6. Analyses of Firm and National Strategies for Development of the Semiconductor Industry

6.1. A comparative schema for understanding strategies and institutions

- The interaction between forerunners and latecomers

- strategy and organizations for ‘forging ahead’ vs. ‘catching-up’

- Differences in capability
  - forerunner or latecomer
  - big or small firm (country)
- Differences in risk-taking preference
  - offensive vs. defensive strategy
  - imitative vs. dependent strategy

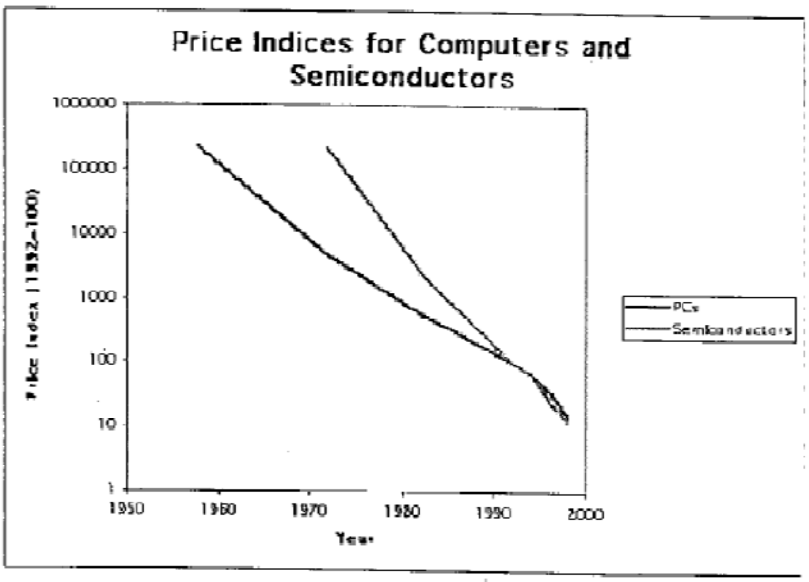
    : willingness and/or necessity to compete directly with forerunners

    → characteristics of political (managerial) leadership, size of a country, historical conditions ….

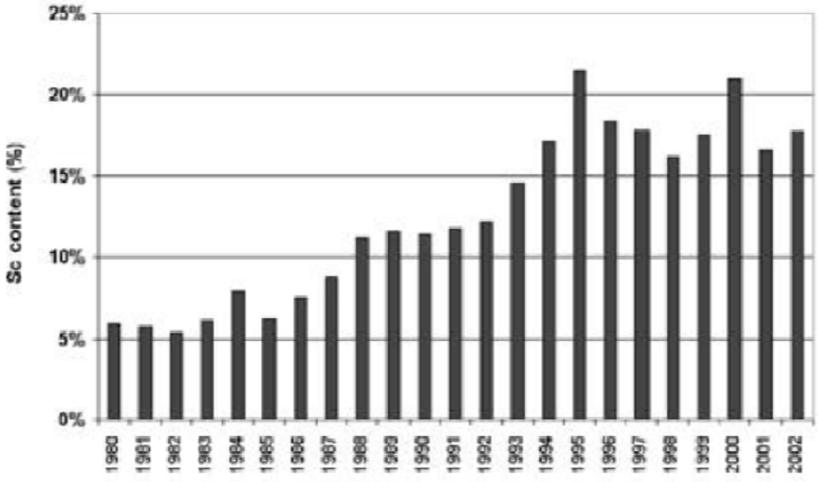
- Technological trend and its imperatives
  - technological trajectory is given, though it is created by firms' and nations' conscious efforts
  - firms and nations attempting to survive and exploit the technological trajectory
  - close examination of technological imperatives necessary

The semiconductor industry

(1) a newly emerging basic industry ('key factor' industry)
- broad adoption



SC contents in electronic goods



The semiconductor industry

(2) system-like characteristics
- computer-on-chip
- the importance of ‘standards’, esp. in microprocessors

The semiconductor industry

(3) rapid product & process innovation
- both capital and R&D intensive
- rapid fall of prices and the need for continual heavy investments
- widespread technology trade due to shorter life cycle of technologies

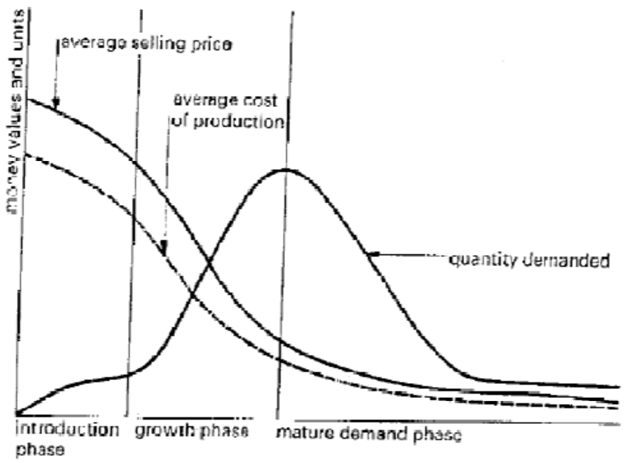
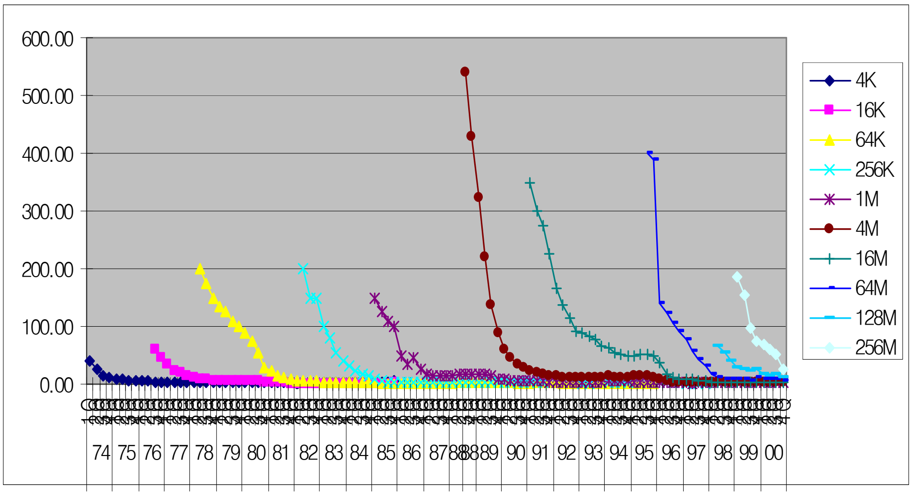


Fig. 7.3 The pattern of a typical semiconductor product cycle
Source: Golding (1972).

DRAM Price Changes



The semiconductor industry

(4) diverse products with different technological and capital requirements within the industry

→ a ‘microcosm’ of the whole industry?

SC Market by products

Unit: US $ billion, %

	1998		1999		2000		2001		2002	
Memories	23.0	18.3%	32.3	21.6%	49.2	24.1%	24.9	17.8%	27.0	19.2%
Logic	29.0	23.1%	33.6	22.5%	45.8	22.4%	32.7	23.6%	31.3	22.2%
Micom	36.9	29.4%	41.3	27.6%	50.3	24.6%	37.3	26.8%	38.1	27.1%
Analog	19.1	15.2%	22.2	14.8%	30.5	14.9%	23.2	16.7%	23.9	17.0%
Digital Bipolar	1.1	0.9%	1.0	0.7%	1.1	0.5%	0.4	0.3%	0.2	0.2%
Opticals	16.5	13.1%	19.2	12.8%	27.4	13.4%	19.6	14.1%	19.1	13.6%
Sensor							0.9	0.7%	1.1	0.8%
Total	125.6	100	149.4	100	204.4	100	139.0	100	140.7	100

Source: WSTS

Structure of Semiconductor Production by Countries
(%)

	Discrete & Opto	Bipolar	Analog	Micro	Logic	Memory	Total
U.S	6.1	0.8	13.7	51.1	16.7	11.6	100
Japan	22.9	1.0	12.1	18.5	20.8	24.7	100
Korea	5.3		4.3	3.5	4.4	82.5	100
World	13.5	0.9	15.9	36.2	15.5	18.0	100

(Source : Dataqeust '98. 5, KSIA '98. 6)

The semiconductor industry

(5) Spatial separability of production process & ‘marked polarisation of the skill structure of its labour force’

- pioneering the Global Production Network of the electronics industry

→ the possibility of ‘enclave’ development

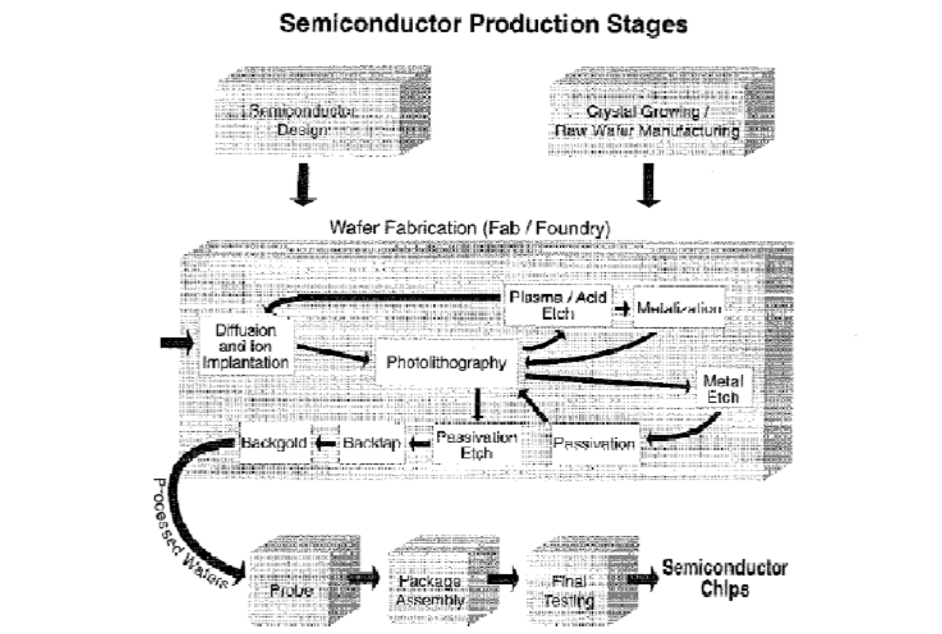
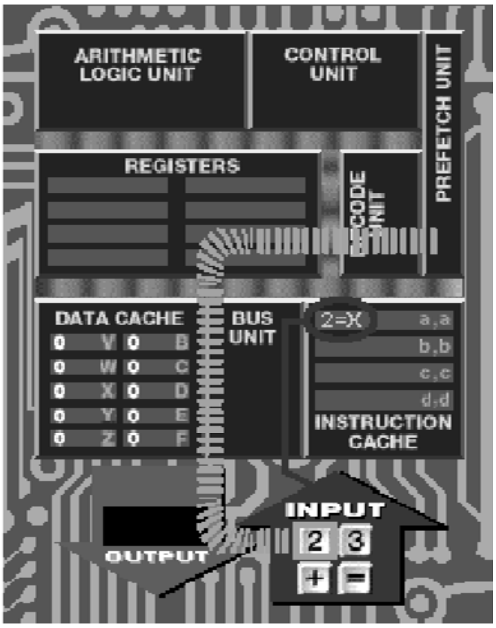


Figure 2. Principal stages in the production of semiconductors

intel inside

pentium®
PROCESSOR



6.2. The USA System and Development of the SC Industry

NIS of the USA after World War 2

(1) The existence of established large firms and financial institutions

* Bell Labs $\rightarrow$ pioneer of transistor, theoretical & engineering works on computers …
* IBM's dominance in the computer industry
  - the largest producer of advanced ICs in 1965 purely on the strength of its own internal demand

NIS of the USA

(2) Natural spin-off model

- the centre of R&D: military technology

cf. small federal expenditure for R&D before WW2

→ 40-50% during the postwar period (Mowery 1992: 134)

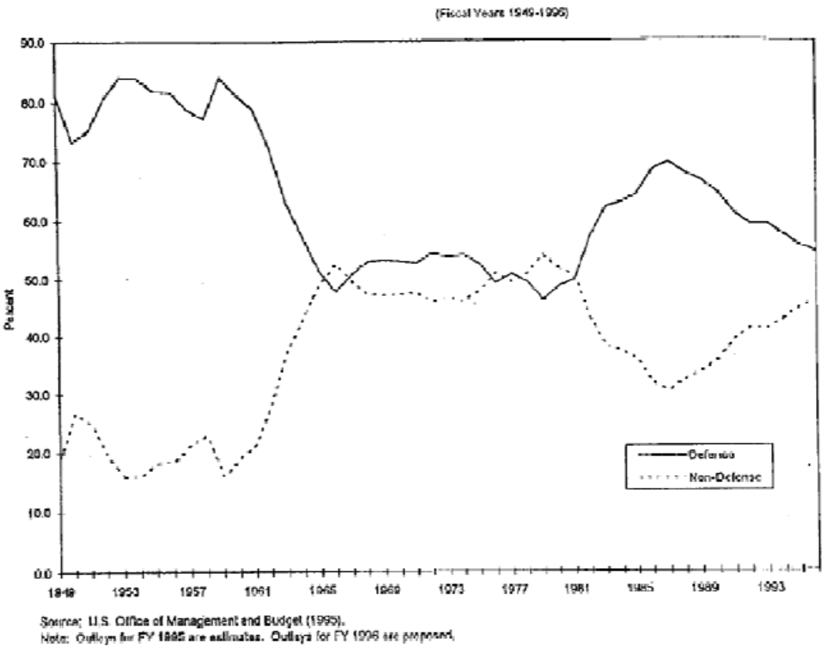


Fig. 1. The conduct of federal R&D: defense and non-defense shares (FY 1949–1996). Source: U.S. Office of Management and Budget (1995). Note: Outlays for FY 1995 are estimates, outlays for FY 1996 are proposed.

Military demand & R&D support for the SC industry

- Military demand for SCs
  36-39% in 1955-58
  → 45-48% in 1959-60

Table 2.2. *Value of U.S. Transistors by End-Use, 1963*

Military		*Industrial*		*Consumer*	
Space	33.0	Computers	41.6	Car radios	20.6
Aircraft	22.8	Communications	16.0	Portable radios	12.6
Missiles	20.3	Test and measuring	11.7	Organs and hearing aids	7.3
Communications	16.8	Controls	11.5		
Surface systems	10.8	Other	11.5	Television	0.3
Strategic systems	8.8				
Other	6.7				
Total:	**119.2**		**92.3**		**40.8**
Percent:	**47.2**		**36.6**		**16.2**

Source: Dodson (1966, pp. 95–97).

Military demand & R&D support for the SC industry

- Emphasis on quality
  - ‘miniaturisation and high quality’
    “... willing to pay the high prices the earliest devices commanded” (Langlois & Steinmueller 1999: 35)

  → dominance of silicon over germanium

Table 2.1. *U.S. Sales of Germanium and Silicon Transistors (Nominal $)*

	Germanium		*Silicon*	
	Units (M)	Average Value ($)	Units (M)	Average Value ($)
1957	27.7	1.85	1.0	17.81
1958	45.0	1.79	2.1	15.57
1959	77.5	1.96	4.8	14.53
1960	119.1	1.70	8.8	11.27
1961	177.9	1.14	13.0	7.48
1962	213.7	0.82	26.6	4.39
1963	249.4	0.69	50.6	2.65
1964	288.8	0.57	118.1	1.46
1965	333.6	0.50	274.5	0.86

Source: EIA (1974, p. 87).

Military demand & R&D support for the SC industry

- R&D
  - ‘about a quarter of all semiconductor R&D in the 1950s
  - no deliberate attempt at connecting military technologies to commercial technologies.

Table 2.3. *Estimated U.S. Government Direct Funding for R&D and Production Refinement, 1955–1961*

	1955	1956	1957	1958	1959	1960	1961	Totals
Research and development	3.2	4.1	3.8	4.0	6.3	6.8	11.0	39.3
Production refinement								
Transistors	2.7	14.0	0.0	1.9	1.0	0.0	1.7	21.3
Diodes and rectifiers	2.2	0.8	0.5	0.2	0.0	1.1	0.8	5.6
Total	8.1	18.9	4.3	6.1	7.3	7.9	13.5	66.1

Source: U.S. Department of Commerce (1961, p. 13, Table 8)

NIS of the USA

(3) Top universities

- already achieved excellence in applied research, esp. in engineering

  → closer linkage with industry

- inflow of foreign talents

  "[during the prewar period], virtually all 'serious' U.S. scientists completed their studies at European universities" (Mowery 1992: 133)

NIS of the USA

(4) The importance of anti-trust law

- difficult for big firms to monopolize new technologies
- incentives for engineers who are engaged in 'peripheral technologies' in those firms to set up new firms

NIS of the USA

Eg1. the AT&T case (1956)

: liberal patent licensing + prohibiting AT&T from commercial activities outside telecommunications

→ opportunity for startups to enter microelctronics

NIS of the USA

Eg 2. the IBM case (1956)

- mandated liberal licensing of its punchcard and computer patents at reasonable rates

NIS of the USA

(5) Dynamic small firms in commercialising new technologies

- the incubator role of universities and large firms

  → scientific and technological knowledge ‘walked out the door’ with individuals

- development of venture capital market

  : \$100-200 million per year throughout the 1970s

- generous procurement policy by the government

  : largest customer for semiconductors and computers by the end of 1960s

The dominance of merchant producers in the SC industry

- Fragmented producers

"... the new leaders were either specialized start-ups or multidivisional firms (like TI, Fairchild, and Motorola) in which the semiconductor division dominated overall corporate strategy ..... By contrast, the semiconductor divisions of the integrated system firms were a small part of corporate sales and of corporate strategy ..." (Langlois & Steinmueller 1999: 33)

Table 2.5. *Production and Consumption of Semiconductors by Country, Selected Years*

Country	Consumption (1956)	Production (1958)	Consumption (1960)	Production (1961)
United States	80	236	560	607
Japan	5	19	54	78
W. Germany	3	10	25	30
Great Britain	2	8	28	35
France	2	8	27	32

Note: $ million (nominal).
Source: Malerba (1985).

Table 2.6. *Leading U.S. Merchant Semiconductor Manufacturers, 1955–1975*

1955 *Transistors*	*1960* *Semiconductors*	*1965* *Semiconductors*	*1975* *Integrated Circuits*
Hughes ✓	Texas Instruments	Texas Instruments	Texas Instruments
Transitron	Transitron	Motorola	Fairchild
Philco	Philco	Fairchild	National
Sylvania	General Electric	General Instrument	Intel
Texas Instruments	RCA	General Electric	Motorola
General Electric ✓	Motorola	RCA	Rockwell
RCA ✓	Clevite	Sprague	General Instrument
Westinghouse ✓	Fairchild	Philco-Ford	RCA
Motorola	Hughes	Transitron	Signetics (Phillips)
Clevite	Sylvania	Raytheon	American Microsystems

Source: Mackintosh (1978, p. 54).

The Case of Intel

- Founders (1968)
  - Gordon Moore: Moore's Law
  - Robert Noyce: Father of IC
- Venture capitalist
  - Arthur Rock: coined 'venture capital'
  - raising US$2.3 million in one afternoon
  - 50 phone calls and 50 acceptance

Pre-history

- Working in Bell Labs
- Setting up Shockley Lab in 1956
- The “Traitorous Eight”

→ Setting up Fairchild Semiconductors with $1.5 million investment from Sherman Fairchild

→ a great success, but big decisions always made in New York

“Fairchild became the electronics industry’s equivalent of a sycamore tree with its winged seeds: Every season, seeds from Fairchild would spin away gently in the wind, land somewhere nearby, and burst into growth as new saplings.” (Jackson 1997: 21)

DRAM

- Previously, ICs had been only used in Logic
- Memories by 'magnetic core'
- Race for developing SC memory (dozen companies…)
- Fairchild pioneering MOS (metal oxide on silicon) method
- Loose enforcement of property right in the 1960s

DRAM

- Key to success?

 - engineering capability
 - reducing prices through design improvement & mass production
 - $10.24 per chip
 - $566,000 of sales in 1969
 - $4.2 million of sales in 1970

Microprocessor

- Order from Nippon Calculating Machine Corporation
  - 8 logic chips for Busicom
  - a basic 4-chip set structure: CPU, ROM, Memory, and I/O
  - delay + competition → demanding a price cut
  - refunding $60,000

Microprocessor

- Intel 4004 in 1971
- New era of ‘computer on a chip’
  - size, cost ($100)
  - matching the power of ENIAC

  “One of the most revolutionary products in the history of mankind” (Jackson 73)

Microprocessor

- Intel's early ignorance of the market for microprocessor
  - 20,000 mainframe computers in 1971
    → 10% market share: a week's production
- DRAM customers
  - "Who's who" of the industry
- Micom customers?

Microprocessor

- The emergence of new driving forces in the computer industry
  - the first personal computer
    : the domain of 'hackers' or 'hobbists'
  - the first S/W for PCs
  → 'Wintel' alliance

Second-sourcing and AMD

- Second sourcing
  - customers' (esp. the government') request
  - a forced sharing of monopolized technologies