Semiconductor Engineers in a Global Economy

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National Academy of Engineering
Workshop on the Offshoring of Engineering: Facts, Myths, Unknowns, and Implications
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The Good, the Bad, and the Ugly

Concern: Globalization of semiconductor activities (and jobs) are rapidly expanding in low-wage countries

Impact

- Good: Reduced costs and global networks support growth of markets and rapid innovation
- Bad: Increased competition increases job turbulence, and makes R&D riskier
- Ugly: Some U.S. engineers lose jobs, and supply of engineers in U.S. less certain

Q: How is offshoring affecting semiconductor engineering work in the U.S.?

1. Engineering labor market is healthy with some concerns:
   - opportunities for older engineers becoming less attractive
   - premium for graduate degrees declining
   - offshoring and H-1B visas may be limiting salary growth, especially with experience
2. U.S. engineer labor market depends on **immigration and education policies**, with foreign students/workers important
3. So far: **offshore activities appear to complement design activities with expansion at home.**
   - China and India will play an increasingly important role both as **markets** and **suppliers**.
   - Government policies may be more important than company decisions

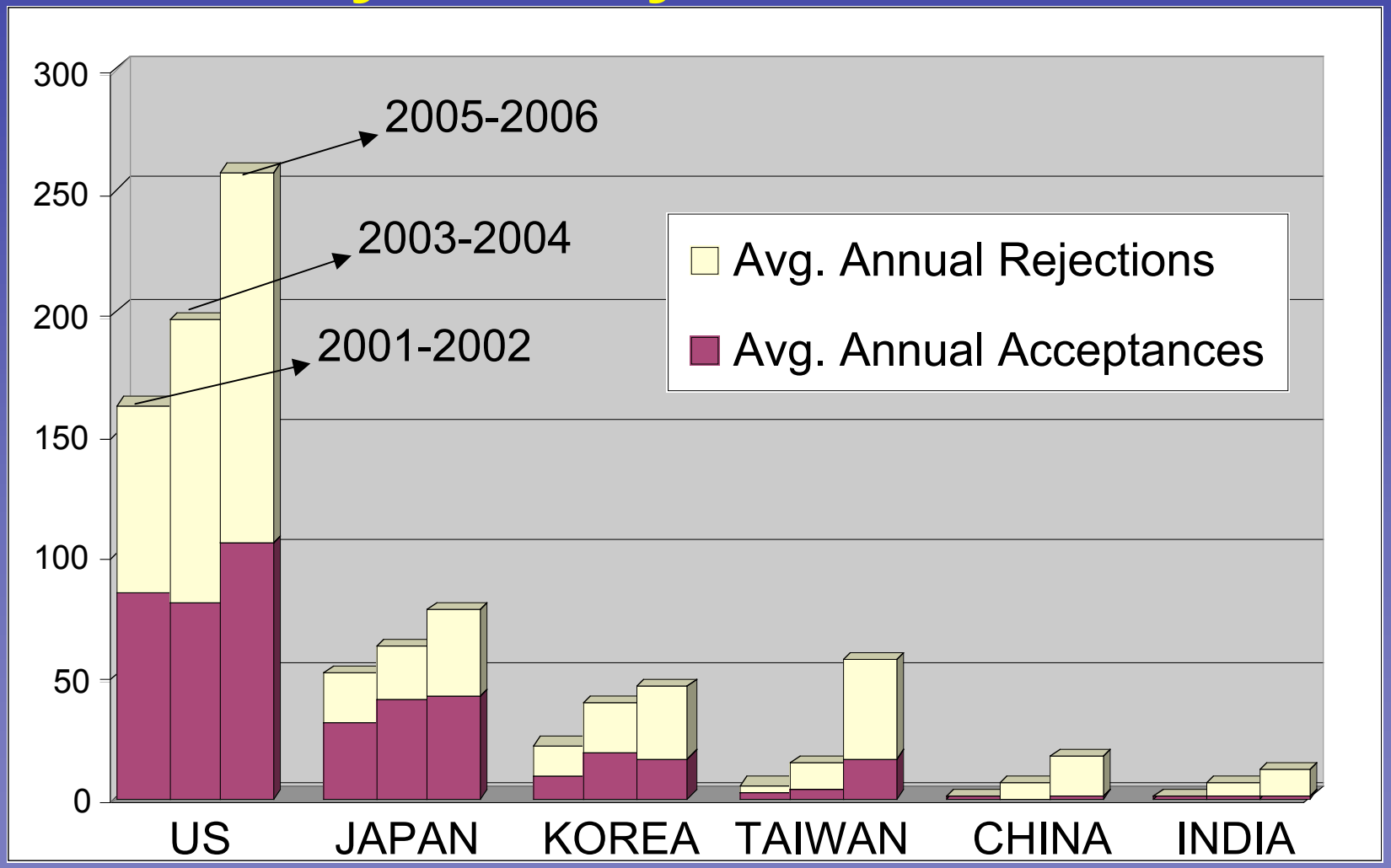
Growing Cost Pressures

- Each technology generation has higher fixed costs
  - Increased cost of plant and equipment
    - A new 300mm fab costs US$ 3 billion
  - Increased cost of designs
    - Functional integration and system-level chips
    - Typical 130nm chip design costs up to US$10 million, which requires $100 million sales to break even.
- Design productivity has not kept pace with chip productivity (Moore's Law)
  - Higher fixed costs require higher volumes
- Growth in price-sensitive consumer markets with short product cycles

Position of U.S. Industry

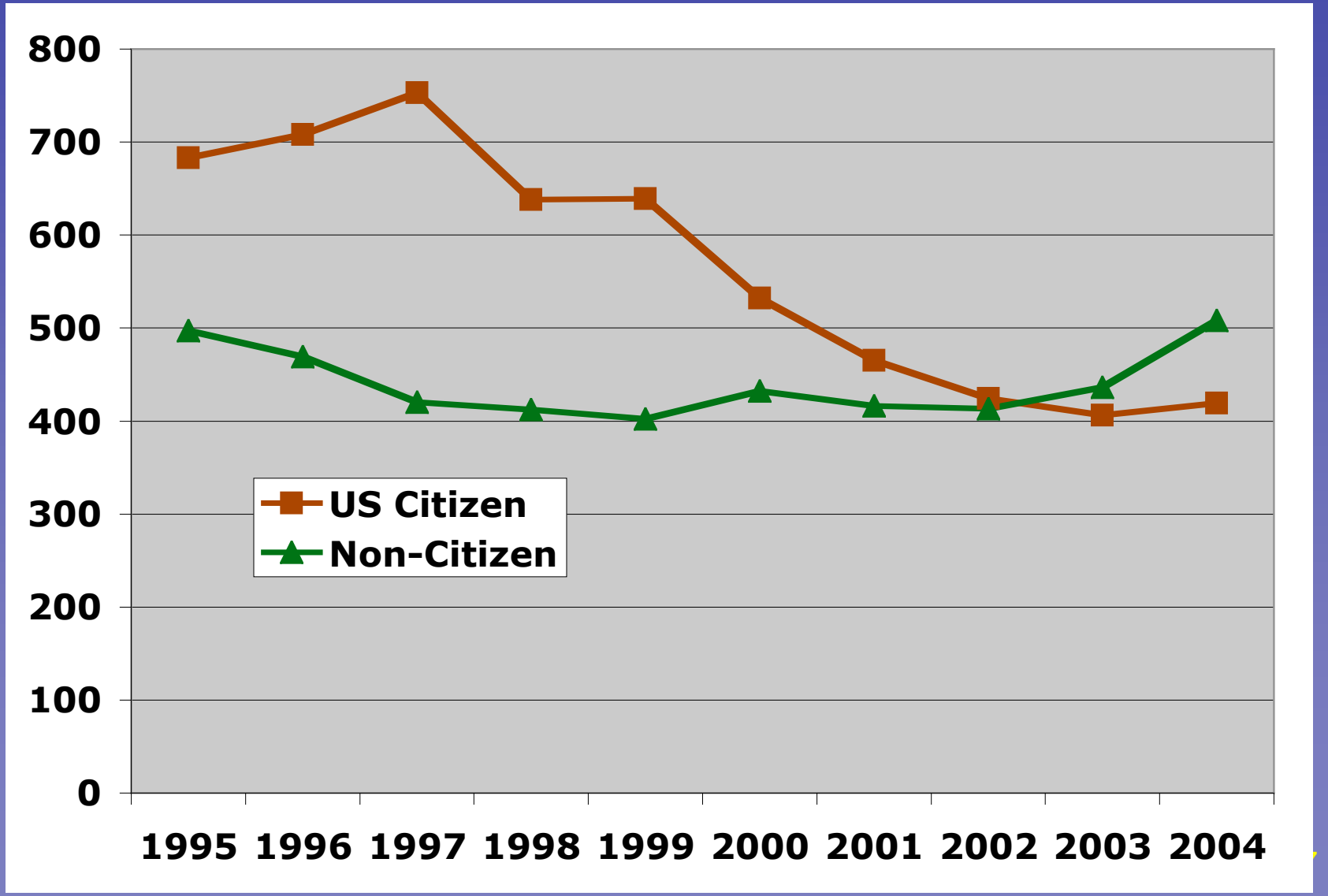
- U.S. chip firms account for one-half of market
  - Two of top three IDMs are U.S. (Intel, TI) and account for 19% of $235B market
  - Eight of top 10 fabless companies are U.S. and account for 43% of $33B market (2004)
  - U.S. still leader in advanced chip design
- U.S.-owned fabs account for 31% of global capital expense from 1995 to 2006
- U.S. universities still leaders in graduate training
  - U.S. has 53 of the top 100 universities
  - PhD engineer students primarily from abroad

ISSCC Paper Acceptances and Rejections by Country, 2001-2006



- The acceptance rate fell from 53% to 38% and the number of acceptances grew 54% over the period

US-granted EE PhDs by Citizenship



Offshoring: Reasons and Results

- Gain **competitive advantage** from:
  - Access to engineering **talent**
  - **Cost** reduction (engineer salaries as much as 90% lower, but estimated total cost reduction is 25-50%)
  - Development of **markets,** esp in high growth areas

- Ideal Result: firms 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

Engineer Salaries, # Designers, IP Protection, Fab Ownership Table 7

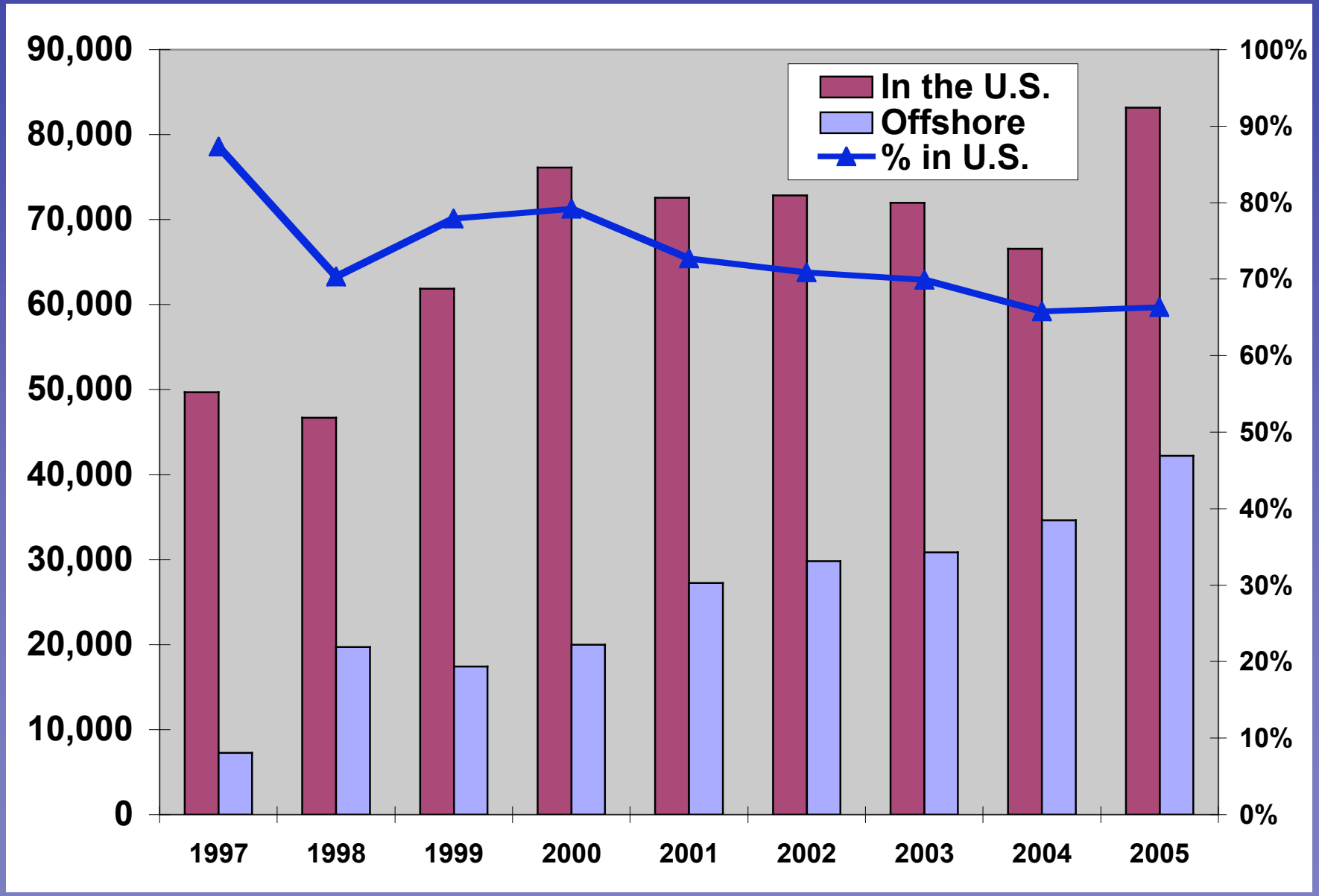
	EE/CS Eng Salary (ann.)	# of chip designers	IP protection	Value Fabs (1995-2006)
U.S.	$ 82,000	45,000	8.7	$74B
Japan	$ 60,000	--	6.2	$66B
Taiwan	$ 30,000	14,000	6.7	$72B
China	$ 12,000	5,000	4.0	$26B
India	$ 15,000	5,000	4.2	$ -0-

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

Other Costs of Design Offshoring

- Need to **codify/specify task requirements** more precisely
- Extra controls over **intellectual property**
- **Management costs**: especially recruitment, training, monitoring, travel and communications
  - communications across time zones/cultures difficult and costly for MNCs
  - projects often late and require strict monitoring
- **Reduced productivity** and/or **slower time to market**, which increases risk

Engineers at US Chip Firms by Location

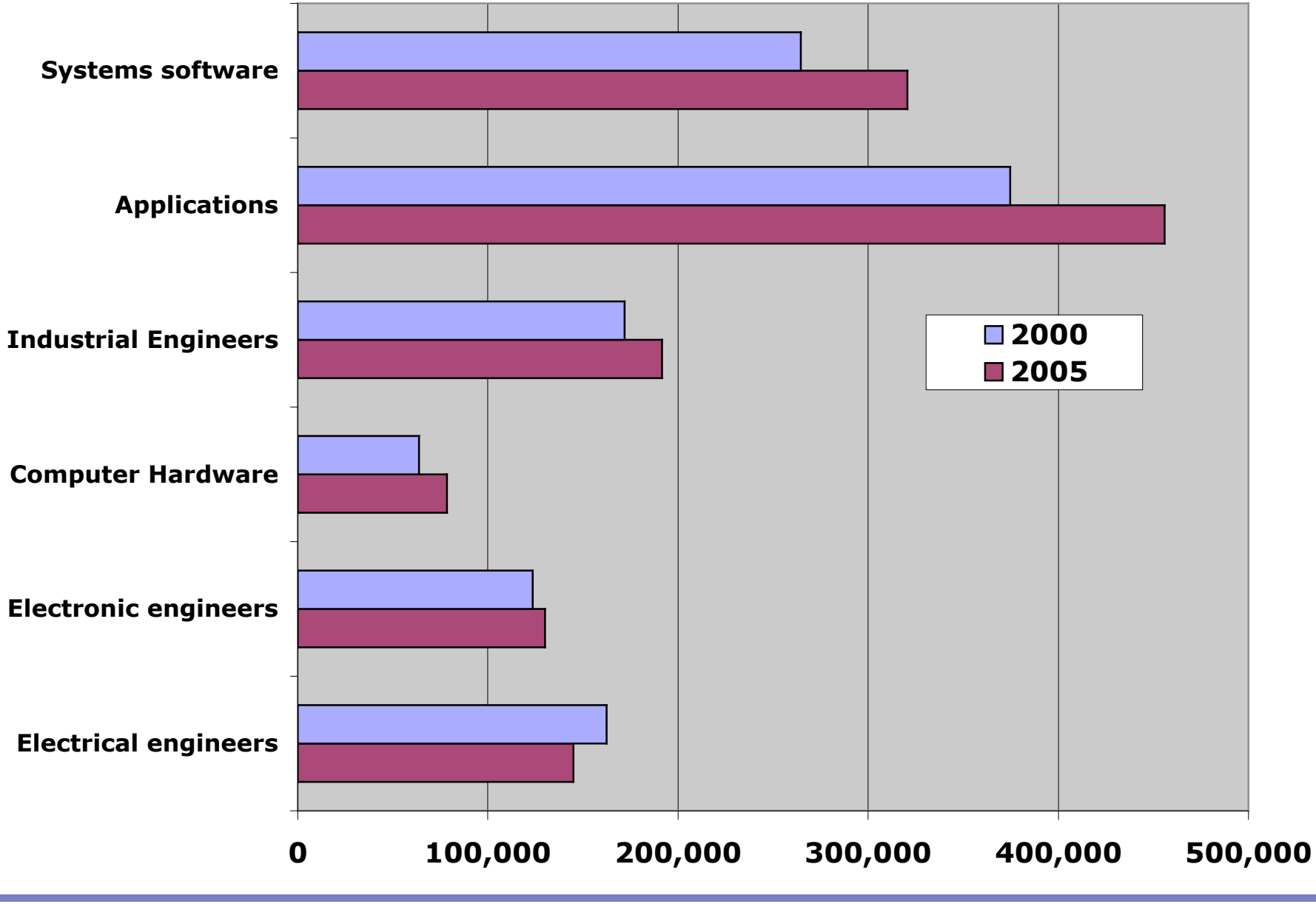


Source: SIA survey results; values may not be comparable between years

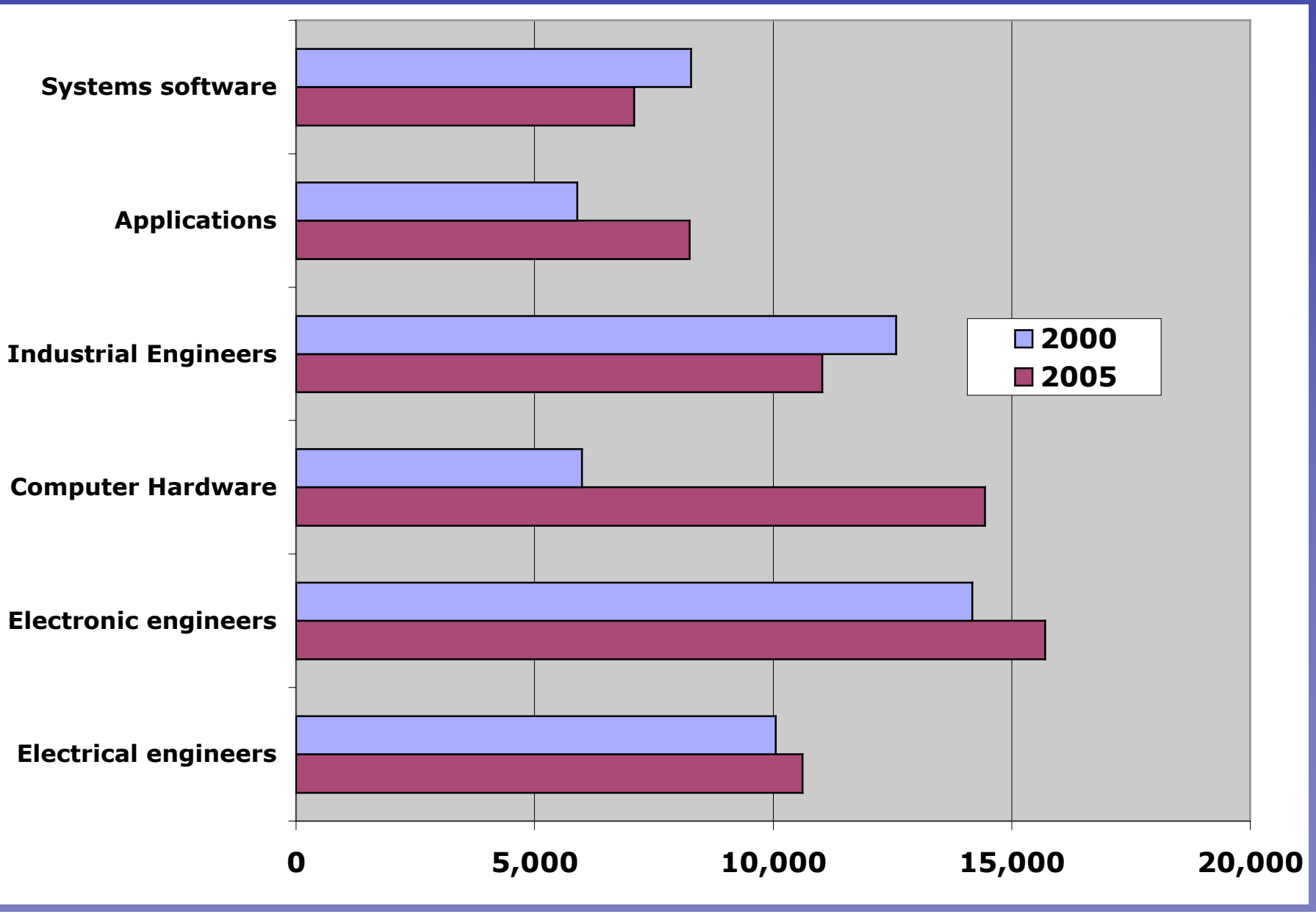
US chip engineer jobs: Overall Good News (2000, 2005; Table 1, p7)

- Experienced better job and earnings growth than engineers in other industries
- Employment fell for IE and CS (systems) chip engineers, but grew for other specialties.
- Earnings growth was relatively high only for computer hardware engineers and electronic engineers
  - Semiconductor engineers have high average annual earnings, ranging from $74,250 for industrial engineers to $90,820 for software systems engineers (2005)

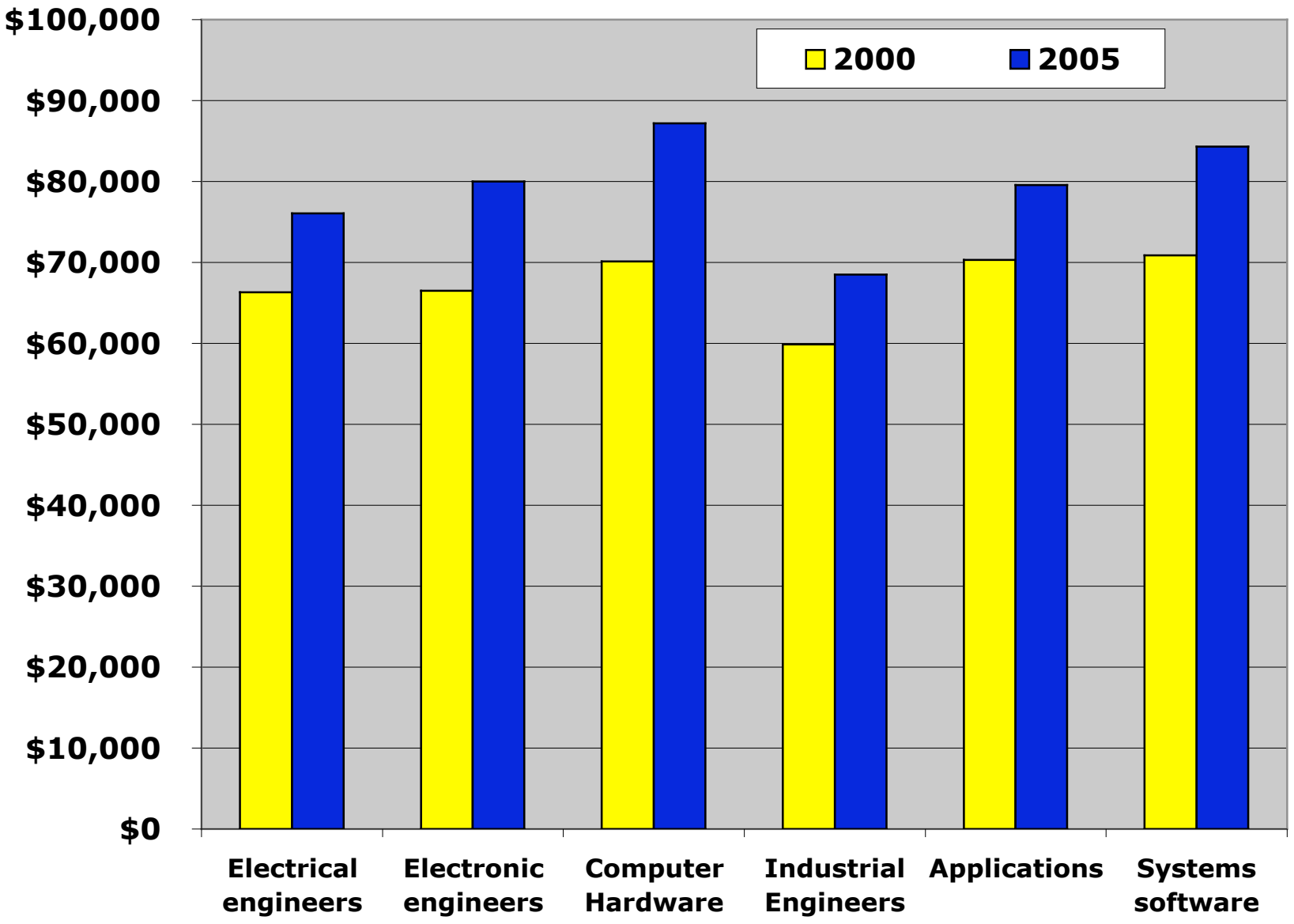
Engineer Employment - All Industries



Engineer Employment - “Semiconductors”



Engineer Wages - All Industries



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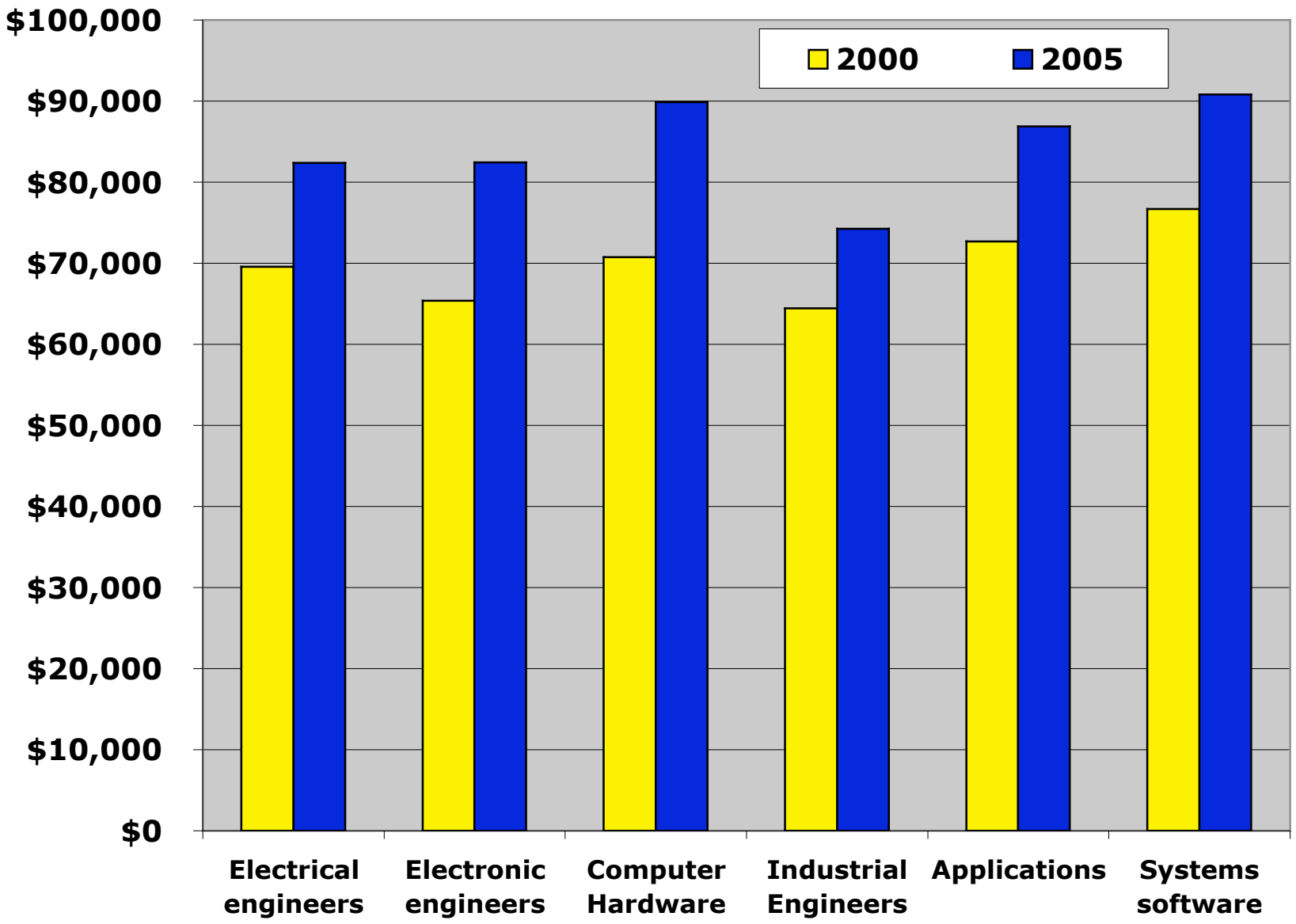
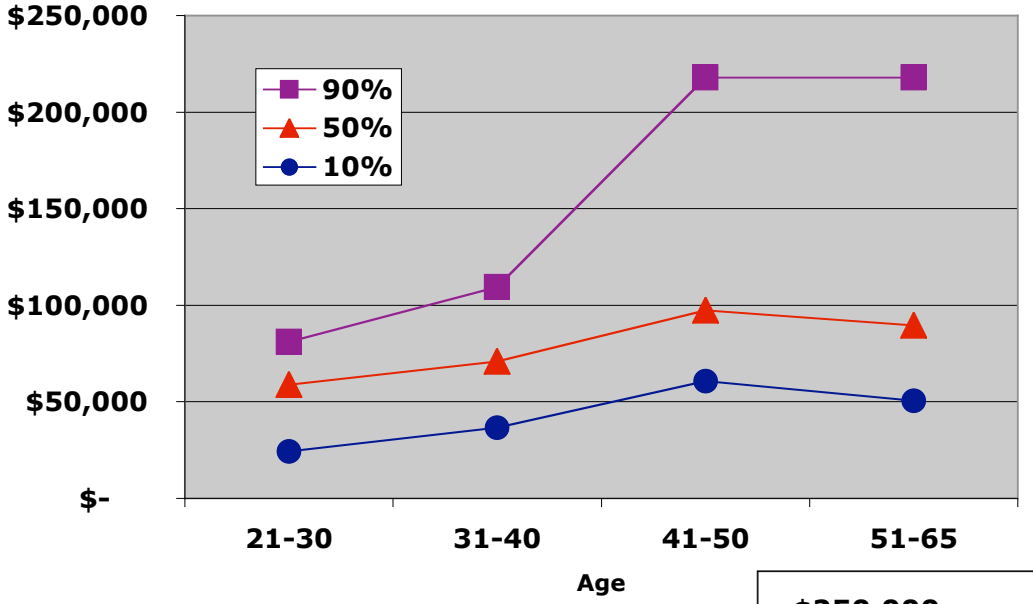


Education-Experience-Earnings Profiles (2004; Table 2, p 11)

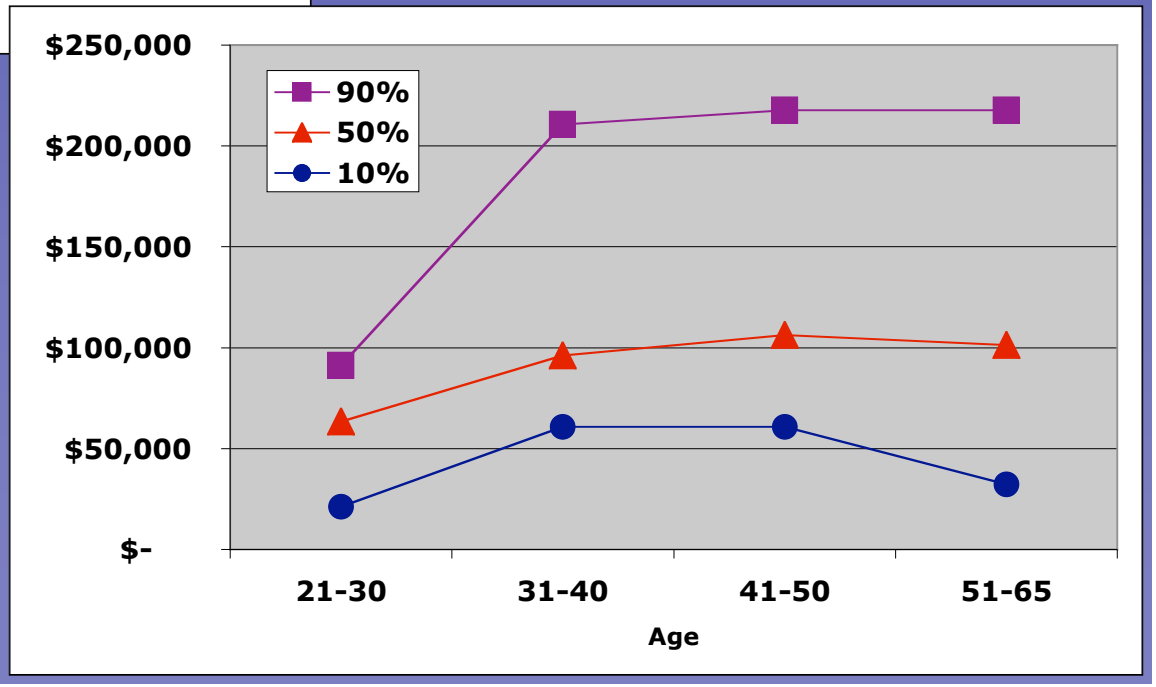
- Engineers with BS typically have higher returns to experience than engineers with MS/PhD
  - Typical young engineer (aged 21-30) with BS made slightly less pay than typical engineer without a BS but with ten years more experience (aged 31-40)
  - Typical engineer (aged 31-40) with MS/PhD made slightly less pay than typical engineer with BS but with ten years more experience (aged 41-50)
- Caution: Earnings typically grow until age 50, then stagnate or fall (more for MS/PhD than BS)

Age-Earnings Profiles, 2004



MS and PhD Holders

BS Holders



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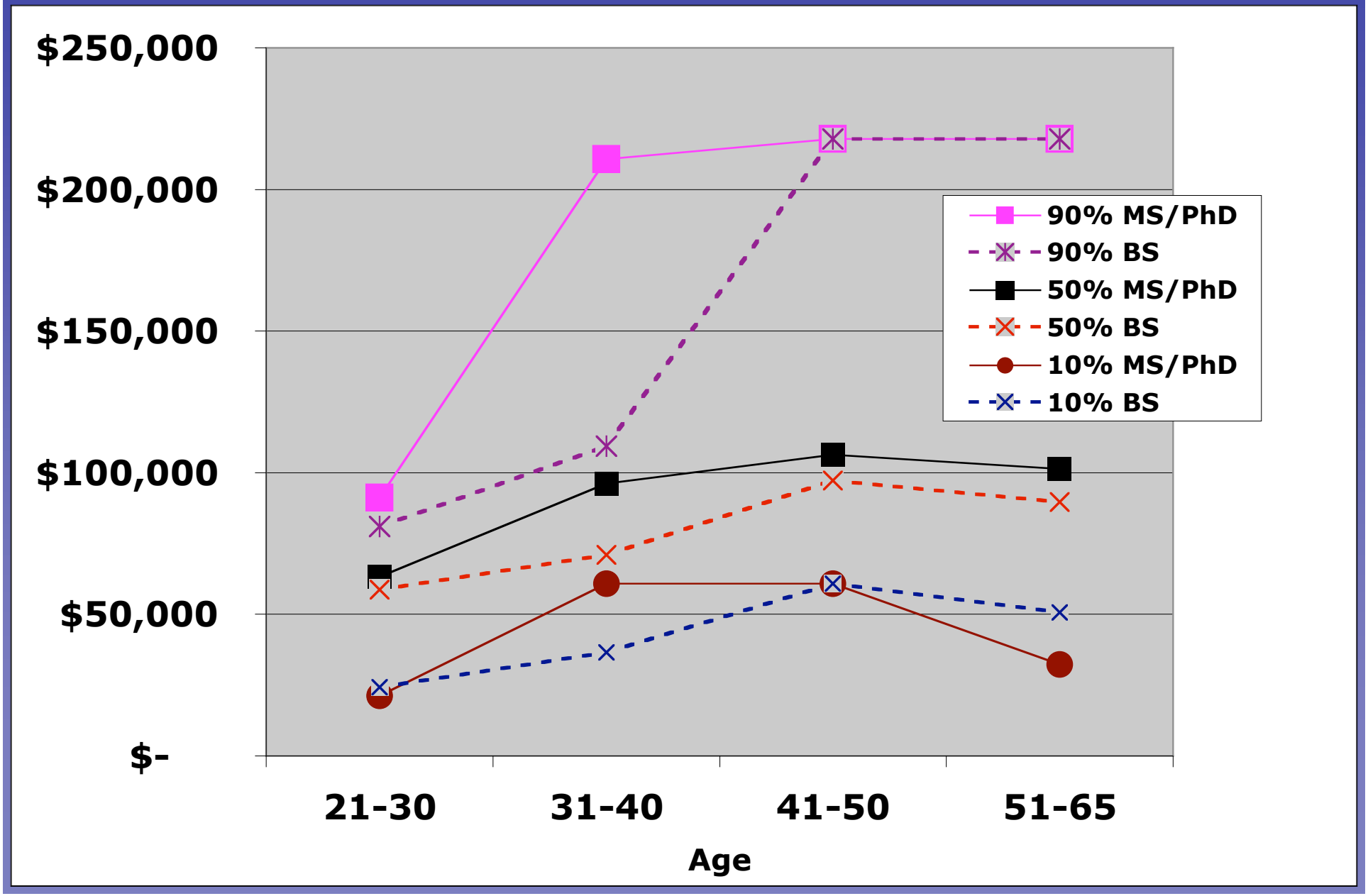


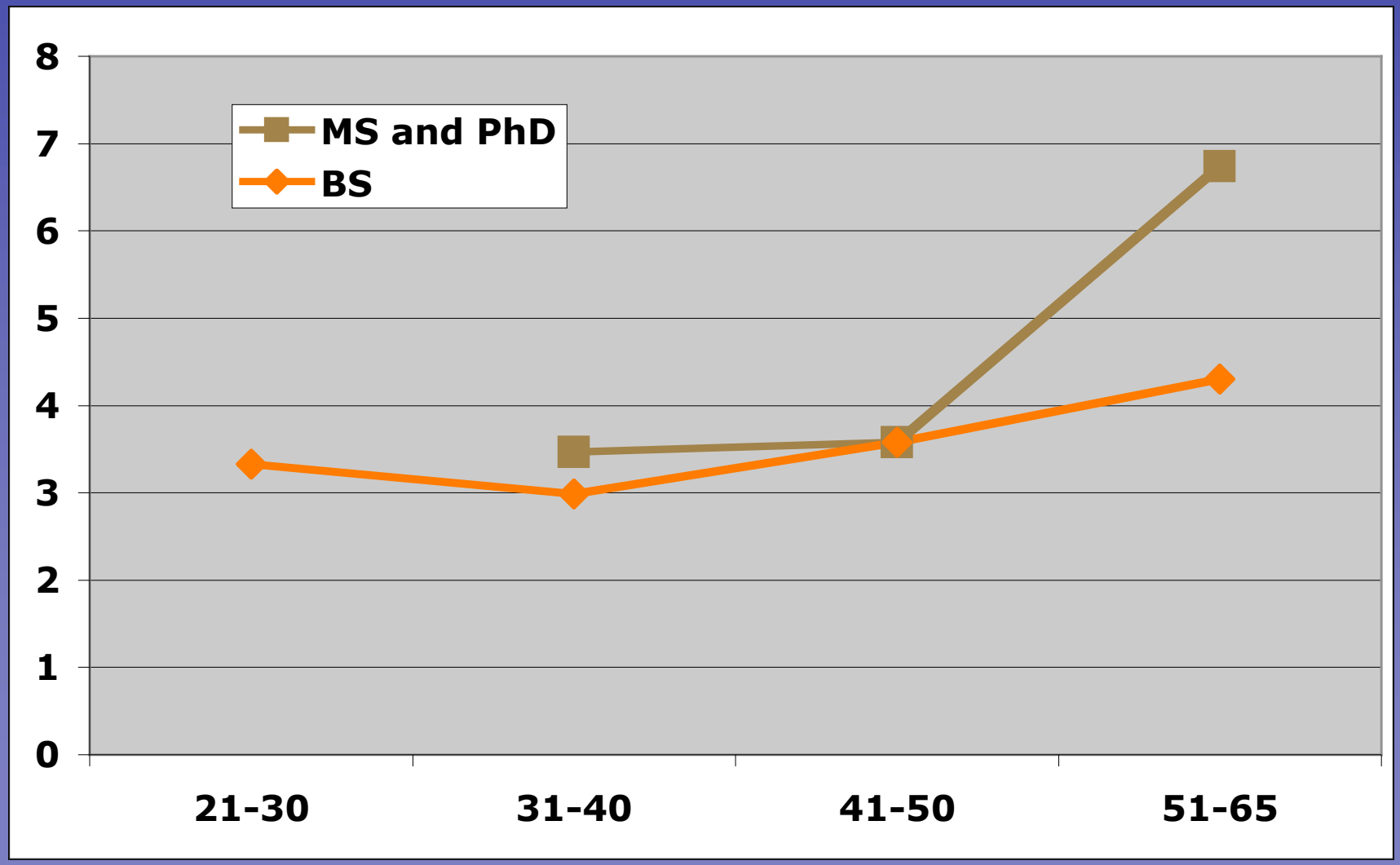
Engineers with BS/MS/PhD (Table 2, p 11)

- Variance in earnings (90/10 ratio) increases with age (after age 30)

  Caution: For age 50+, this reflects fall in pay of bottom 10%.

- Caution: Graduate degree premium of only 10% for engineers age 40+ indicates labor market problems

Variance (90-10 Ratio) by Degree and Age Group, 2004



Looking for More Work? (Table 3, p 13)

- Caution: Decline in earnings after age 50 partly reflects decline in weeks worked (all Ed groups)
  - Workers age 50+ are much more likely than younger groups to work <48 weeks

- Caution: Many older engineers face declining and inadequate job opportunities.

Role of H-1B Visas

- Top 10 U.S. chip companies received 14,035 H-1B visa certificates in 2001-2005
  - Top 10 non-U.S. companies received 1,749 H-1B visa certificates in 2001-2005
- U.S. chip companies applied for H-1B visas for CS (52%) and EE(37%) jobs
- Top 20 chip companies accounted for 56% of EE applications and 5% of CS applications in 2005

H-1B Visa Earnings: Top 10 US Cos

(Table 5, p 20)

- EE jobs
  - avg earnings $77,560 or avg min $66,944
- CS jobs
  - avg earnings $78,537 or avg min $75,685
- H-1B applications for EE-CS jobs in the chip industry carry a premium compared to other industries.

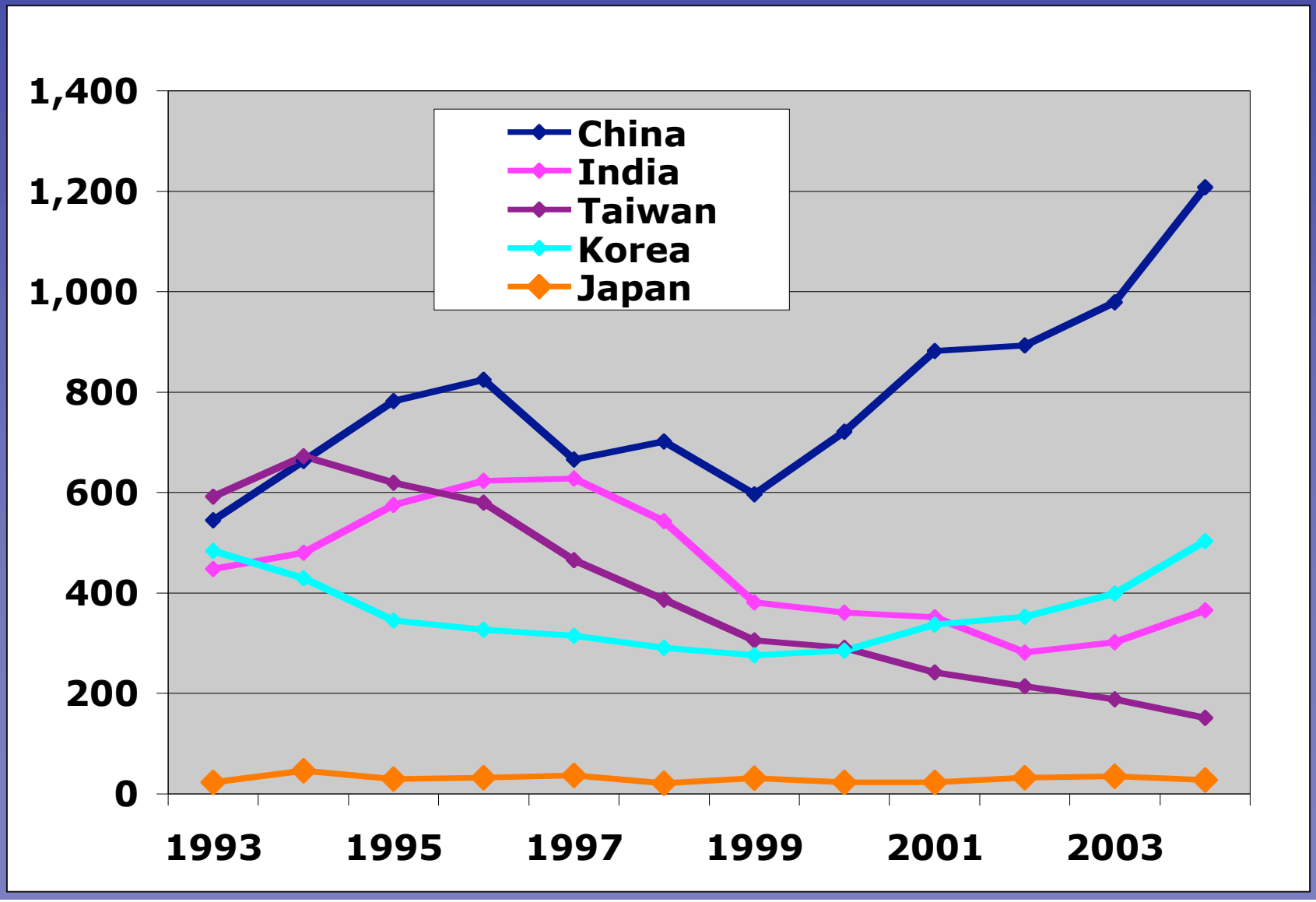
How does H-1B pay compare?

- Engineer MS and PhD graduates of U.S. universities likely earn competitive pay.
- H-1B workers brought into U.S. are probably at low end of pay scale.
- Overall, the average H-1B visa application earnings are consistent with the earnings in national data
- Hard to compare without knowing age, experience and education of engineers.
  - Top chip companies use H-1B visas for high-level as well as low-level engineering jobs

High-Tech Capability: U.S.

- **Strengths**
  - best graduate engineering education
  - large pool of experienced engineers
  - large product market (both chip users and end customers)
  - home to the most successful fabless start-ups
- **Weaknesses**
  - older engineers may experience career problems
  - dependence on foreign engineers may cause supply problems
  - high labor market mobility may cause transition problems for some firms and workers

Engineering PhDs in the US by Country of Origin



Close-up on China

- Quality of engineering graduates highly variable
  - Skill transfer from returnees from U.S. and Taiwan
- Best design being done by local system firms and a few world-class start-ups headed by U.S. returnees
  - Local system firms provide a sizable market for local fabless start-ups
  - Hundreds of fabless start-ups funded by government without well-developed business plans
- Weak IP protection

Close-up on India

- Shortage of engineering talent, but strong software skills and use of English
  - quality of engineering graduates highly variable
  - wages rise rapidly with experience
  - few engineers can manage the entire product cycle
- Leading in MNC offshoring, especially from US
  - MNCs attract best engineers, which slows diffusion to local firms
  - Local firms predominantly in design services
  - fewer returnees from US than in China
- Weak infrastructure (roads, energy, housing, schooling) constrains growth and raises living costs

Future of High Tech: China and India

- Lessons so far:
  - Offshoring is an important step in the integration of China and India into the global economy
  - China and India appear to be pursuing different roles vis-à-vis the US, with China as competitor and India as complementor.
- Outlook
  - China and India will play an increasingly important role in high-tech industries, both as markets and suppliers
  - Both held back by education, financial and political systems, and IP protection

Future of High Tech: U.S.

- Lessons so far:
  - U.S. industries benefit from globalization (lower costs, expanding markets, large talent pool)
  - Brain circulation and universities have supported innovation
  - Job problems: Jobs at the bottom deteriorating;
    Older engineers face worsening opportunities
    Graduate degree premium declining
- Cautionary Outlook:
  - Dependence on foreign engineering students and workers may result in supply problems
  - Rapid growth of emerging markets may reduce global leadership of U.S. companies
  - Low savings rate weakens economy and investment

Three Lessons

1. U.S. continues to be chip industry leader
   - China and India are in early stages of industry development, but are moving up rapidly
   - U.S. will keep leadership even as its relative competitive advantage declines
2. A strong university system with state-of-the-art graduate training drives innovation and labor supply
3. A strong national economy is critical for investment and future growth
   - U.S. is hurt by its low savings rate

What questions are we asking?

- Does the U.S. have a shortage of engineers?
  - of U.S.-citizen engineers?
  - of U.S.-citizen MS/PhD engineers?
- Is U.S. losing leadership in innovation,
  or is its competitive advantage declining?
- Do companies face a shortage of engineers,
  or a shortage of young engineers with latest skills (and unwilling to train experienced engineers)?
- How is offshoring affecting engineering work,
  or what are the major forces affecting engineer employment and earnings (U.S. and globally)?