4.3. The ME Revolution and Information Society

Information society

- Importance of information?
  - "Knowledge is power"
  - capitalism: capital as knowledge embodiment
- New aspect?
  - mass production and consumption of knowledge
  - IT, ME (micro-electronics), digital revolution, KBE …

ME Revolution and PCs

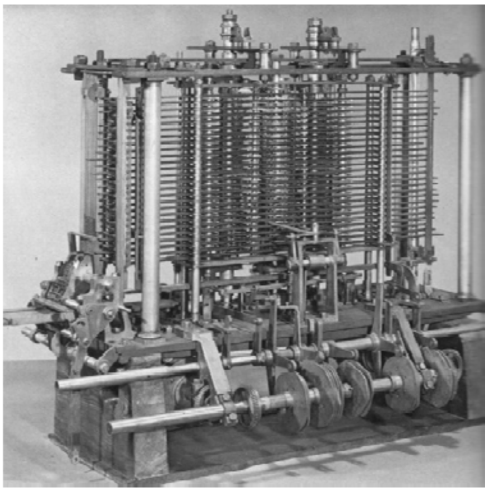
- Key factor inputs: chips
  - Introduction of transistor in 1947
  - 'Moore's Law' (1965)
  - Mass production and mass deployment of chips

Computer industry before the advent of microchips

- Computers developed as tools for scientists
  - Blaise Pascal and arithmetic machine (1642): addition & subtraction
  - Charles Babbage and analytical engine (1882): idea of using punch cards, £17,000 development grants from the British govt for over 20 years
  - George Bool: Boolean algebra (1847); logic as mathematics → logic operation on binary number

Pascal and his Arithmetic Machine

Charles Babbage and his Analytical Engine



Commercial usage of computing machine

- Herman Hollerith, American statistician working on 1880 census
  → electronmechanical machine reading holes in perforated cards
- 1890 census carried out by the machine: 1/3 of the time taken in 1880
- Setting up Tabulating Machine Company in 1896
  → later International Business Machine (IBM)

Herman Hollerith and Punched Card Tabulator

Continued scientific development of computers

- Zuse computer (1936-41)
  - the first electronic computer
  - used in aircraft design calculation
- Automatic Sequence Controlled Calculator (ASCC) (1937-43)
  - the first Harvard-IBM computer
  - Mark I 1944
- Bletchley machine to crack ‘Enigma’ of Germany

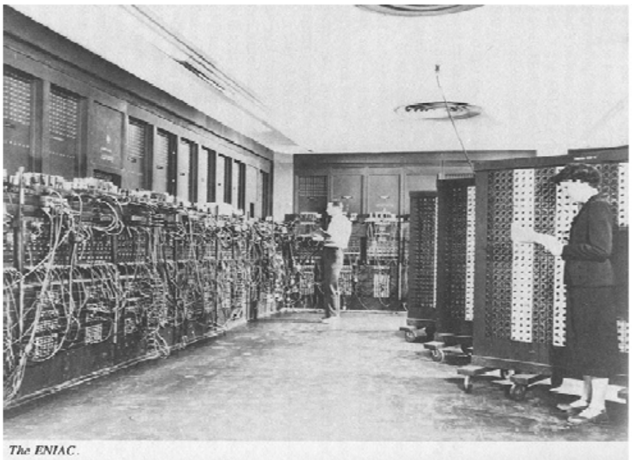
The Bletchley Machine

Continued scientific development of computers

- ENIAC (1946)

  "The ballistics calculation that took 12 hours on a hand calculator could be done in just 30 seconds. That means the ENIAC was faster by a factor of 1,440.

ENIAC



The ENIAC.
Smithsonian Institution Photo No. 53192.

Commercial development of computers

- Spurred by public contract programs (1945-1955)

  - the US Army, Navy and Air Force, the Atomic Energy Commission, National Bureau of Standards …

  - the growth of Remington Rand (Univac) and IBM

Commercial development of computers

- Still commercial uncertainties felt by the private sector

  "Their (IBM's) Product Planning and Sales Department forecast that there would be no normal commercial sales of the 650 [which they produced under the pressures of the Korean War]"… Thomas Watson … felt that the one SSEC machine which was on display at IBM's New York offices 'could solve all the scientific problems in the world involving scientific calculations" (Freeman & Soete 1997: 172)

Commercial development of computers

"In the eventual outcome, over 1,800 machines were sold and the 650 became know as the 'Model T' of the computer industry" (Freeman 1997: 173)

Commercial development of computers

- The increasing commercial demand of computers in the 1950s
  - about 40% from the private sector
  - still, 60% of sales came from the public sector
- The explosive growth of demand in the 1960s
  - IBM employs 15,000 R&D personnels
  - failed entrants by RCA, GE …

One of 4000 Logic Modules for an IBM 704 Computer (1954)

Emergence of transistors

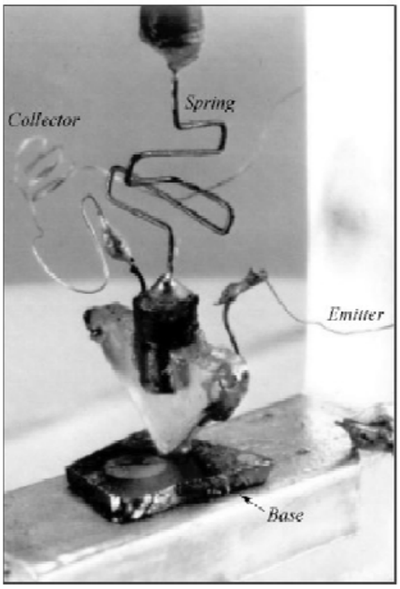
- The first transistor developed by Bell Labs in 1947 → awarded Nobel Prize in 1948

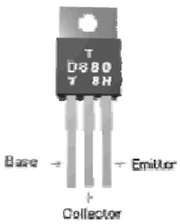
  - the great commercial potential

The first point contact transistor

William Shockley, John Bardeen, and Walter Brattain

Bell Laboratories, Murray Hill, New Jersey (1947)





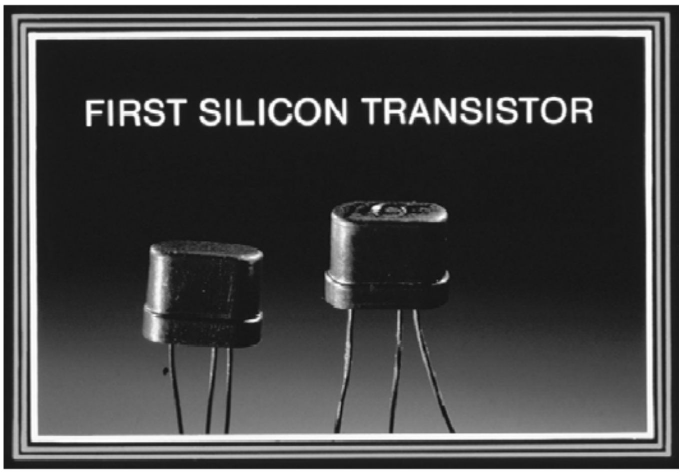


Table 7.1 Technical progress in computers

Measure	*Vacuum-tube computers (early 1950s)*	*Hybrid integrated circuits-360 system (late 1960s)*
Components per cubic foot	2,000	30,000
Multiplication per second[a]	2,500	375,000
Cost ($) of 100,000 computations	1.38	0.04

[a] A single multiplication on mechanical or the first electromechanical computers took more than one second.

Source: Fortune (1966), September.

Emergence of transistors

- Huge R&D investment on transistors and transistorized equipment
  - £2.7 million up to 1953
  - £28 million up to the end of 1960
  - £57 million up to Sept. 1964
- Investments for development of its technology system
  - capacitor, resistor, boards …

Diffusion of transistors

- US anti-trust law

  - started in 1949 and settled in 1956

  "The Bell basic patents in transistors were made available to all-comers on payment of a $25,000 advance royalty" (Freeman 1997: 178)

  - total about £9 million of royalty income during 1952-1963

  : far below Bell's R&D costs
- First transistor radio developed by Japanese

Development of transistors into Integrated circuits (ICs)

- Initially regarded as one component of electronic goods

  - this itself has a very important economic significance
- Increasing complexity and integration

  - the significance of MOS technology

  - mass production with quality control

  - a stepping stone to transform IC from a part to a brain

Table 7.2 Major product innovations in the semiconductor industry since the integrated circuit (1960s–1970s)

Innovations	*Firm*	*First commercial production*
MOS transistor	Fairchild	1962
DTL integrated circuit	Signetics	1962
Gunn diodes	IBM	1963
Light-emitting diodes	Texas Instruments	1964
TTL integrated circuit	TRW	1964
MOS integrated circuit	General Microelectronics	1965
	General Instruments	
Magnetic bubble memory	Western Electric	
MOSFET (MOS field-effect transistor)	Western Electric	1968
	Philips	
Schottky TTL	Texas Instruments	1969
CCD (charge coupled device)	Fairchild	1969
Complementary MOS	RCA	1969
Static RAM	Intel	1969
Silicon-on-sapphire (SOS)	RCA	1970
P-MOS		1971
3-transistor cell dynamic RAM (1K bits)	Intel	1971
CMOS		1971
Microprocessor	Intel	1972
I^2L integrated circuit	Philips	1973
1-Translator cell dynamic RAM (4K bits)	Intel	1974
VMOS integrated circuit	AMI	1975
C^2L integrated circuit		1976
MNOS		1976
Micro-computer (8048)	Intel	1977
V-MOS	Mitsubishi	1978
64-K bits memory	Fujitsu	1978

Source: Dosi (1981).

Mass Production of Chips

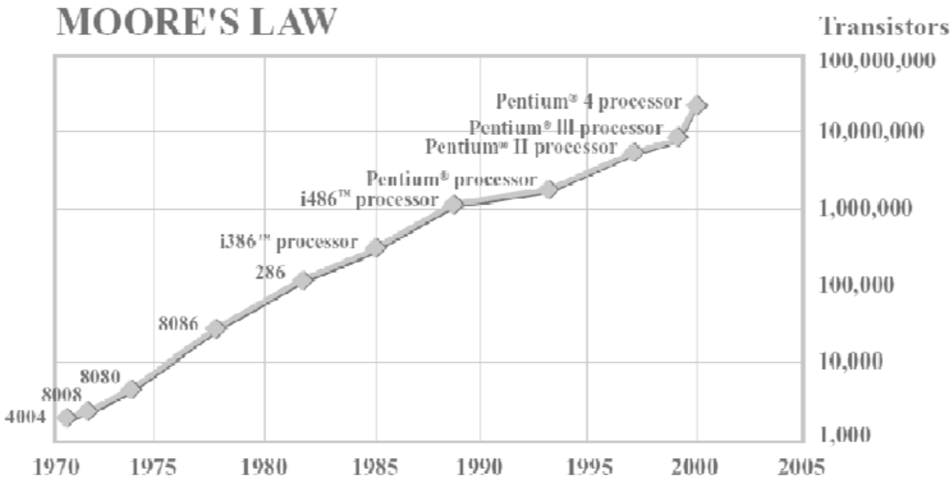
- "In 26 years the number of transistors on a chip has increased more than 3,200 times, from 2,300 on the 4004 in 1971 to 7.5 million on the Pentium II processor."
- 4 Mega chip – 4 million times better than transistor

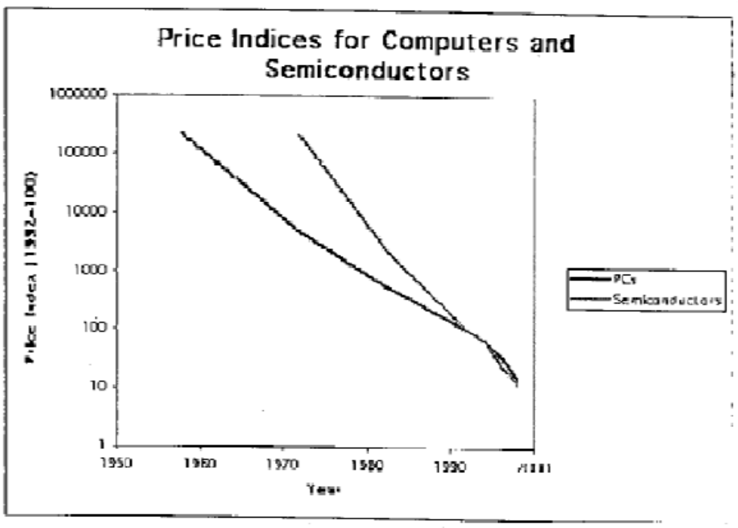
Mass Production of Chips

- “There are now more than half a billion transistors manufactured - every second. Every hour, more than a trillion of them are packed into everything from computers to car engines, satellite systems to gas pumps.” (in 1998)

Falling Prices of Chips

- “Fifty years ago, it cost $5 for every transistor. Today, it costs 1/100th of a cent. In just a few years, it will cost a billionth of a cent (in 1998).


MOORE'S LAW
Transistors
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
Pentium® 4 processor
Pentium® III processor
Pentium® II processor
Pentium® processor
i486™ processor
i386™ processor
286
8086
8080
8008
4004
1970
1975
1980
1985
1990
1995
2000
2005


Price Indices for Computers and Semiconductors
1000000
100000
10000
1000
100
10
1
1950
1960
1970
1980
1990
PCs
Semiconductors
Year

The Age of PC

- The revolutionary features of microprocessor

- ‘computer in chip’

- enabling the separation between H/W and S/W in the computer industry

- assembling a PC became an everybody’s job

Mass Production of Information

- Capacity increase in information production, processing, storage, delivery and so on

- progress in microprocessors, RAMs, hard disks …

- transition to digital technologies
  cf. MPEG

Mass Use of Information

- Easier processing, retrieval and recombination of information
- S/W
- DB industry
- Increasing flexibility and easier customisation

IT Industry

- New engine of growth
- A battle field for industrial hegemony in the ME techno-economic paradigm

‘New Economy’

- Productivity increase through intensive and systematic use of information
- ‘Productivity paradox’ in the 1980s

  “the computers are everywhere but in the [aggregate] productivity statistics?” (Solow 1987)

  cf. Freeman’s ‘structural crisis’

‘New Economy’

- Trend increase in productivity growth rate from the middle of the 1990s
- Productivity growth without employment growth in the 2000s

New Economy: Case of Intel

- Intel's D2000

$\rightarrow$ a dramatic decrease in R&D costs through information sharing & simulation.

"... Intel discovered that more than 60 percent of the problems that designers faced had already been solved by another team… created a database of best-known methods for addressing technical problems …and used a browser interface to ensure access from its half dozen different design sites… D2000 program have helped Intel to almost double the speed at which it has ramped up new product production since 1994.

Fusion across industries

- 'New Combinations' based on more intensive and easier use of information
- Increased opportunities for innovations

Multimedia industry

- A consequence of increased digitalisation of information
- Fusion between consumer electronics, telecommunication, computer, media, publishing ....

  eg. PC TV, PDA, MP3, Camera-phone …

  → Waves of M&As

  eg. AOL and Time Warner ...

Mechatronics

- Mechanics + Electronics
- Chips in machine
- Improved interface between machine and computer

  → increasing accuracy and broadening the scope of work

  eg. Electronicisation of car, NC milling machine, factory automation, CAD/CAM ...

Finance Industry

- Transforming rapidly into a genuine information industry
  - U.S. in 1994 60-70% costs: physical delivery of finance

  e.g. global portfolio management, ATM, smart card, Internet banking, Internet trading, e-cash …
- Increased instability in the international financial market

Internet and E-Commerce

- ‘Market transaction through Internet’
  - interactiveness
  - openness
- A truly global market from the beginning
  - no national border
- Increasing economic significance

Competition for Increasing Knowledge Intensity

- Increasing importance of intangible assets compared to tangible assets

  eg. Toyota case
- 'Knowledge workers'

Competition for Flexibility

- Continued restructuring
- Time-to-market. Just-in-time, team organisation…

  eg 1. Compaq case

  - shifting from conveyor system to total manufacturing

Case of Boeing

- Integrated design build team system

  " … the team at Boeing producing the new 777 aircraft… Grouped into small teams of 8 to 10 people, they have been assigned to refine and mesh all aspects of the aircraft from top to bottom. The idea is to have each team consider the aircraft as a whole, and to empower each team to act quickly on ideas free from chain of command second-guessing. .."

Competition for Fusion

- Competition for creating new combinations across sectors
- New industries
- M&As, strategic alliances …
- Re-organisation of industries

Global Competition

- 'Space-shrinking' technologies
  - reduction in transportation costs
  - reduction in communication costs
  - 'co-location' without geographical proximity
- Shorter life-cycles of products
  - time-to-market
  - the spread of GPN

Interpreting liberalisation in the 1980s and onwards

- Not simple deregulations, but institutional changes towards providing rooms for experiments with new fusions and flexibility