How Crisis Reshapes the Semiconductor Industry

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Solid State Technology and Devices Seminar

Based on book *Chips and Change* (MIT Press, 2009) with co-author Greg Linden.

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Overview

- Economic study of dynamics of semiconductor industry since mid-1980s
  - Eight “crises”: How do costs and market conditions shape a crisis and the industry’s response?
- Whose perspective?
  - Country (US, Asia)
  - Firm
  - Worker
  - Consumer (businesses, individuals)

Eight Crises

1. Loss of competitive advantage
2. Rising costs of fabrication
3. Rising costs of design
4. Consumer price squeeze
5. Limits to Moore's Law
6. Finding talent
7. Low returns, high risk
8. New global competition

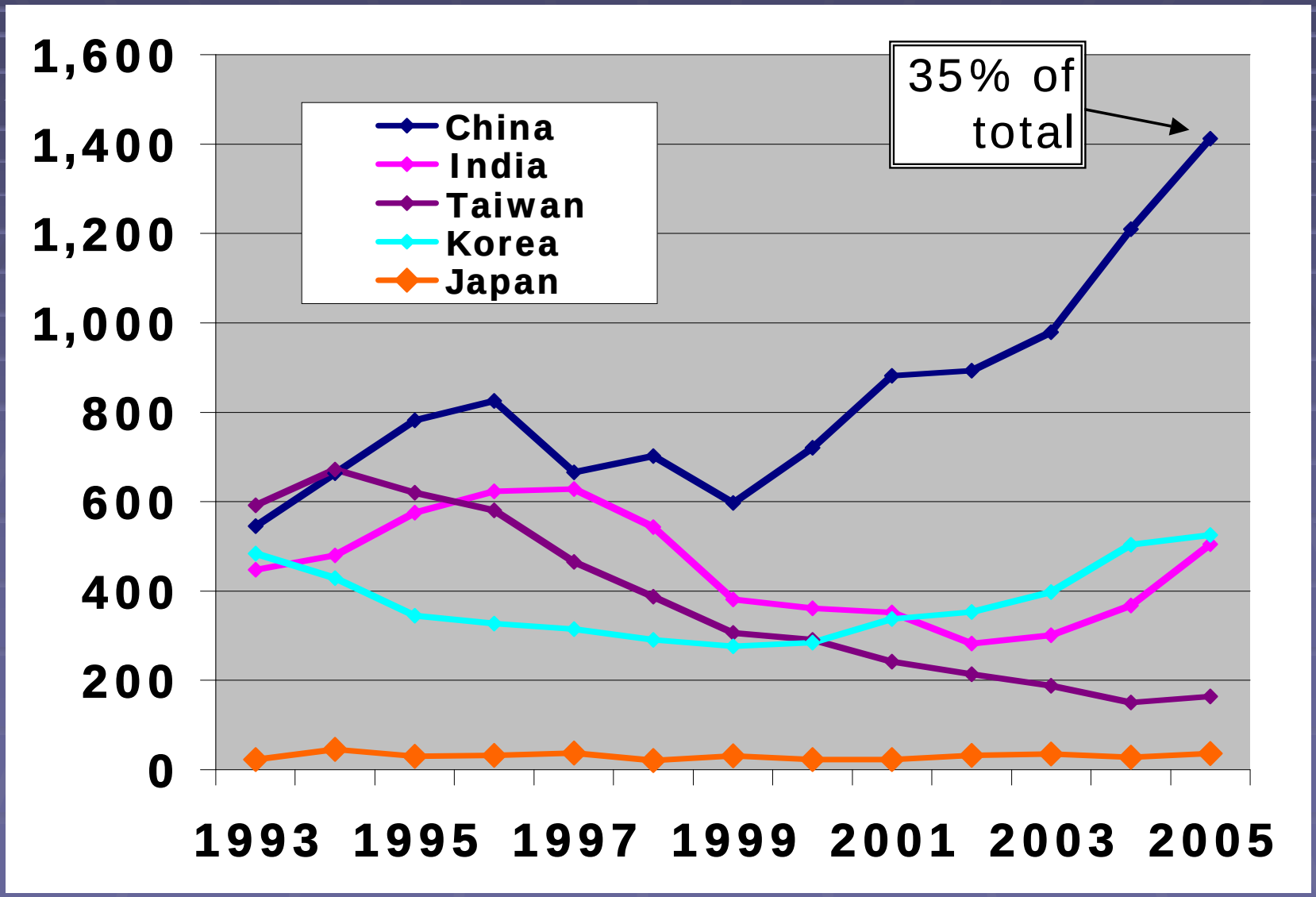
Labor Market for Engineers in US (Before the Great Recession)

- How good is career path for high-tech engineers?
  - Young engineers have high initial earnings that grow with experience
  - Real earnings fall after age 50
- What is return on graduate degree for high-tech engineers?
  - MS/PhD (age 40) earns 17% ($15,500) more than BS engineer, but MS/PhD's total career earnings up to age 40 are $51,000 **lower** because of foregone earnings
- Attractiveness of engineering jobs depends on if citizen or immigrant

Immigrant's Opportunities

- Engineering degree from US university provide high living standard to students from developing countries
  - Foreigners earned 63% of 6404 engineering PhDs with 40% to students from China, Korea, India and Taiwan (2005)
  - Foreigners earned 69% of PhD degrees in Electrical Engineering
- Obtaining visas presents hurdle to remaining in U.S.

Role of US: Engineering PhDs to Non-Citizens (by Country of Origin)



Global Competition

How quickly can China's and India's semiconductor industries catch up to U.S. position?

Two popular theories:

- "manufacturing pull": R&D will inevitably follow chip manufacturing to Asia
- "large market pull": domestic industries will become global leaders by building on technology offshored by MNCs and supported by rapidly growing and potentially vast product markets.

Manufacturing Pull (fab process R&D)

- Role of equipment manufacturers
  - Top ten equipment suppliers (60% global sales) have primary research labs near HQs in US (4 cos), Japan (4 cos), Netherlands (2 cos)—see Table 8.1
- Process Development Alliances
  - Japan's ASET, IBM's Common Platform Alliance, EU's IMEC.
- Impact on U.S. innovation and engineers' knowledge
  - TI develops digital process technology (0.032-micron on) with foundry leaders TSMC and UMC.
  - U.S. has 15% of global 300mm fab capacity (Table 2.10)

Manufacturing Pull (fabless chip design)

- Even weaker argument for chip design
  - U.S. leader in fabless chip design companies
  - Taiwan is leader in foundries (contract chip manufacture), and Taiwan's fabless sector is distant second in fabless design companies
    - Taiwan's fabless sector helped by numerous systems companies as well as foundries
- U.S. chip design activities move offshore usually for cost-based or talent reasons and not because of foundry location
  - India as example

Large-Market Pull

- Large markets of China and India will create competitive advantage
  - Support national champions (eg Samsung)
  - Lower costs for talent, land, and resources
  - Lower taxes, fewer environmental regulations
- How quickly can countries move up technology curve?

Ability to move up technology curve: Two factors to consider

- Talent: engineering capabilities and costs
  - Educational system
  - Integration into global brain circulation
- Infrastructure and environment
  - Role of government
  - Financial system and IP protection
  - Access to customers (systems firms and end product markets)

China Rapidly Expanding Bachelor's Degree Programs

	Engineering, 2001	Engineering, CS and IT, 2004
U.S.	110,000	137,437
Japan	110,000	-
Taiwan	35,000	-
China	**220,000**	**351,537**
India	110,000	112,000

(multiple sources)

Salary Differences Not As Great As They Seem

	EE/CS Annual Salary (2004)
U.S.	$ 82,000
Japan	$ 60,000
Taiwan	$ 30,000
China	$ 12,000
India	$ 15,000

Although these numbers suggest savings up to 85%, in practice, hidden costs (lower productivity, coordination, monitoring) reduce saving to the range of 25 to 50%

Note: US & Japan: salary for middle-aged engineers; China & India: salary for those with 3 to 5 years. Salary growth with experience much slower in US than in Asia.

Infrastructure: Asia Building Design and Fabrication Capacity

	Number of Chip Designers	Fab Value If Equipped (1995-2006)
U.S.	45,000	$74B
Japan	?	$66B
Taiwan	14,000	$72B
China	5,000	$26B
India	7,000	$ -0-

(multiple sources)

Chip Design in Practice: EDA Revenue, 2007
(by Consuming Region, US $ M)

Region	EDA Consumption	Share of World Total
North America	$ 2,658.3	46%
Japan	$ 1,175.7	20%
Western Europe	$ 1,079.1	19%
Rest of World	$ 856.2	15%

(EDAC.org data)

Contributions by design engineers
ISSCC acceptances, rejections by country 2001-2006

- ISSCC papers submissions as measure of engineering knowledge—see table
  - Submissions from South Korea, China, India, and esp Taiwan increased 2001-2006.
  - Absolute acceptances rose in Taiwan, China, and Korea.
  - Expect: acceptances from India and China will increase in the near future as their university engineering programs improve.

China Design: Mostly Local

- Government claims over 500 fabless firms
  - Most are small, or in services
  - Several have passed $100M in revenue
- Also chip design at local system firms
- Multinational R&D still limited
  - by language difference (esp. US firms)
  - by IP concerns
  - Exceptions are ‘prestige’ investments to satisfy government

China: Start-Up Fever

- Complete industry ecosystem in place
- Favorable conditions
  - Government sponsorship
  - Good infrastructure
  - Expats returning from the U.S.
- Government promoting China-owned standards
- Foundry model has taken root
  - SMIC became #3 ahead of Chartered in H1 2007 (Gartner)

India Design: Services Culture

- Local design firms predominantly in design services, not fabless
  - Home to major design service suppliers
    - Largest is Wipro (2,100 chip designers)
  - Product-based start-up culture is only starting to take root
- Leader in offshore design centers
  - As of June ‘06: 18 of top 20 US chip firms had India design centers

Selected Design Centers in India

Year Started	Owner	Employees	Reported as of
1985	T.I.	1,000	4/06
1993	STMicro	1,500	4/06
1998	Freescale	780	7/06
1999	Intel	2,700	5/06
2000	NXP	815	5/07

India: Commitment Problem

- Less favorable conditions for domestic development than in China
  - Poor infrastructure
  - Notorious bureaucracy
  - MNCs attract best talent (including returnees)
- Fab construction still hypothetical
  - Five fab projects in various stages of planning
  - Government incentive package details announced 9/07 after long delay
  - Initial applications for solar and LCD, not chips

Popular Theories Right?

- “manufacturing pull”: Not inevitable. R&D has not followed chip manufacturing to Asia.
  - Equipment suppliers important in process R&D
  - Fabless companies important in design R&D
- “large market pull”: Not inevitable. R&D has not followed market growth in chips.
  - Large markets determine types of products developed, and location of activities can be globally distributed.
- But…China and India will continue to play important and growing roles as suppliers and customers, and as complements and competitors to U.S. companies.

Threats to U.S. Leadership

Offshoring: ***not*** adversely affecting U.S. leadership in chip design and innovation.

- Restructuring (spin-offs, buyouts) is emptying out the industry's "deep pockets" & decline in support for university R&D

→ investment in R&D squeeze

- Global brain circulation may be "back to home country" as opportunities improve, coupled with visa hurdles, inferior STEM K-12 education, higher rewards for "bankers"

→ talent squeeze

What's occurring: rest of the world is catching up in design capability as well as constituting a growing share of chip product markets, and U.S. is not preparing for potential brain drain.

Thanks for your interest.

More comments and questions?

Semiconductor Engineers at U.S. Companies, By Location, 1997-2007