# Offshoring in the Semiconductor Industry:
## Lessons from History

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## Overview of Presentation

Introduction: Chip Industry and Its Challenges in Japan

Three Stages of Offshoring

1. Offshoring and Outsourcing Assembly
   – Result was the U.S. semiconductor industry becoming more cost competitive with Japanese suppliers
2. Outsourcing Fabrication
   – Result was rise of the fast-growing fabless sector with U.S. leadership
3. On-going Stage of Offshoring of Design
   – Reasons for offshoring design

Q: What is impact of design offshoring on industry?

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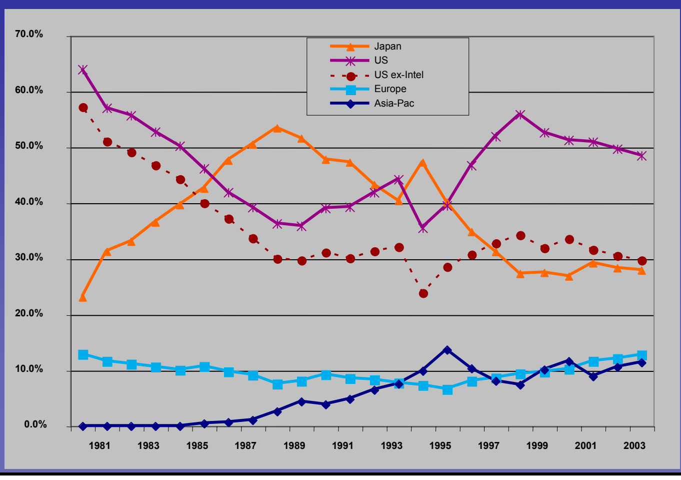
## Semiconductor Market Shares

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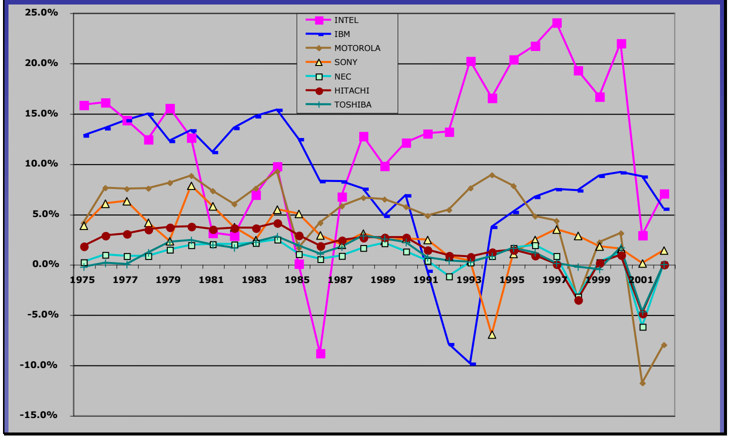
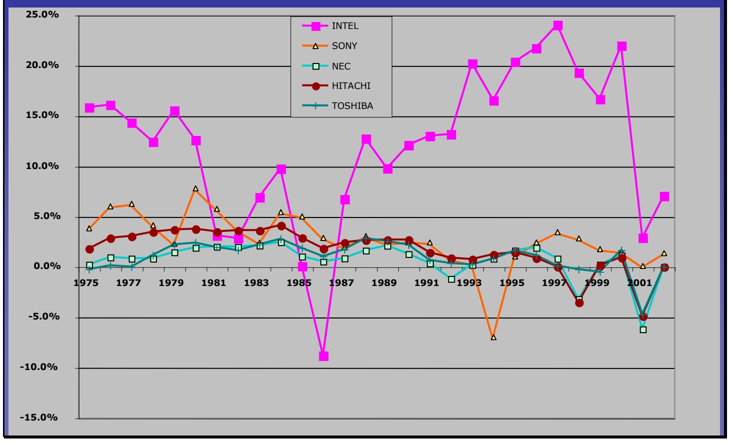
# ROA - Integrated Firms




# ROA - Japanese Firms




# Developing Global Markets:
## How Much Do Chip Firms Rely On Their Domestic Market?

- “Home Substitution Index”: how much companies in one region sell domestically relative to the “ideal” global outcome where sales are distributed by the market size of each region.
  - The index ranges from 0 (perfectly globalized sales) to 100 (total dependence on the home market).

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## Home Substitution Index For Global Semiconductor Sales, 1992-2000

| Region | 1992 | '93 | '94 | '95 | '96 | '97 | '98 | '99 | 2000 |
|---|---|---|---|---|---|---|---|---|---|
| U.S. | 30 | 27 | 26 | 24 | 22 | 22 | 21 | 19 | 20 |
| Japan | 46 | 41 | 37 | 34 | 40 | 42 | 44 | 44 | 46 |
| Europe | 53 | 47 | 43 | 45 | 40 | 40 | 40 | 34 | 27 |
| Korea/ Taiwan | 42 | 38 | 27 | 25 | 26 | 30 | 32 | 24 | 23 |

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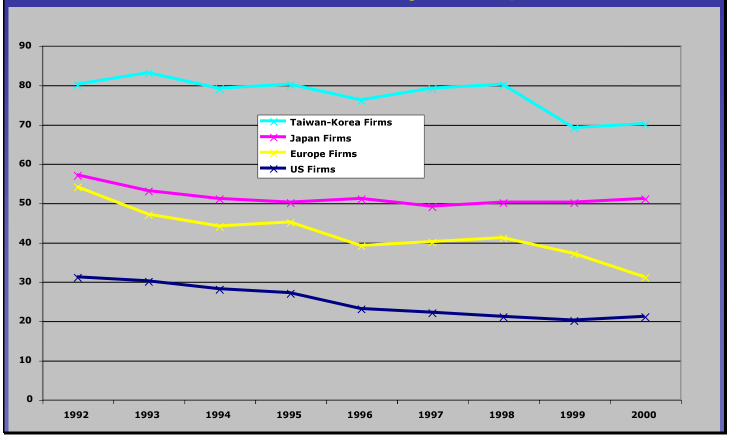
## Home Substitution Index for Non-Memory Chips




## Disconnect between Value Capture and Value Creation

- Market demand no longer driven only by lower price, but also by new and differentiated products
- Value capture depends on firm's business model
  - development of product market
  - bargaining power with suppliers and customers
- Ever-shrinking product life cycles increase risk of R&D investment
  - firms have shorter time period to capture ROI even in well-defined product markets

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## Implications

- Japanese companies cannot do all activities in the value chain domestically and remain competitive
- Japanese companies cannot depend on domestic markets to generate their ideas for foreign markets
- Japanese companies must create alliances with foreign companies and extend global networks through offshoring in order to learn needs of foreign customers and gain access to markets

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## Overview of Semiconductor Production

- Three activities with different economic characteristics
  - **Design of chip** (IC or integrated circuit)
    - Skill intensive
    - Uses EDA (electronic design automation) tools
  - **Fabrication** (front end) of die on wafers
    - Large fixed investment in plant and equipment (fab)
    - Materials handling and IT eventually automated
  - **Test and Assembly** (back end) of chips into packages
    - Lower fixed costs than fab
    - More direct labor input
- Worker skill requirement decreases along value chain

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## Offshoring: Reasons and Results

- Gain competitive advantage from:
  - Access to engineering talent
  - Cost reduction
  - Development of markets
- Result: firm will grow and hire more workers at home and abroad
  - some domestic workers engaged in the activity that shifted offshore may lose their jobs
  - only the remaining home country workers and consumers benefit from the firm’s move offshore

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## Summary of U.S. Offshoring Across 3 Stages

- Shift of **assembly offshore** helped U.S. companies stay competitive with low-cost rivals and to maintain high-value jobs at home
- **Offshore fabrication** by foundries gave rise to growth of fabless companies and helped IDMs manage large fixed costs and risks
- **Offshore design**
  - Lower costs to expand consumer markets
  - Rivals are mainly Japanese and European IDMs (not low-cost Asian rivals)
  - Design Center jobs moving up design skill trajectory

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## 1. Offshoring and Outsourcing Assembly: Factors contributing to US offshoring assembly

- Japanese manufacturers automated their assembly lines, provided stiff competition for American producers
  - Automation was a more feasible strategy for Japanese because of greater reliance on high-volume DRAM
- U.S. companies produced wider range of products that were less economical to automate
  - U.S. policy tariffs limited to value added offshore, which in assembly was small portion of total – about 12% in late 1970s
- Price pressures in consumer electronics industry, so lower cost unskilled labor, land, and taxes of Asia attracted assembly (since 1961)

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## Offshore Assembly by Japanese IC Firms

- Most Japanese chip companies located some assembly plants in SE Asian countries during the 1970s alongside US rivals
- A significant percentage of assembly remains in Japan
- Outsourcing of assembly is taking place
  - sale of some assembly plants to foreign assembly contractors
  - subcontracting to foreign firms

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## Lessons from Offshoring Assembly

- Move to offshore assembly led to “hollowing out” of US chip assembly, but kept US chip industry cost-competitive with Japanese and European rivals
  - Lesson: moving one part of the value chain abroad may be necessary to “save” the domestic industry
- Asian competitors sprang up and took over large portion of market, so assembly went from offshoring to outsourcing
- One country can try to keep an activity at home, but it cannot control the evolution of that activity abroad
  - Lesson: low-cost capable foreign suppliers may still grow to dominate market

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## 2. Outsourcing Fabrication

- Offshore investments in 1970s for market access in Japan and Europe, where trade barriers made U.S. exports uneconomical
  - Somewhat offset by cross-investments of European and Japanese producers in U.S.
- Cost reductions did not drive offshore fabrication
  - Labor was only 16% of costs (200mm)
  - Other concerns important: taxes, technical talent, water and utilities, environmental regulations
- Taiwan originated foundry model in 1987
  - Government brought together investors, licensed older production technology from U.S., and attracted Taiwanese engineers and managers back from U.S. chip companies
  - TSMC founded by Morris Chang (MIT, Stanford, TI)

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## Foundries: Industry Response

- Foundries facilitated growth of design-only (“fabless”) chip companies, especially in California during 1990s
  - Earlier, U.S. fabless companies mainly used Japanese fabs (capacity and IP issues)
- Integrated firms also use foundries for buffer capacity and for leading-edge chips with short product life or uncertain volume
  - IDMs are 45% of foundry revenue
  - 20-25% of industry outsourced to foundries (est max: 50%)
- Past decade, fabless revenue (20% CAGR) has grown faster then total semiconductor revenue (7% CAGR)
  - worldwide fabless revenue: $33 billion in 2004
  - 20 of top 30 fabless firms are U.S.-based; 6 are Taiwanese

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## Offshore Fabrication by Japanese IC Firms

- Japanese companies invested in tariff-hopping fabs in the US and Europe in 1970s
- Most large Japanese IDMs make limited use of foundry services
- Institutional factors have limited the prospects for fabless start-ups in Japan

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## Rise of China

- SMIC: China's entry into foundry services
  - Use of engineering and management talent from Taiwan (especially TSMC)
- Increased competition in foundry services
- Pressures especially on Taiwanese foundries and on attempts by other Asian companies trying to enter foundry business

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## Worldwide Fab Capacity and Ownership

- Shift of fab capacity from U.S. and Japan to Taiwan and South Korea

| | U.S. | Japan | Other Asia |
|---|---|---|---|
| 1980 | 42% | 38% | 4% |
| 2001 | 29% | 20% | 38% |

- Shift of fab ownership from U.S. and Japan to Taiwan and South Korea

| | U.S. | Japan | Other Asia |
|---|---|---|---|
| 1980 | 44% | 37% | 3% |
| 2001 | 38% | 24% | 39% |

Note: ownership row total for 2001 adds to more than 100 because jointly owned capacity was credited in full to all owners

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## 300mm Fab Capacity (as of Oct 2004)

- 300mm fabs: global capacity in production/underway

Japan 24% | Taiwan 19%
U.S. 24% | South Korea 12%
Europe, Singapore, China 20%

- Threat of oversupply:
  - Each of new 300mm fabs will require annual revenues of $5-$7 billion to be profitable.
  - The 300mm capacity being added in late 2004 equals 520,000 wafers per month, which is in addition to existing 300mm capacity of 690,000 wafers per month.

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## 3. Offshore Design

- Design has increased in complexity faster than EDA tools have been developed
- Stages of design
  - Specification
  - logic design (front end)
  - physical design (back end)
  - plus verification and final validation
  - plus software-hardware co-design (especially for system-level chips)

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## Engineer Hours to Design 1 Million Logic Transistors

| | 350nm | 250nm | 180nm | 130nm | Chg from 350nm to 130nm |
|---|---|---|---|---|---|
| Specification | 23.0 | 29.8 | 91.4 | 271.6 | 1081% |
| Logic Design | 714.2 | 738.4 | 756.4 | 837.7 | 17% |
| Physical Design | 311.0 | 357.2 | 391.7 | 473.5 | 52% |
| Validation | 103.7 | 127.6 | 164.5 | 197.4 | 90% |
| Software | 378.4 | 672.4 | 985.7 | 1798.3 | 375% |
| **Total** | **1530.3** | **1925.4** | **2389.7** | **3578.5** | **134%** |

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## Reasons for Offshoring Design

- Market access
  - Need for closer contact with customers of ASIC (application-specific IC) chips designed for specific customer
  - Adapting existing chips to local market needs
- Access to specialized skilled labor
  - EX: multimedia or telecom requirements
- Cost reduction
  - Engineer salaries as much as 90% lower
  - Somewhat offset by managerial problems, plus IP risks
    - Actual cost reduction varies (25-50% lower)

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## Outsourcing Design

- Outsourcing along the design flow
  - Use of reusable modules for standardized portions (“cores” or “IP blocks”)
  - Use of outside service providers for specific tasks (e.g., layout)
  - Use of design services provider for turnkey solution
- Growth of design services and design centers abroad, especially in Taiwan, China, and India
  - Top three suppliers of design services worldwide are U.S. companies

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## Cost and Location of Designers and IP Protection

| | Design Eng Salary (yr) | # of chip designers | IP protection (World Econ Forum) |
|---|---|---|---|
| U.S. | $82,000 | 45,000 | 8.7 |
| Japan | $60,000 | -- | 6.2 |
| Taiwan | $ 30,000 | 14,000 | 6.7 |
| China | $ 15,000 | 7,000 | 4.0 |
| India | $ 15,000 | 4,000 | 4.2 |

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## Chip Design Capabilities

- Taiwan
  - Second to U.S. in successful fabless firms
  - Mostly fast followers and chip redesign for Asian markets
- China
  - Government sponsorship, local access to system firms, and involvement of expatriates returning from U.S.
  - Some use of illegal reverse engineering
  - Some advanced design in local firms started by returnees
- India
  - Software skills and English
  - Local firms predominantly in design services
  - Leading in offshoring: TI in India since 1985
    - From design automation software to mixed-signal chip design to DSP chip designs

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## Offshore Design by Japanese IC Firms

- Japanese IDMs have followed U.S. offshoring path
  - Japanese companies have opened offshore design centers in Asia, especially China
  - Some design work is also outsourced both domestically and overseas
  - Language differences make India less attractive to Japanese than to US firms
- Reliance by Japanese companies on domestic market reduces immediate returns to offshoring

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## Impact on Chip Industry

- Many forces affecting global chip industry:
  - business cycle
  - chip capacity growing fast worldwide
  - less venture funding for start-ups
  - higher education policies and immigration policies
- Currently, offshore design centers pose bigger threat to domestic employment than outsourcing
- Over time, rise of design capability abroad may create new rivals for Japanese and U.S. chip designers and companies

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## Q: How is offshoring affecting U.S. chip industry innovation?

- Development of markets and improved global competitive position for U.S. firms
  - reduced design costs and increased flexibility have improved U.S. competitive position
  - lower costs grow consumer markets: advanced products (developed countries) and scaled-down products (developing countries)
    - U.S. companies learning how to develop products for regional markets, and locate design and marketing activities accordingly
    - U.S. HQ learning how to integrate and manage global activities, especially chip development
  - careful management of IP: what to protect/keep at home and what to send offshore

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## Q: What industry response can we expect?

- Restructuring of industry and rise of rivals in other countries
  - "local firm" effect may give rise to new rivals, as observed in Taiwan and being attempted in China
  - design services subcontractors already present, and may be first step toward becoming fabless chip company
    - Taiwanese fabless sector is nearly a generation (2-3 years) behind U.S.
  - capability of Asian firms to develop innovative products expected to improve, and U.S.-trained engineers are playing a role

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## Caveat:
## Protection of Intellectual Property

- Core technology must be protected and remain focus of company R&D
- Development of core technology must be done at home
  - Other design, development, and manufacturing activities can be located in low-cost countries, such as China and India
    - Ex: highly encrypted chip designs sent to Taiwanese foundries
  - Cannot rely upon legal protection of IP globally, especially in China and India

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## Conclusion: Lessons so far

- History shows how industry and workers can benefit from offshoring
  - Constraining offshoring may not help domestic labor market over time
- Offshoring is an important step in developing markets through lower costs and improved market knowledge
- China and India will play an increasingly important role in the semiconductor industry, both as markets and suppliers
  - Industry response to design offshoring and rise of fab capacity in China unknown

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