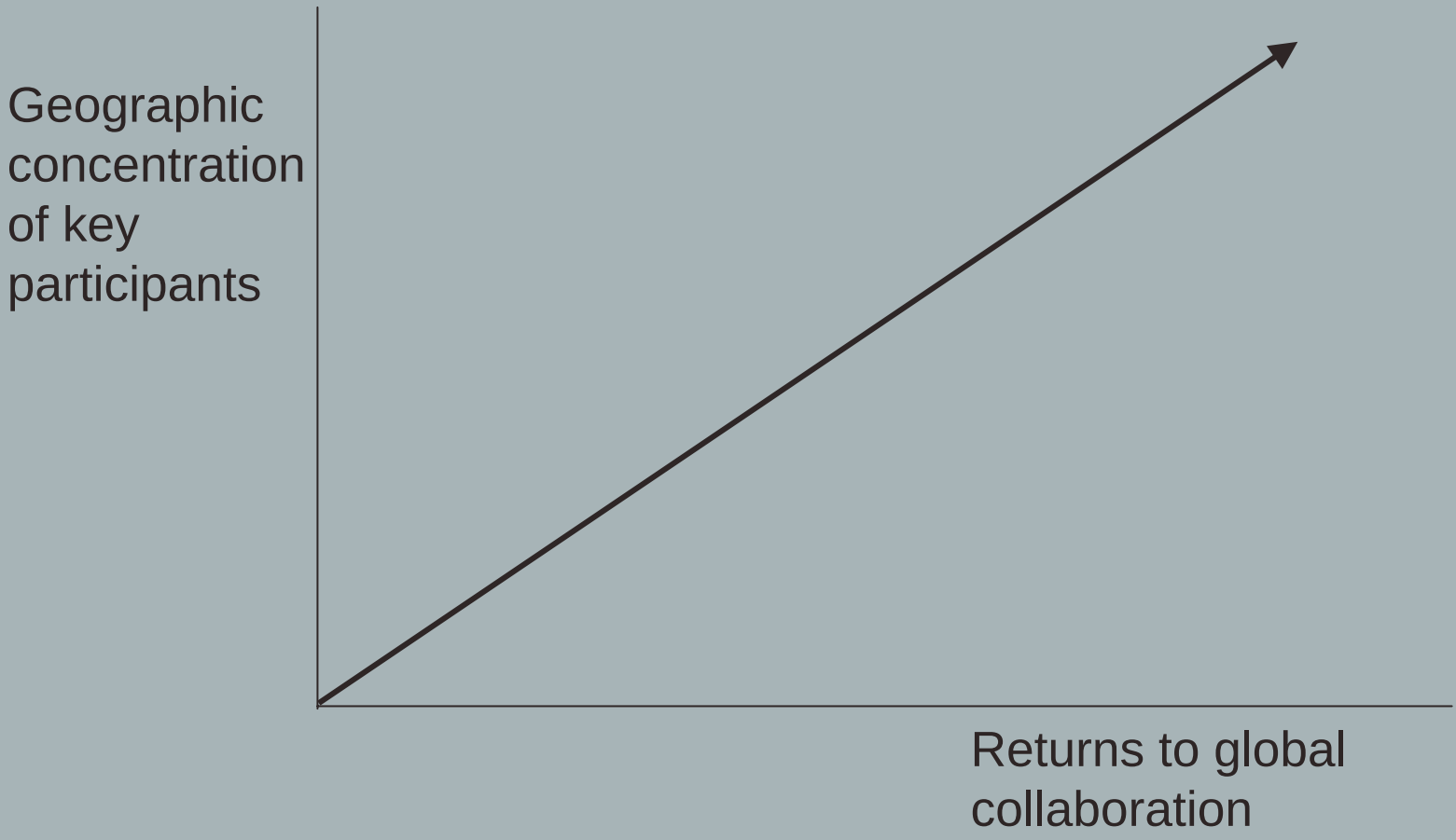


Broken: Codification of knowledge
Solid: Importance of social interaction for knowledge creation

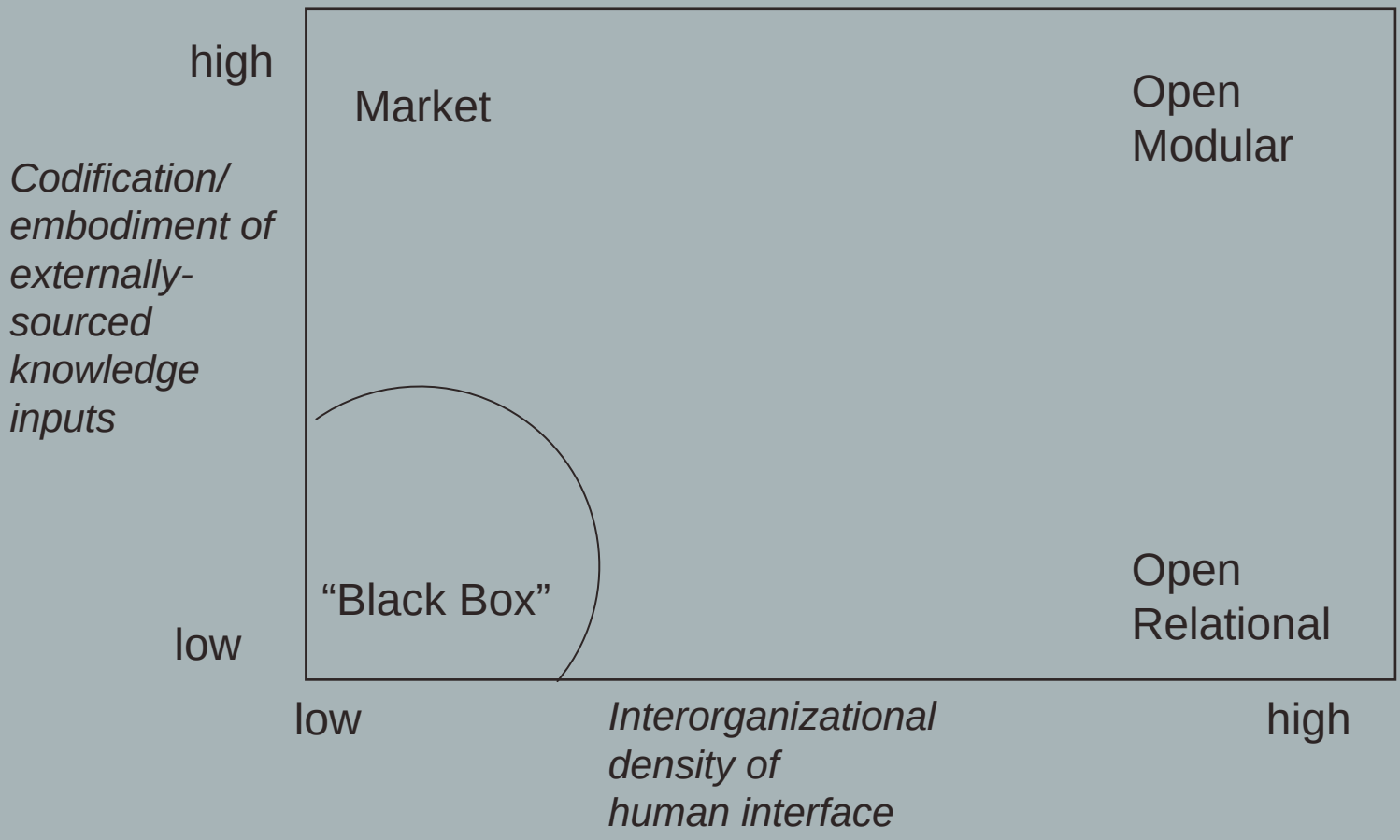
Importance of Social Interaction for Knowledge Creation and Geographic Concentration of Key Participants



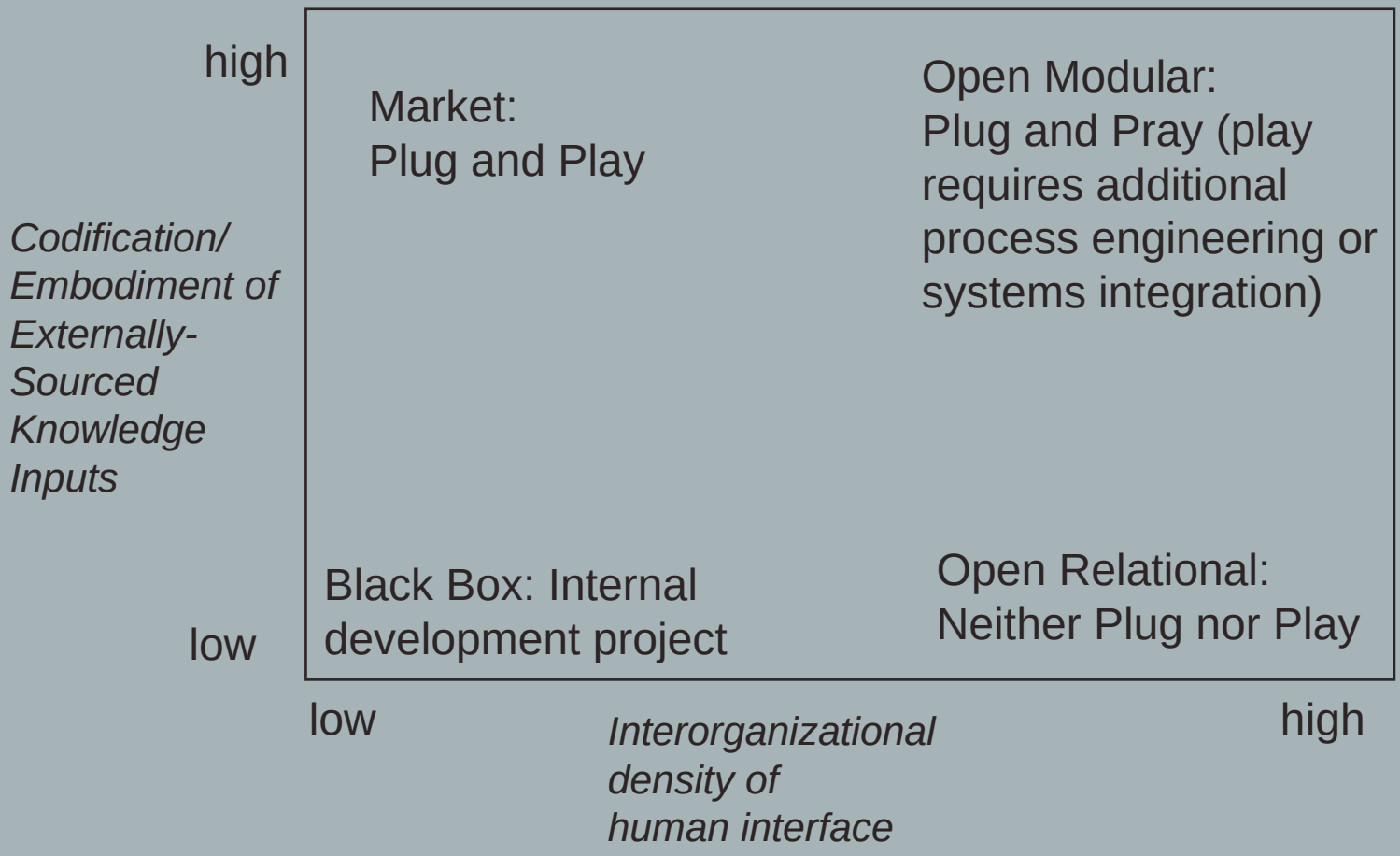
Geographic Concentration of Key Participants and the Returns to Global Collaboration



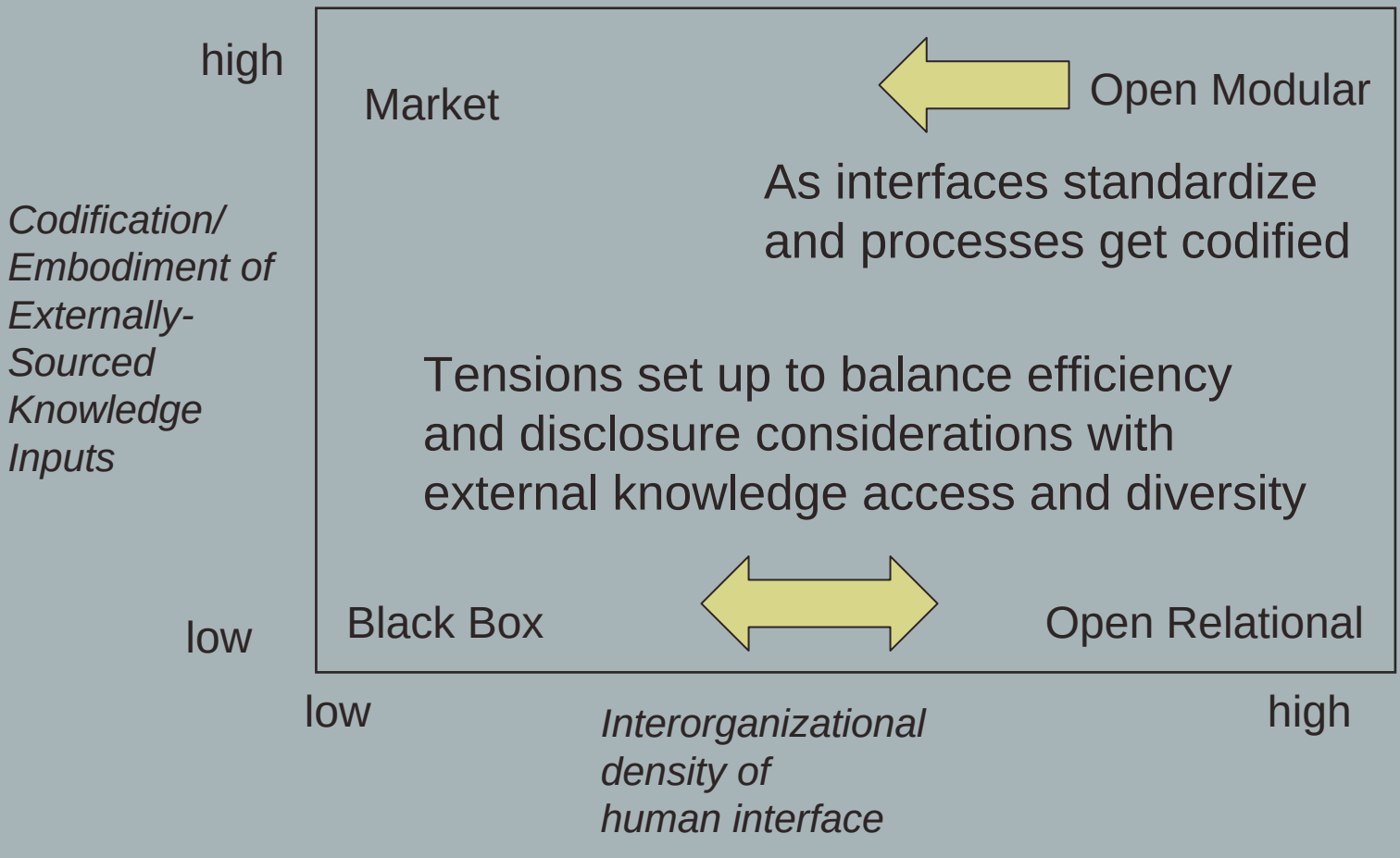
Relationship management process for collaborative innovation



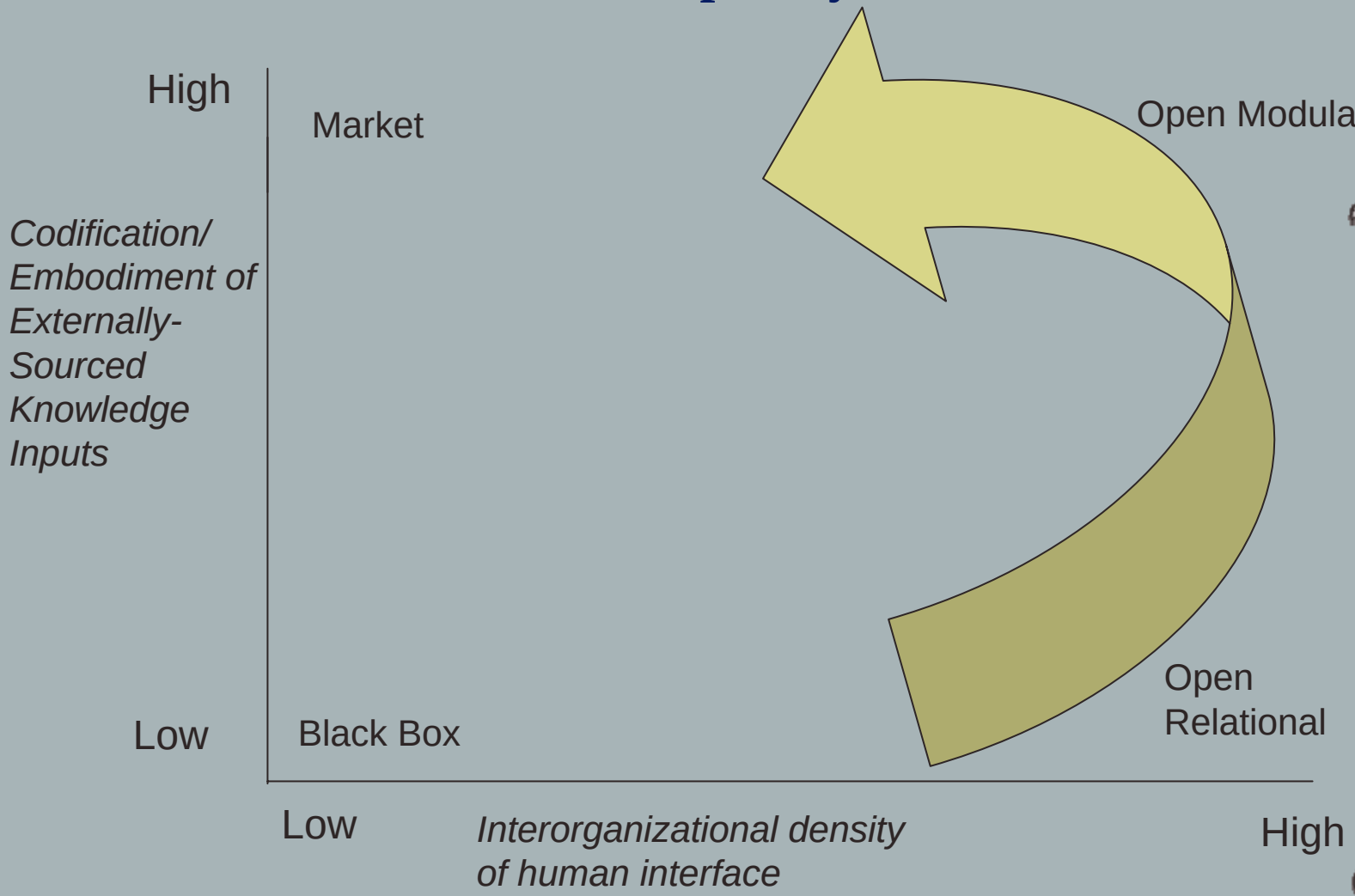
Management process characteristics



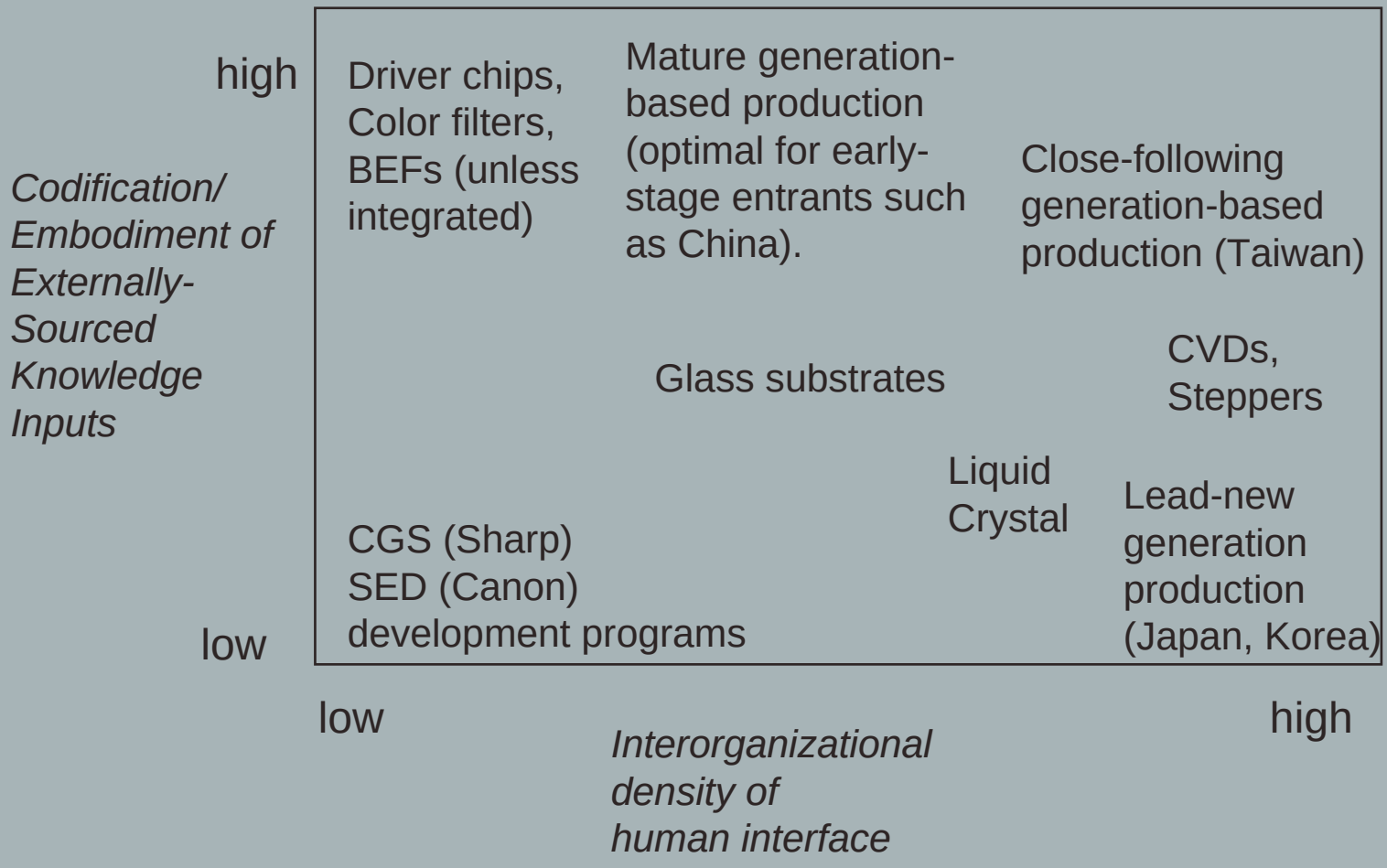
Innovation relationships: tendencies, propensities



Dynamics: scenario that depicts an innovation cycle that unfolds completely in a network

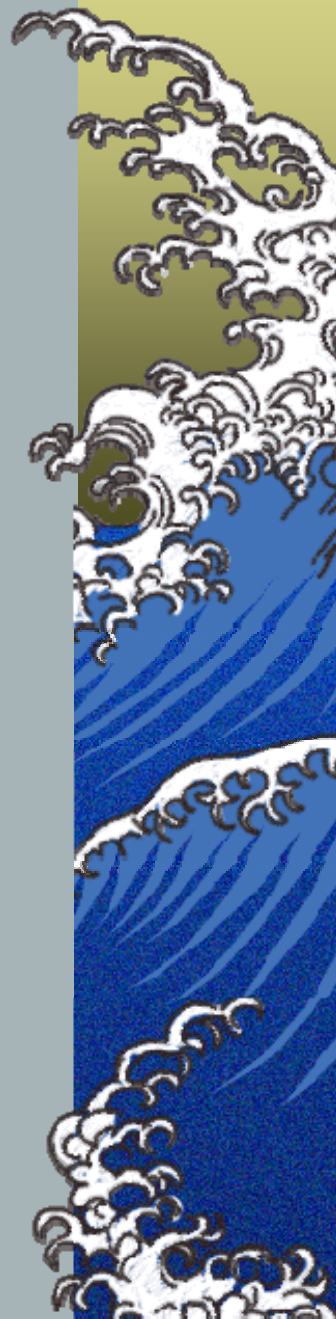


Representative elements of FPD industry knowledge network



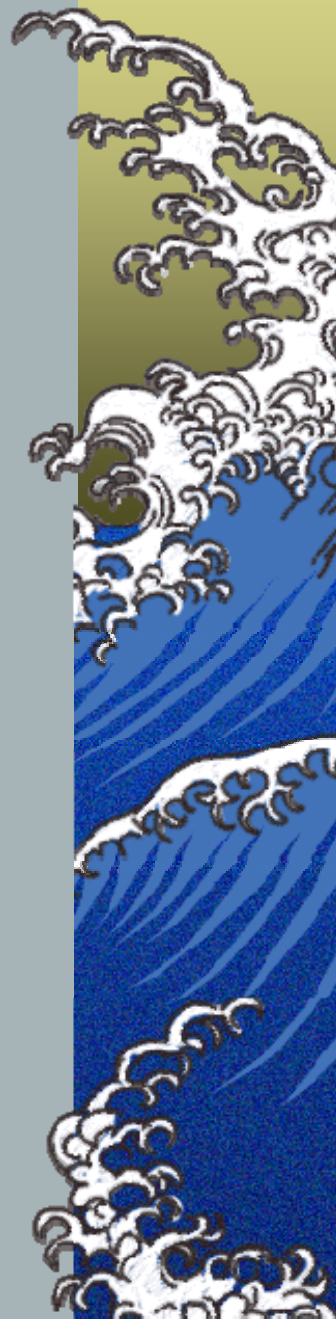
Breakthrough collaborations in FPD industry evolution

- ***IBM, Toshiba****: Large format TFT-LCDs*
- ***Sharp, Applied Materials, IBM, Toshiba, Corning, Merck, others:*** *High volume production paradigm, Generations 2 and 3*
- ***Korean producers, Global equipment/materials providers:*** *lead and continuity in Gen 4+*
- ***LG, Photon Dynamics****: Zero defects*
- ***Japanese, Taiwanese producers****: process innovation, countervailing force to Korea's emerging dominance*
- ***Sony/Samsung*** *joint panel production, connecting technology and markets (Sony Bravia TFT-LCD TV)*



Current Situation: TFT LCDs as heavy manufacturing

- *6th Generation fabs optimized for 6-up 37-inch diagonal FPD televisions, 7th Generation for 6-up 42-inch.*
- *New fabs rank among largest buildings ever built.*
- *New lines cost upwards of $3 billion.*
- *Some equipment requires setup space as large as a basketball court.*



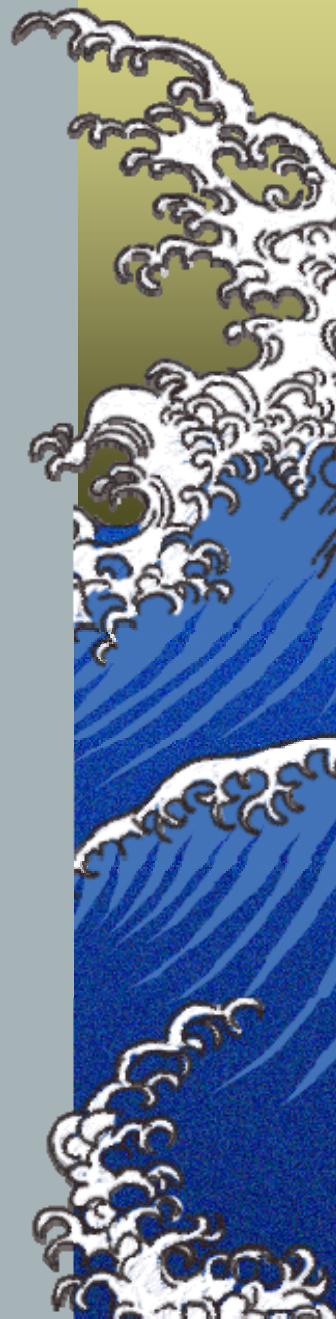
Collaborative and competitive dilemmas I

- *Location-specificity of knowledge (particularly tacit and verbal)*

+ *requirement to leverage suppliers' and customers' firm-specific knowledge*

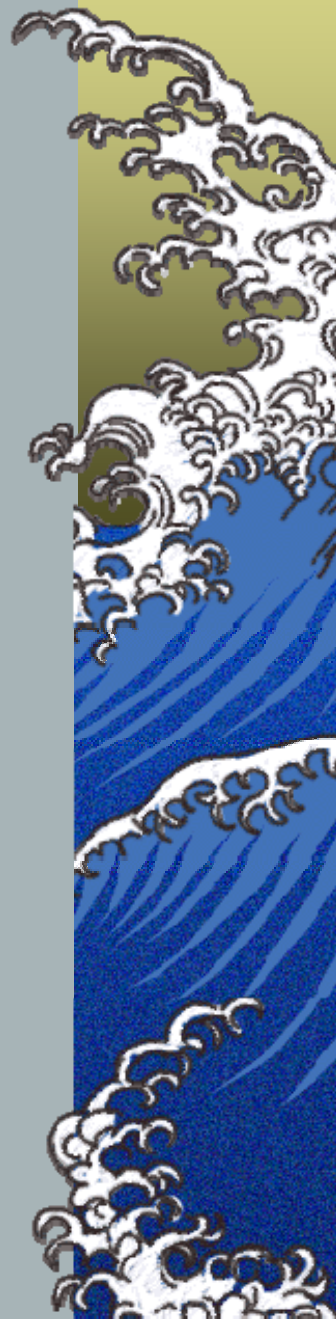
+ *conditions of rapid change*

= *need to create cross-border intra- and inter-firm links even if knowledge is complex, tacit and competitively sensitive.*



Collaborative and competitive dilemmas II

- *Property rights in relationship-specific, jointly-created knowledge.*
- *Confidentiality*
- *Industry generalization of knowledge through multi-client suppliers and OEMs' shopping of specifications.*
- *Standards: Who will set the rules?*
- *Supply/demand consensus.*

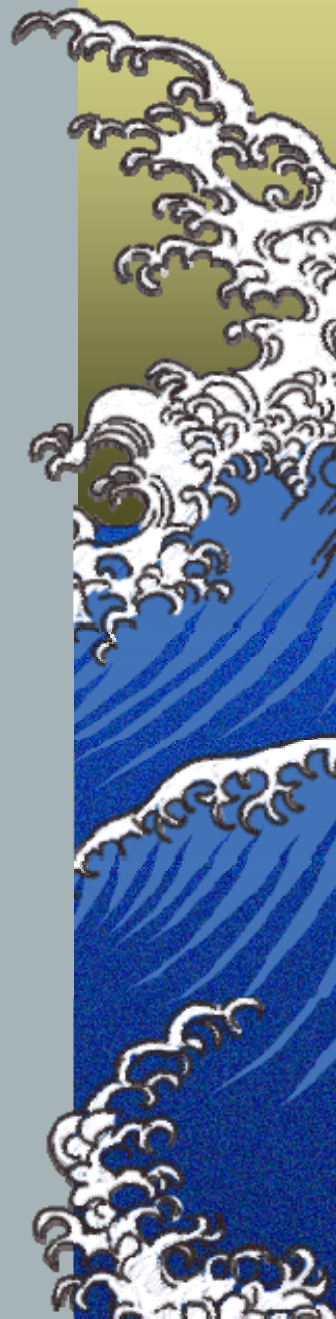


Factors that mitigate vertical integration in the FPD industry innovation system

- *Suppliers' IP and human knowledge capital.*
- *Rapid Gen changes: between 2x and 18x equivalent semiconductor historic phases.*
- *"Bandwidth:" producers' most experienced personnel spread increasingly thin.*
- *Large R&D investments shared by industry.*
- *Collective interest in industry advance: mutual dependence recognized.*

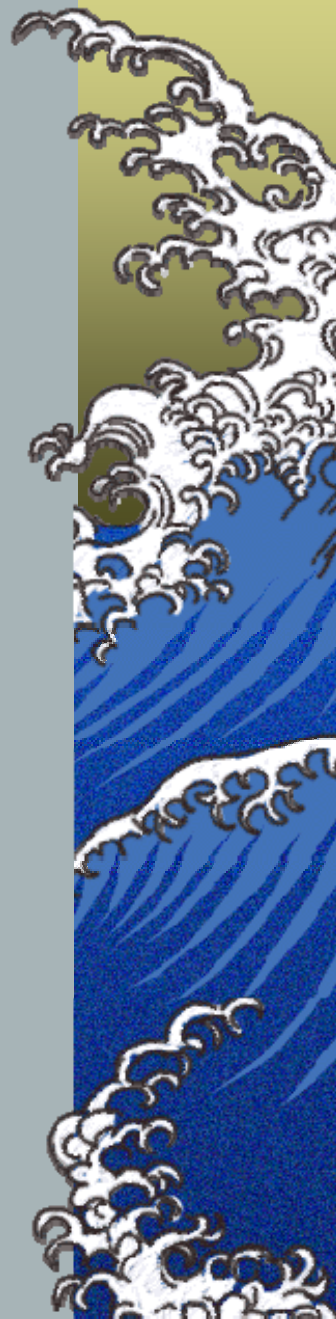
Success factors: IBM, Applied Materials, Corning, Merck . . .

- *Strong pre-existing organizational capabilities in Japan.*
- *Close relations with customers, suppliers and alliance partners with operations in Japan, regardless of nationality.*
- *Responsibility for new global FPD business vested in Japanese affiliate.*
- *Non-reliance on government programs.*



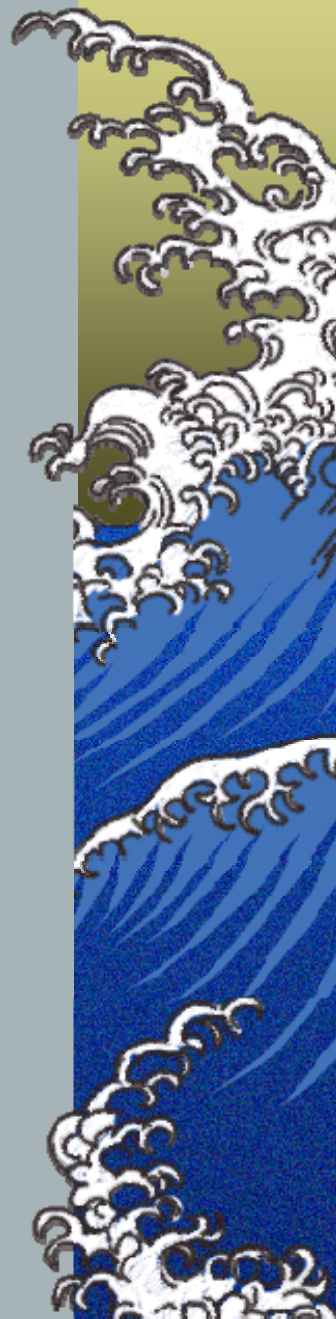
Success detractors: Most U.S. Firms

- *Policy failure: Strings attached to U.S. R&D subsidies distracted many firms from establishing learning relationships in Asia.*
  - *Out-of-touch with industry developments*
  - *Unable to master high volume production*
- *Reluctance to source equipment, materials, process recipes from Japan.*
- *Targeting generational or technological leapfrog without achieving current tech mastery*
- *Confusing market cycles with commodification.*



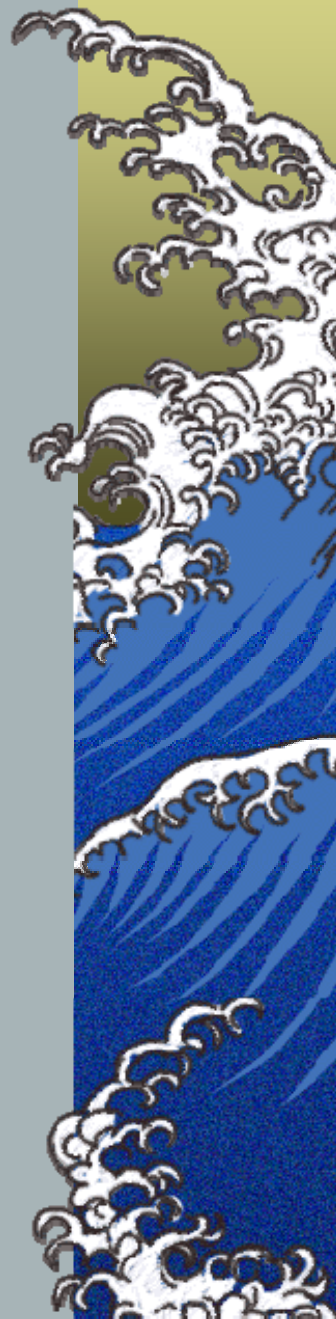
Success factors: Korean firms

- *Willingness to adopt lagging generation technology as learning platform (Gen 2).*
- *Resistance to government policies to mandate industry consolidation.*
- *Global best-supplier policy for equipment and materials, regardless of nationality.*
- *Aggressive Gen 3 fab investment during Asian Financial Crisis (Japanese firms stalled).*
- *For LG, alliance with Philips to raise capital and improve consumer market access.*



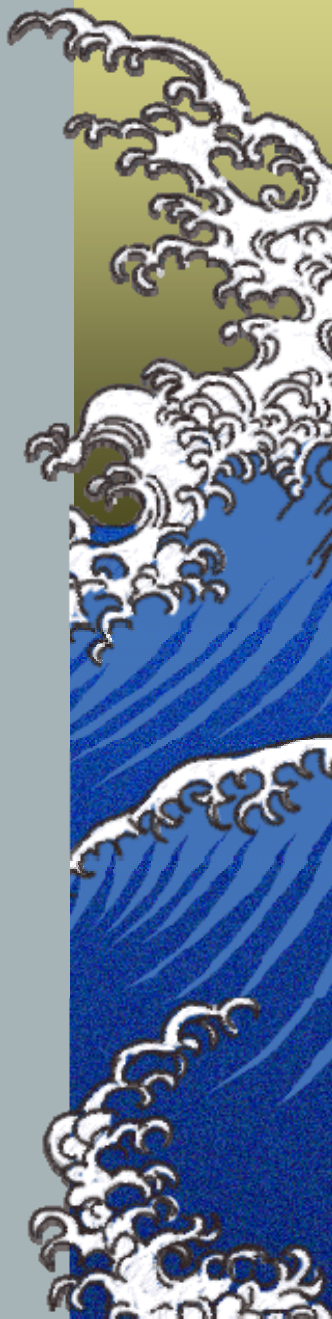
Success factors: Taiwan's firms

- *Adoption of slightly lagging technology as learning platform (Gen 3 and 3.5).*
- *Aggressive Japan technology partnering.*
- *Focus on module and process innovation rather than leading Generational transitions: a challenge to conventional industry cost structure and cyclicality.*
- *Taiwan capital market access.*



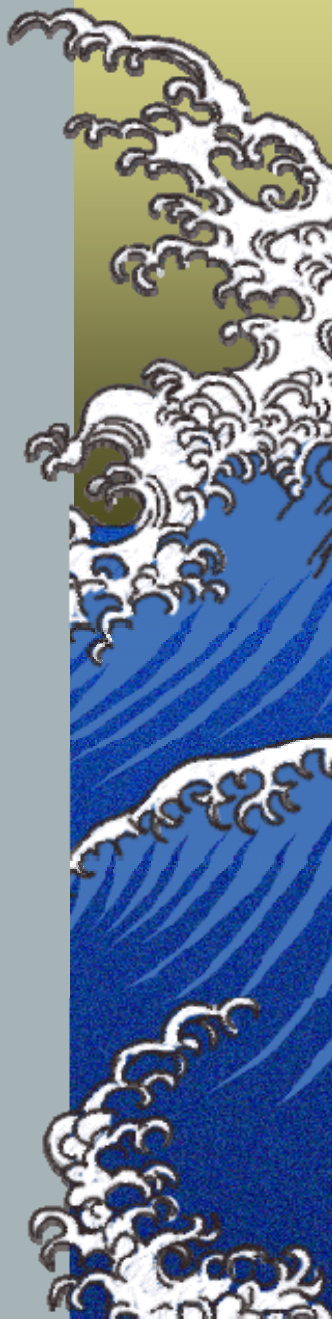
Fab startup as knowledge creation and transfer I

- *New Generation fabs create new technical challenges, new knowledge in startup and line integration.*
- *Suppliers gain extensive, unique knowledge by experiencing equipment and processes in multiple settings.*
- *Some suppliers may know more about yield enhancement than producers.*

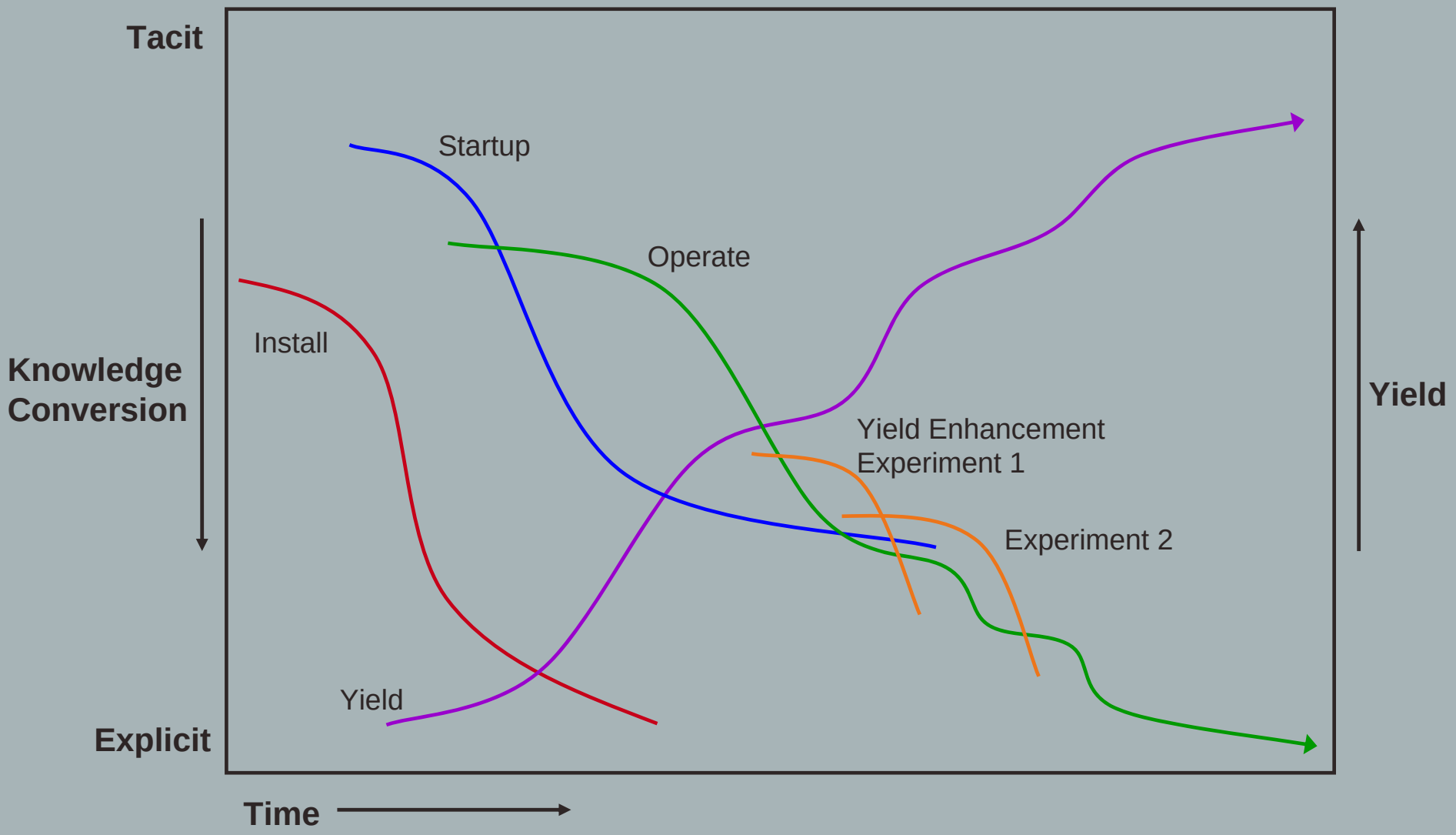


Fab startup as knowledge creation and transfer II

- *Knowledge = principal leverage to maintain intimate customer relations and secure share of innovation rents.*
- *Tacit and verbal elements require close personal interaction on shop floor.*
- *Service groups remain in fabs until client risk of proprietary knowledge diffusion exceeds value of co-creation and transfer.*

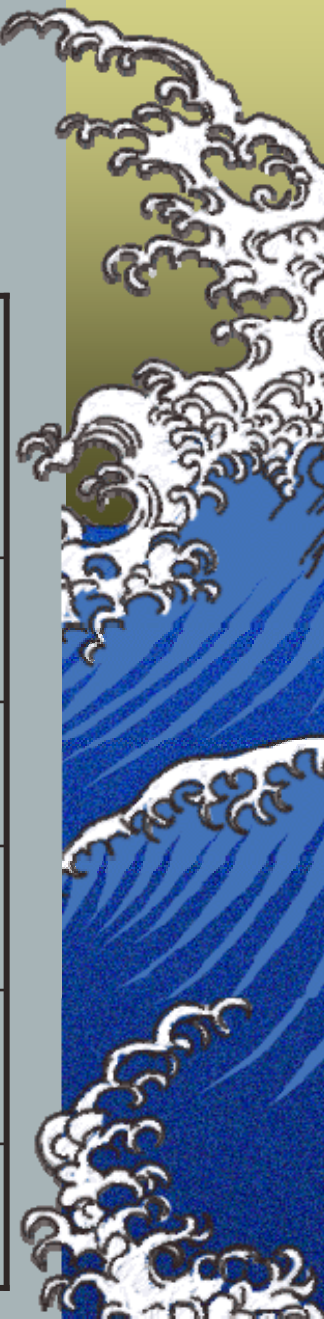


Waking up a new Gen TFT fab: Phases, functional service teams, knowledge conversion, and yields



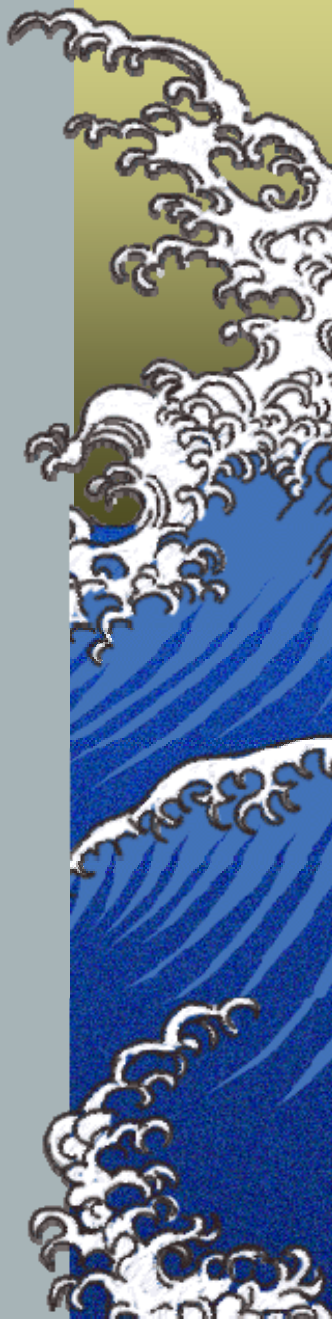
Fab Presence of Supplier Service and Client Teams Startup

	Global Service	*Local Service*	*Client Force*	*Comple-mentary suppliers.*
Install	****			
Startup	****	*	**	*Rarely*
Operate			****	
Enhance	****	**	****	
Aftermkt	*	****		*Rarely*



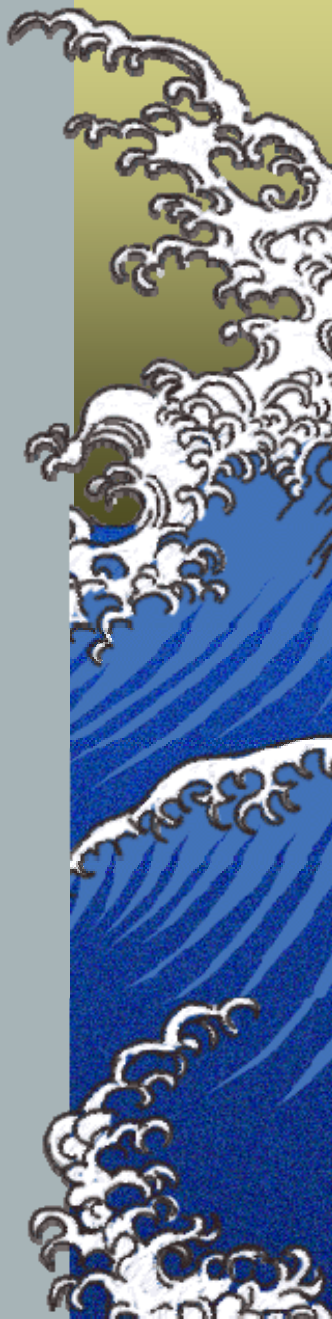
A few common themes regarding FPD networks and collaboration

- *Continuous interaction at operational levels.*
- *Senior management involvement with functional meetings* and *counterparts.*
- *Customer/supplier access and attention vital.*
- *Trust and longevity in relationships.*
- *Humility.*
- *Clear understanding of shared benefit from industry advance as well as those elements that distinguish competitors from each other.*

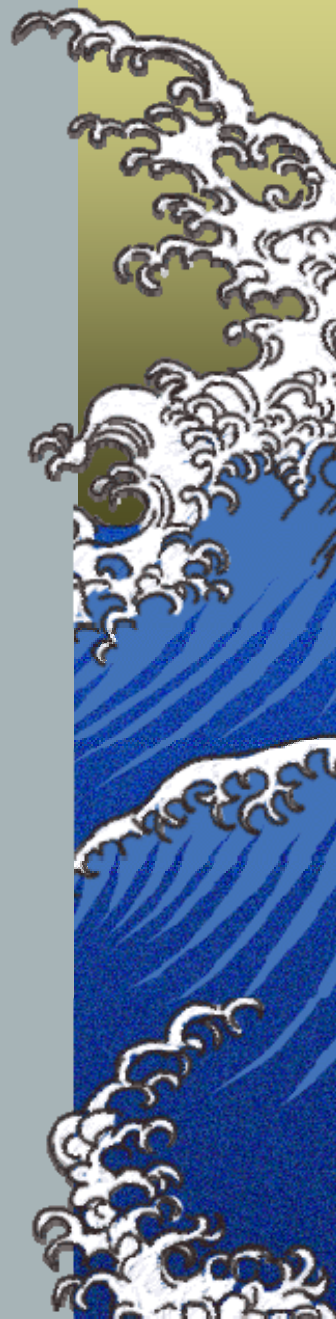


Will firms need more vertically integrated innovation systems?

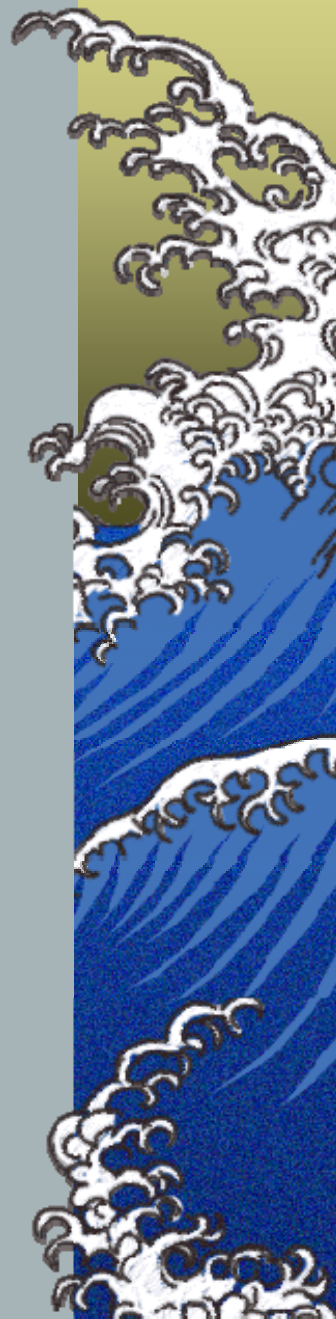
- *Will diminishing returns to scale end cost advantages of generational advances to larger and larger glass sizes?*
- *Will leading firms invest in greater numbers of identical recent generation or older generation fab lines?*
- *Will benefits of sharing a knowledgeable, industry-wide supplier base diminish?*



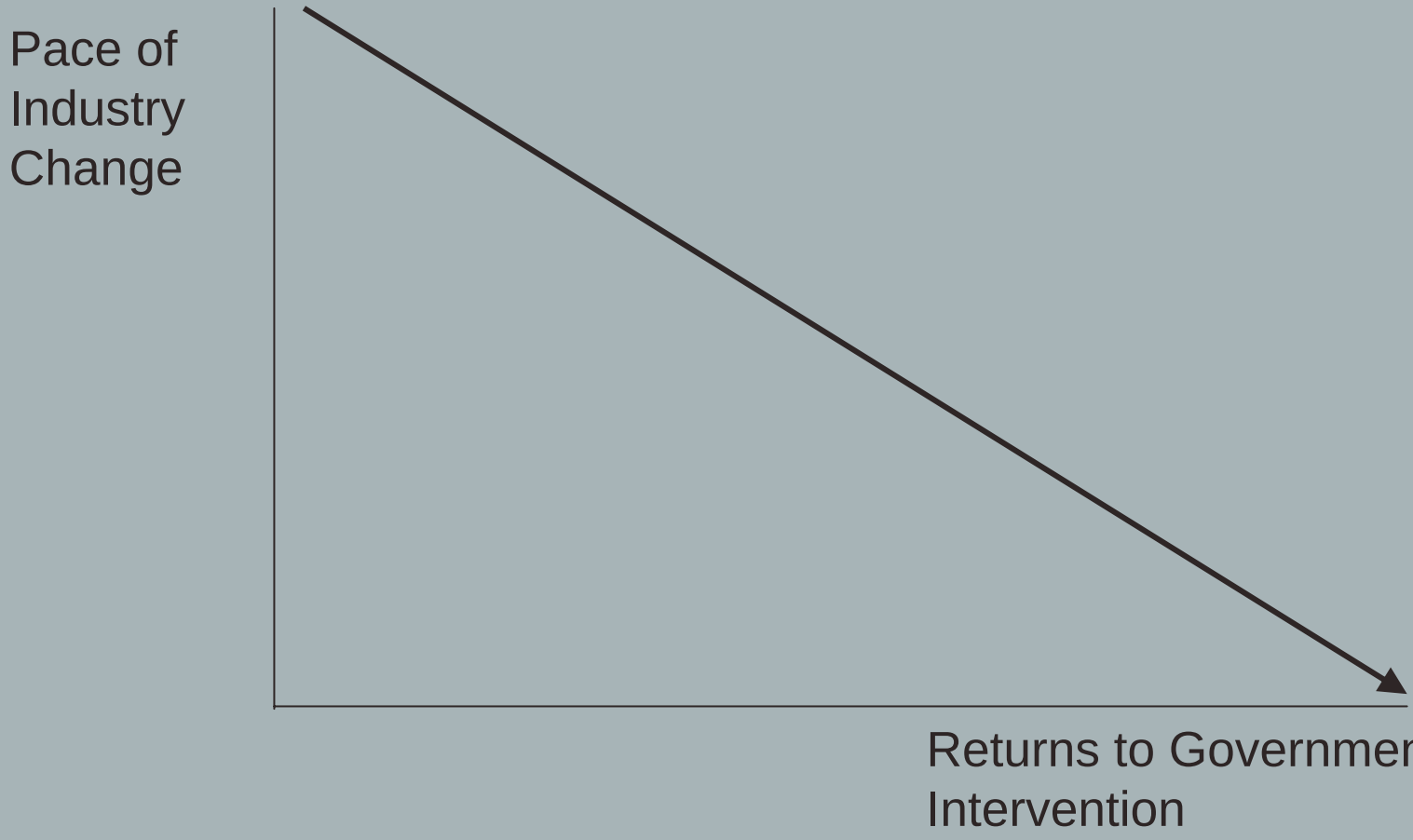
Useful but Unused: provided for reference purposes only.



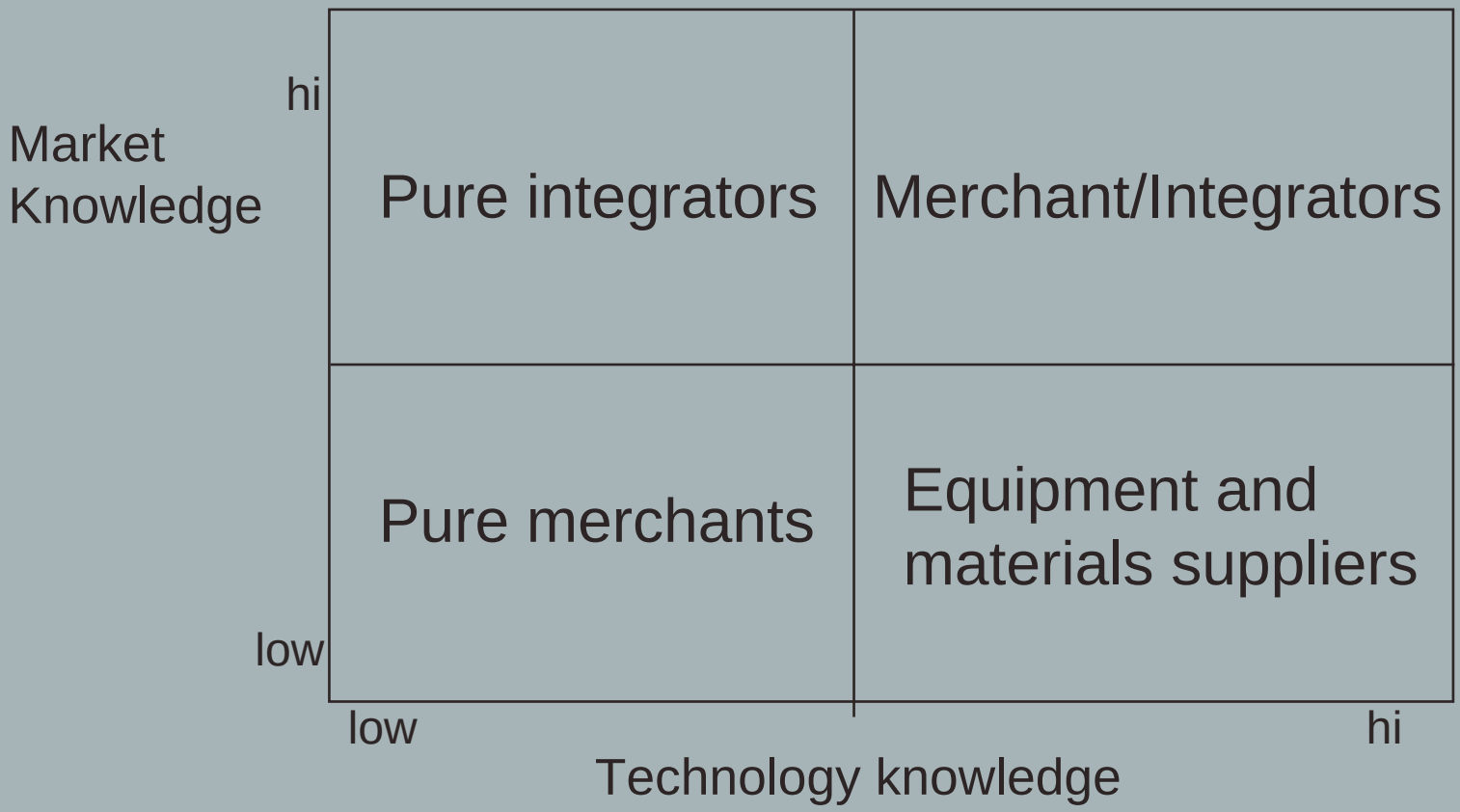
As an exemplar of a global trend, the services component (as opposed to production) in U.S. manufacturing has increased from 32% to 48% of employment since 1993, due mainly to increasing customer needs for specialized engineering and market adaptation of suppliers' core offerings, both before and after sales. Critical knowledge work has both loosened and tightened its ties to geography, as teams of engineers travel among customer sites, offering creative solutions to fundamentally location-bound problems. (Murtha, 2004).



Change and Government Intervention



Global Knowledge Network Interdependencies in the Flat Panel Display Industry

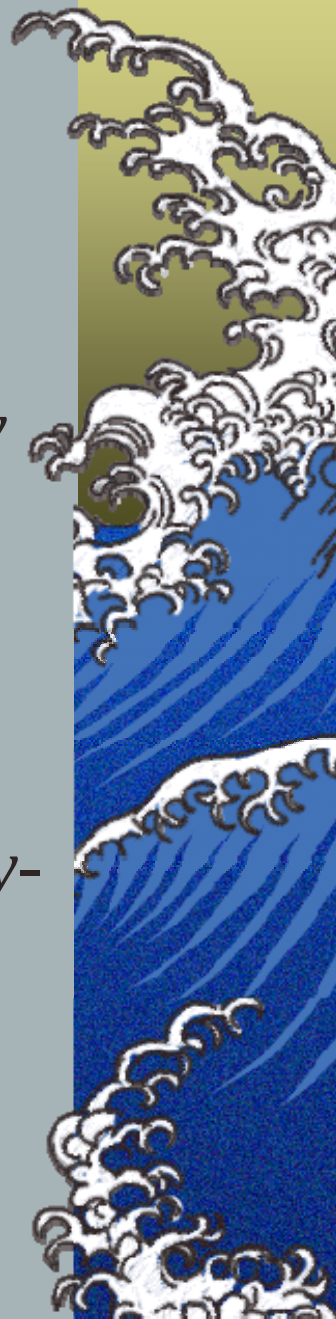


Product vs. Knowledge Based Competition

Competitive Orientation	Product-driven	Knowledge-driven
Value Proposition	cost/differentiation	speed
Internationalization	efficiency/market seeking	knowledge-seeking
Property Rights	vertical integration	access and participation
Sustaining Advantages	protect, exploit adapt	create, share, transcend
Globalization	project, protect national positions	leverage unique national strengths
Nationality	isolate	collaborate

Book available!

- *This presentation covers includes highlights from the book,* **Managing New Industry Creation**, *by Thomas P. Murtha, Stefanie Ann Lenway and Jeffrey A. Hart.*
- *Web sources: Stanford University Press, www.sup.org*
- *www.amazon.com (available through any country-based amazon site, e.g., uk, fr, jp, etc.)*
- *Or request at your local book store*

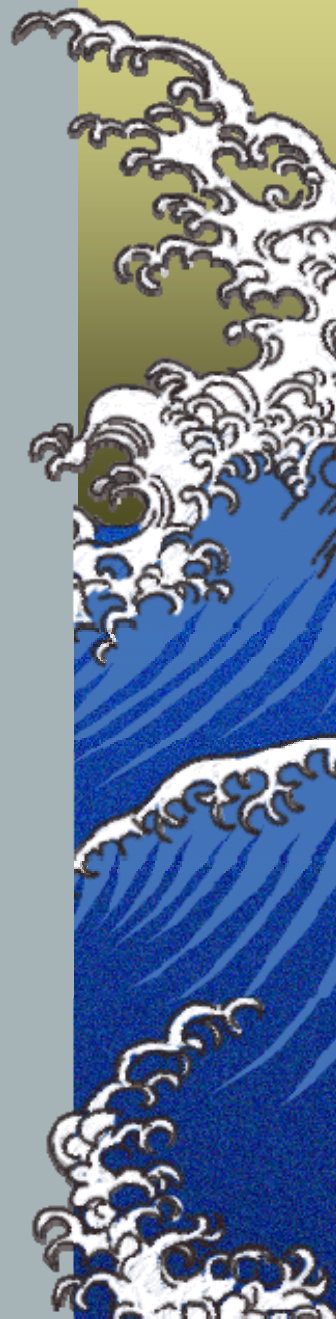


References and caveats:

Unpublished data *in tables derived from author's primary research, informed estimates, and DisplaySearch, Inc.* ***Do not cite without permission.***

Thomas P. Murtha, "The Metanational Firm in Context: Competition in Knowledge-driven Industries." **Advances in International Management**, *Elsevier, 2004: 101-136.*

Thomas P. Murtha, Stefanie Ann Lenway and Jeffrey A. Hart. Managing New Industry Creation: Global Knowledge Formation and Entrepreneurship in High Technology. *Stanford: Stanford University Press, 2001.*



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