

The Need for a Renaissance in Doctoral Education in Engineering

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Outline

- Introduction
- A view of PhD in Engineering
- Overarching themes
 - Recruitment
 - Economics of PhD Education
 - Added values
- Desired Attributes
- Suggestions

- Over the last 30 years, technology has fueled economic growth and paved the way to globalization and a “flattened world.”
- Last 30 years have also shown us “the other side” of technology – environment, increased energy needs, safety
- Specialization – driving force behind the stunning technical advances – is it now an impediment to sustain it?

- Globalization, new technologies, and the rise of competitive engineering have placed increasing demands on universities to educate *a new kind of engineer*
- In addition to technical expertise – a broader understanding of the context in which he or she works, strong communication skills, the ability to adapt and change, and an understanding of the importance of teamwork and leadership.

The focus for change has been on engineering undergraduate education.

A near-complete silence on doctoral programs.

S&E PhD education and Technological Superiority – A Symbiotic Relationship

Graduate engineering education contributes directly to the broader national goals of technological and economic development

Provides future researchers, technology leaders and faculty.

“Graduate schools of science and engineering are ... an indispensable underpinning of national strength and prosperity”

Some Reasons for the Silence

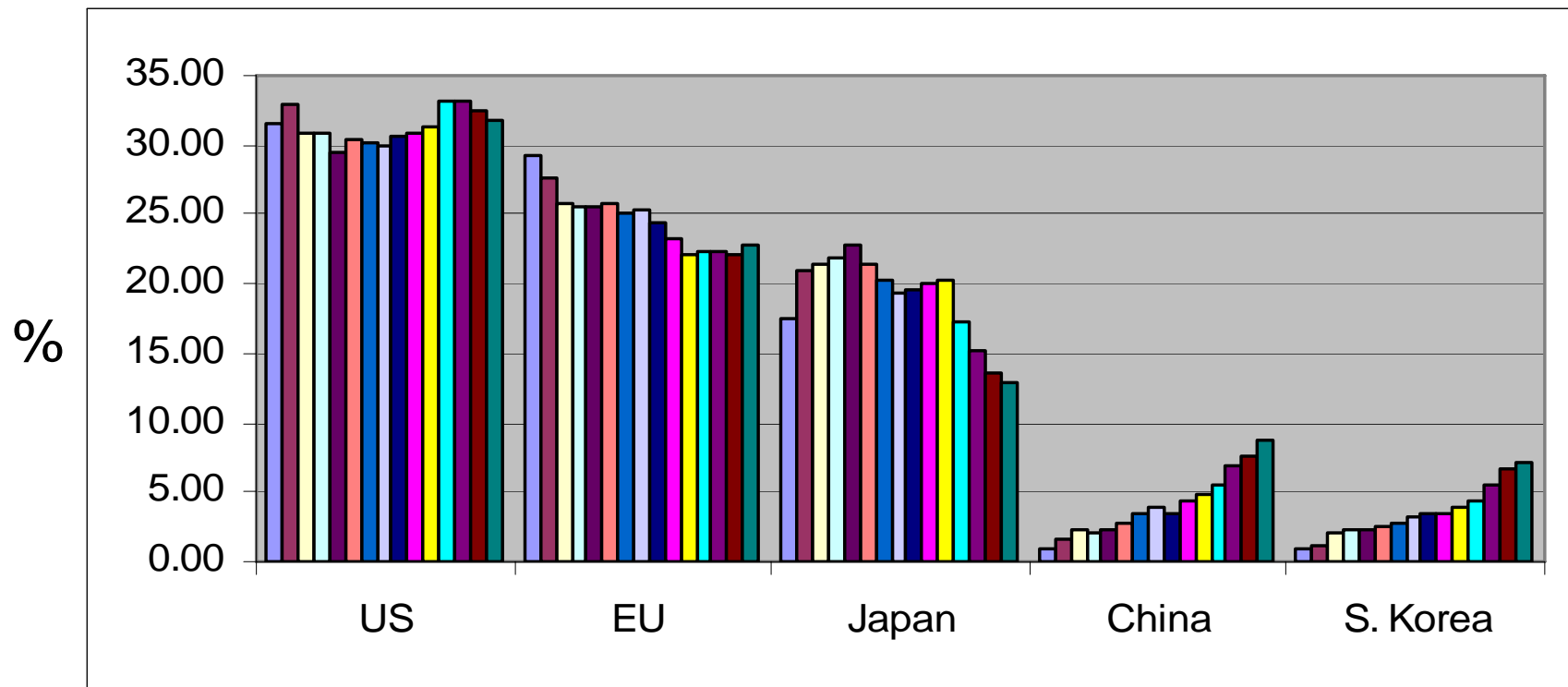
- Much fewer PhD students than UG students
- Role of PhD students within the academic research enterprise – breadth is distraction
- The current model has made the US graduate education the best in the world

“The Best Education in the World”

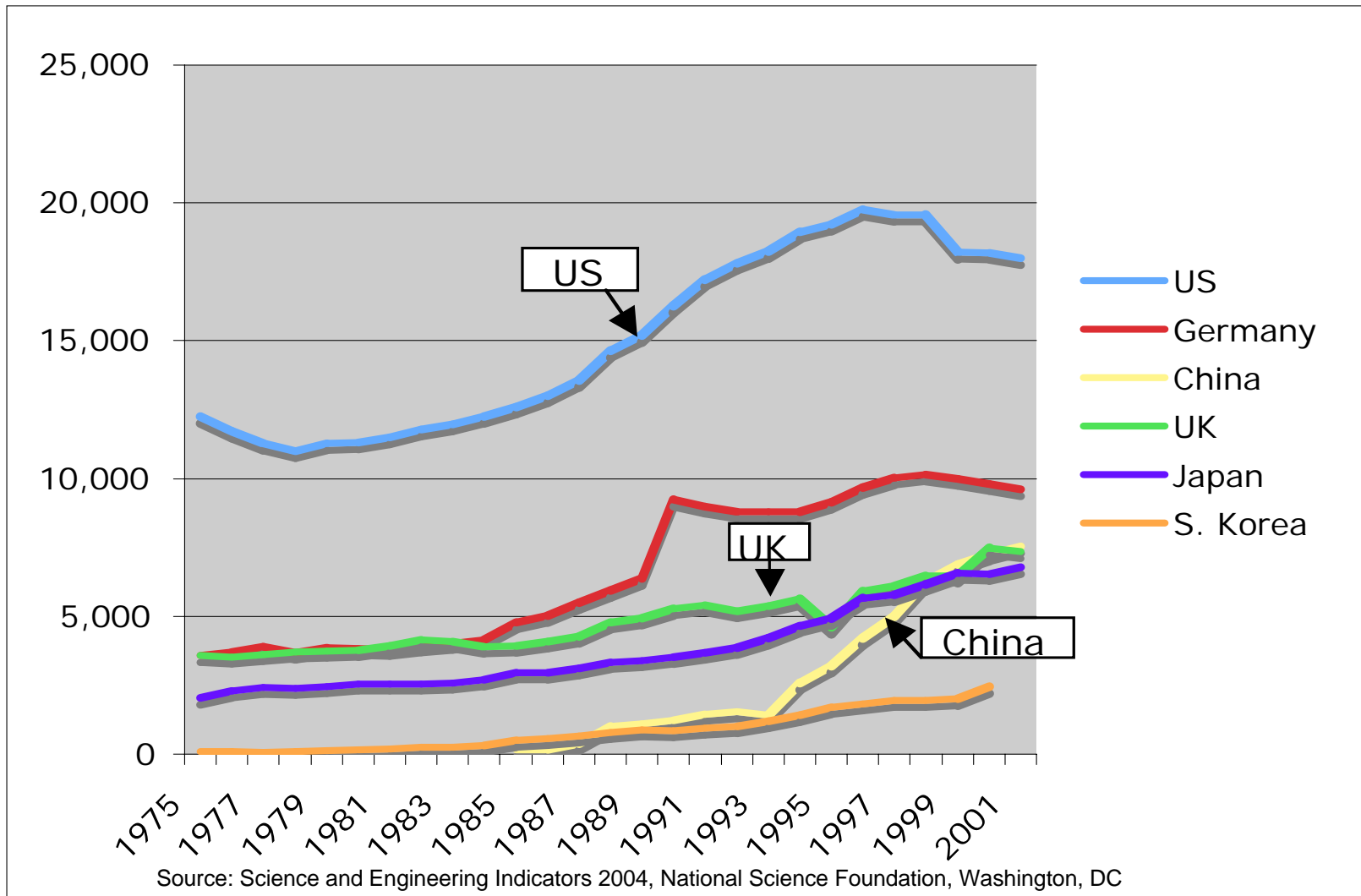
- Attracts the best and the brightest from around the world
- Employs 70% of the world’s Nobel laureates
- Includes the highest ranked universities in the world
- Ranked first in technology and innovation, in technological readiness, in company spending research and technology

Inherent value or lack of competition?

Global High-Technology Market Share by Selected Country or Region



Science & Engineering Doctoral Degrees



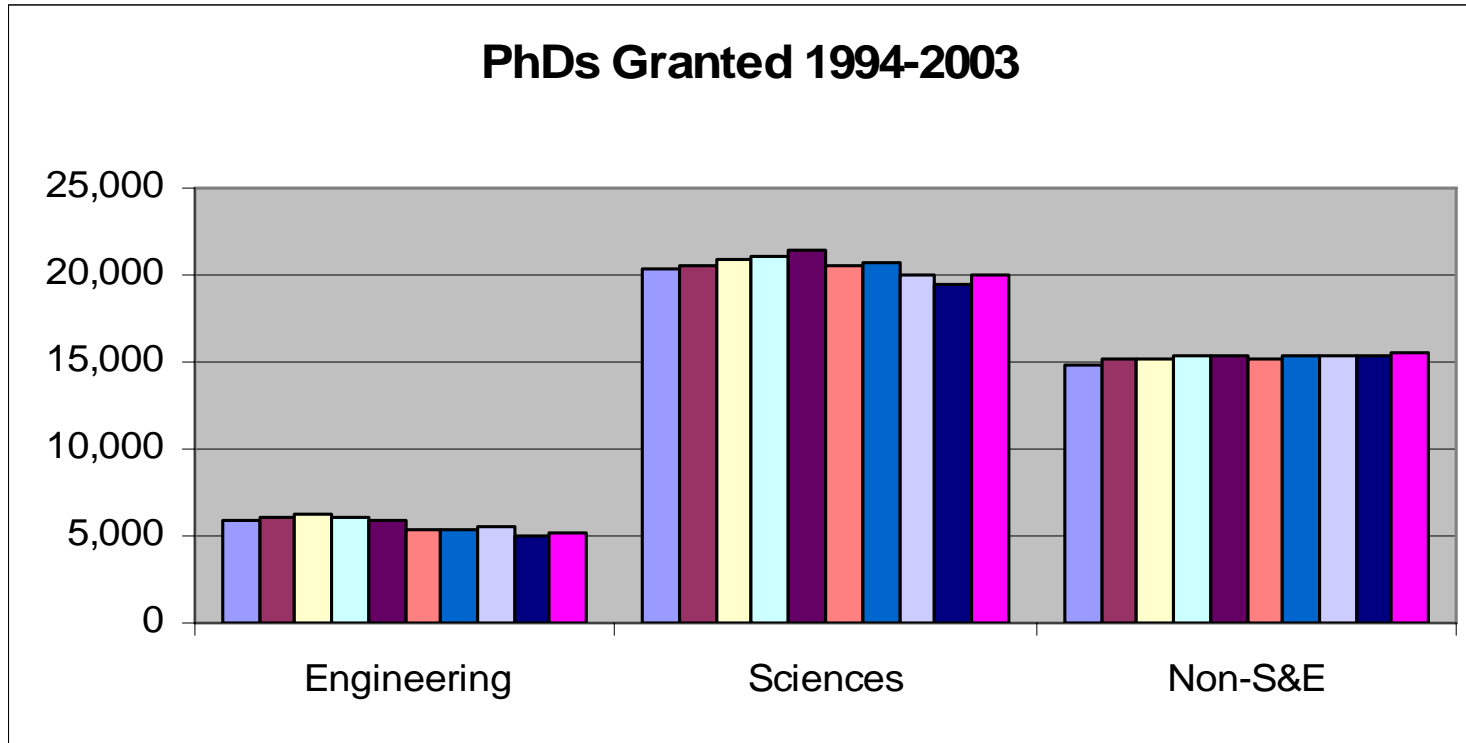
The Technology “Race”

- China, India, and Russia have the three highest GDP growth rates
- Patent applications
 - in China, South Korea, and Japan has risen by 24%
 - In the same time period, the patent application growth rate in the U.S. is at 3.8%

The US still provides the most nurturing environment required for innovation.

However, there are indications that other nations are starting to attract talent that U.S. universities previously had no trouble recruiting

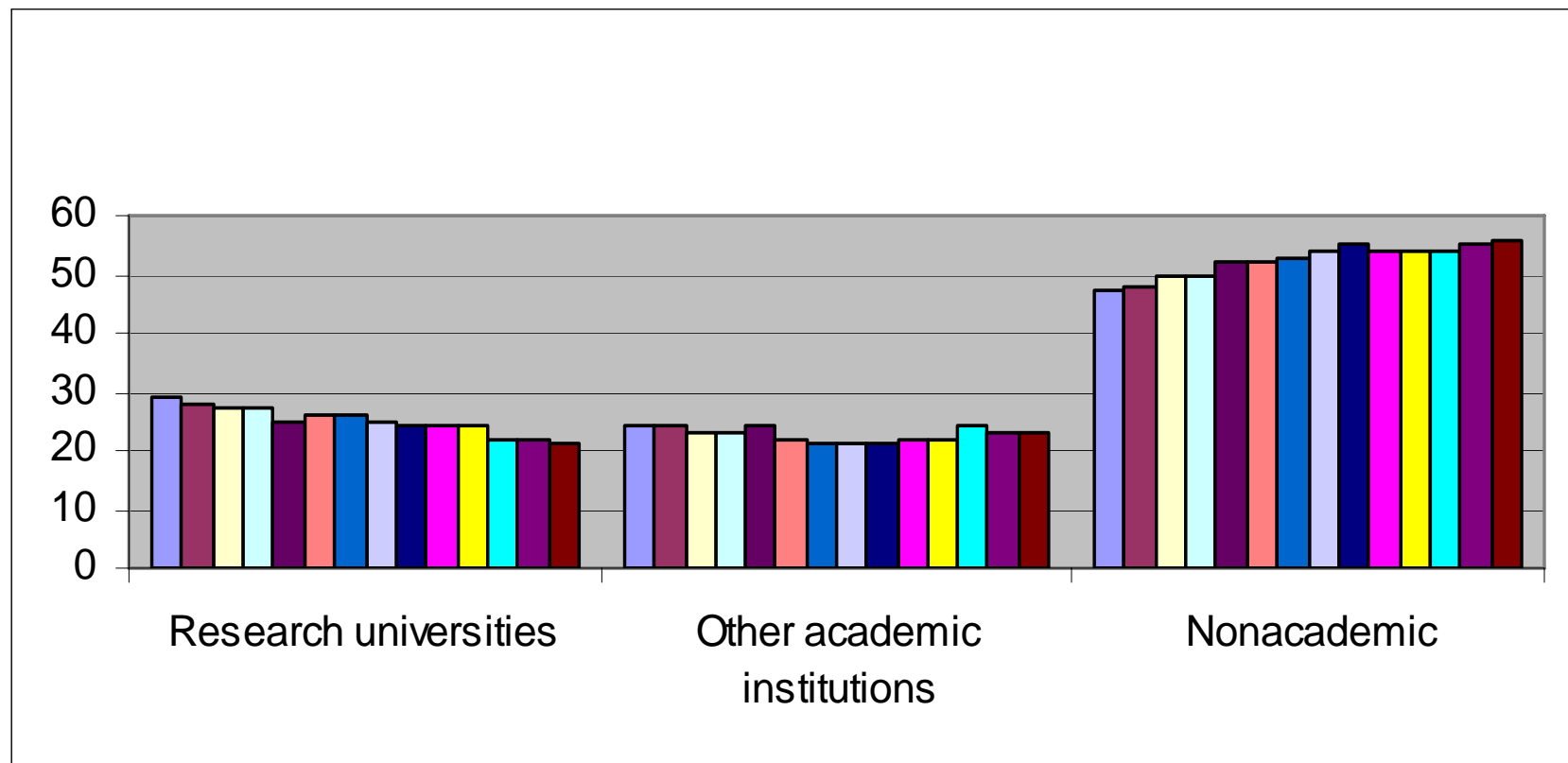
Recent Trends – Numbers



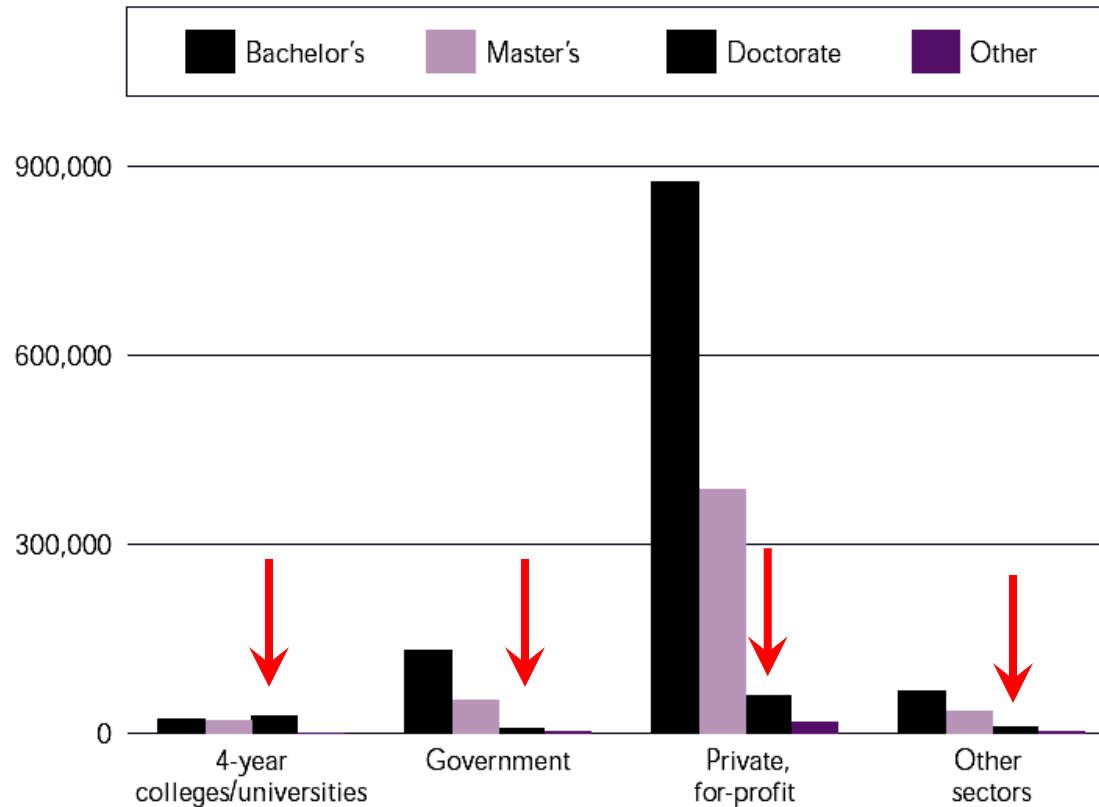
5,000/Yr ENG PhDs out of a total of 40,000 / Yr in all fields

S&E Doctorate Holders in the US

1975 - 2001



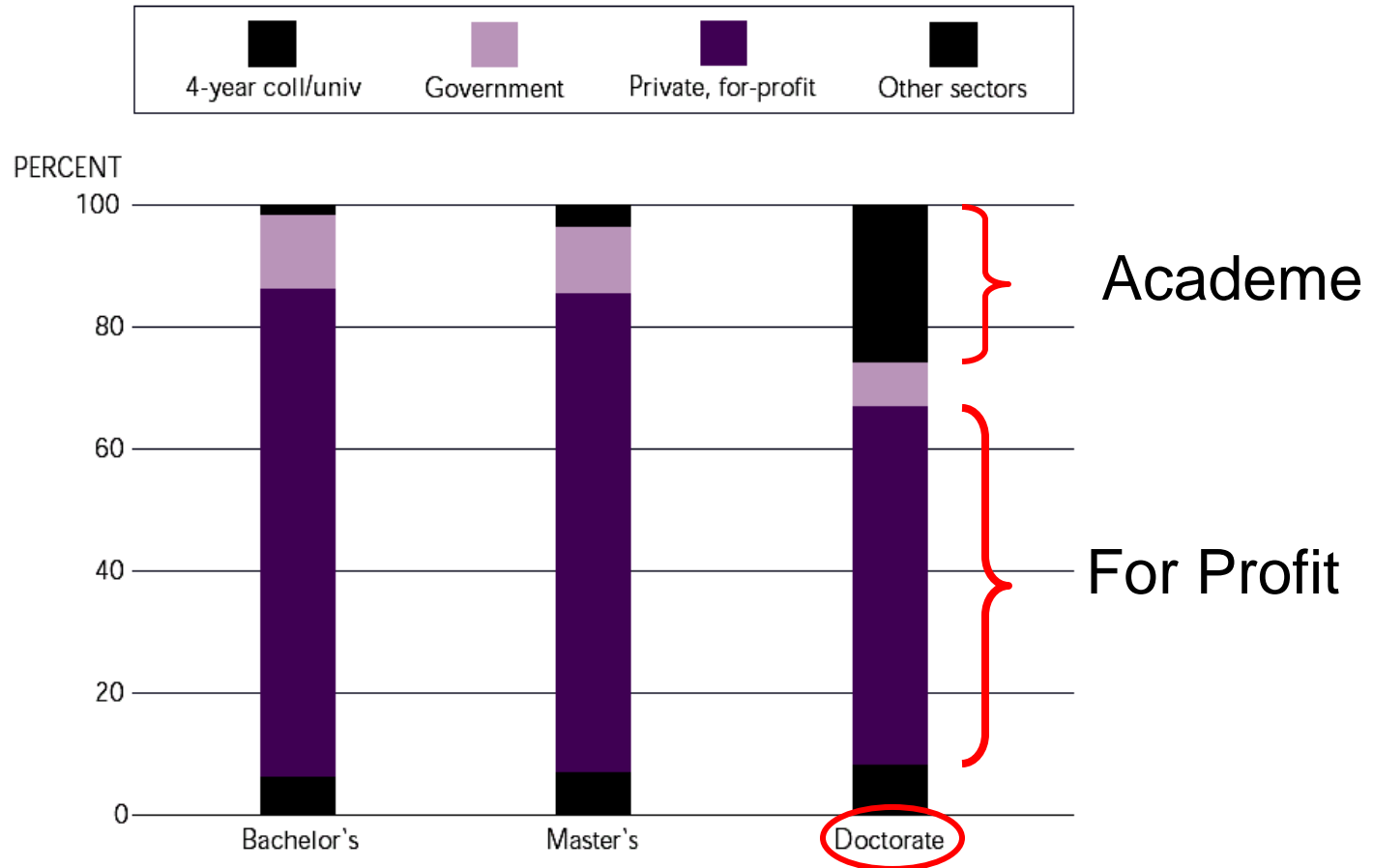
Engineering Employment



NOTE: A small number of engineers whose highest degree is a professional degree are omitted. Four-year colleges/universities includes medical schools and university-affiliated research institutes. Other sectors includes nonprofit organizations and self-employment.

SOURCE: National Science Foundation/Division of Science Resources Statistics, SESTAT (Scientists and Engineers Statistical Data System), 1999.

Engineering Employment



NOTE: A small number of engineers whose last degree is a professional degree are omitted. Four-year colleges/universities includes medical schools and university-affiliated research institutes. Other sectors includes nonprofit organizations and self-employment.

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How well are they prepared?

Are there missed opportunities?

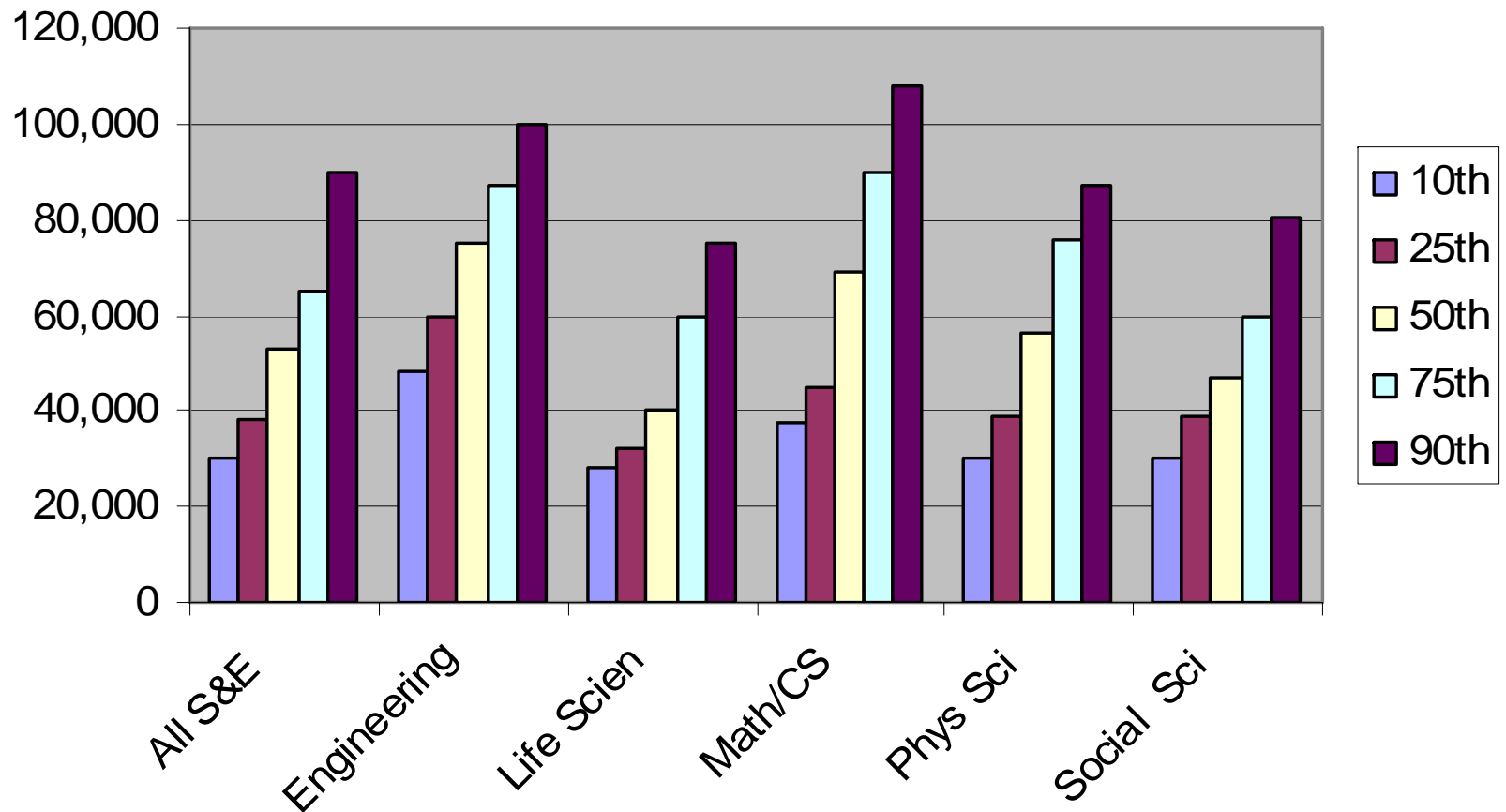
Perceptions & Criticisms

- Non-Academic Employers
 - PhD students are educated and trained too narrowly
 - They lack key professional skills
 - effective collaboration, working in teams,
 - organizational and managerial skills;
 - appreciation of applied problems;
 - knowledge *and culture* of other fields
- Academic Employers (Teaching institutions)
 - Ill-prepared to teach
- National policy makers
 - Too long to complete their degrees
- Current and former students
 - Ill-informed about non-academic employment opportunities

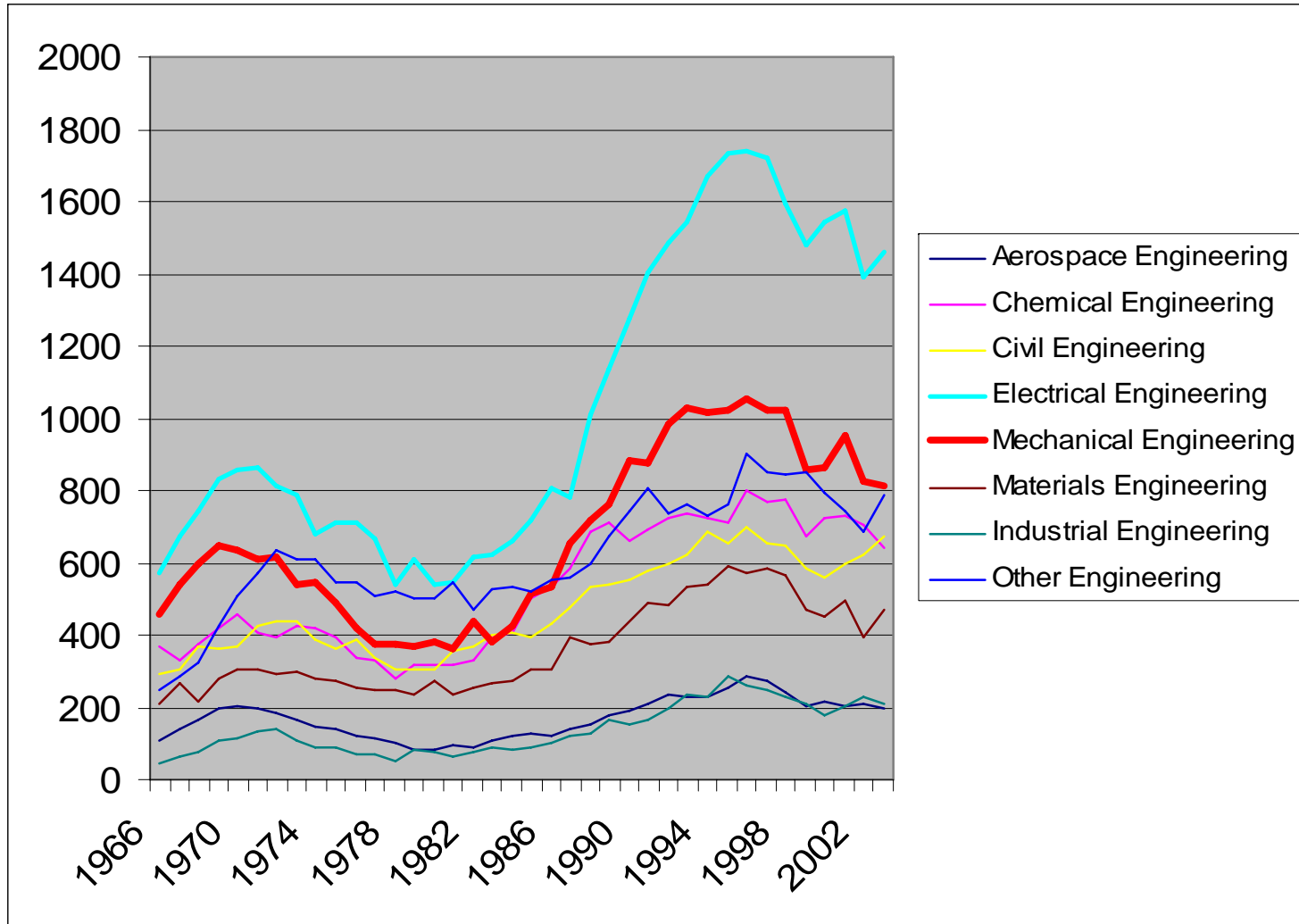
Three Overarching Themes

- Economics of PhD education
- Recruitment of PhD students
- Added-value of PhD education

Median Annual Salary of Recent (1-3 yrs) PhDs By Percentile



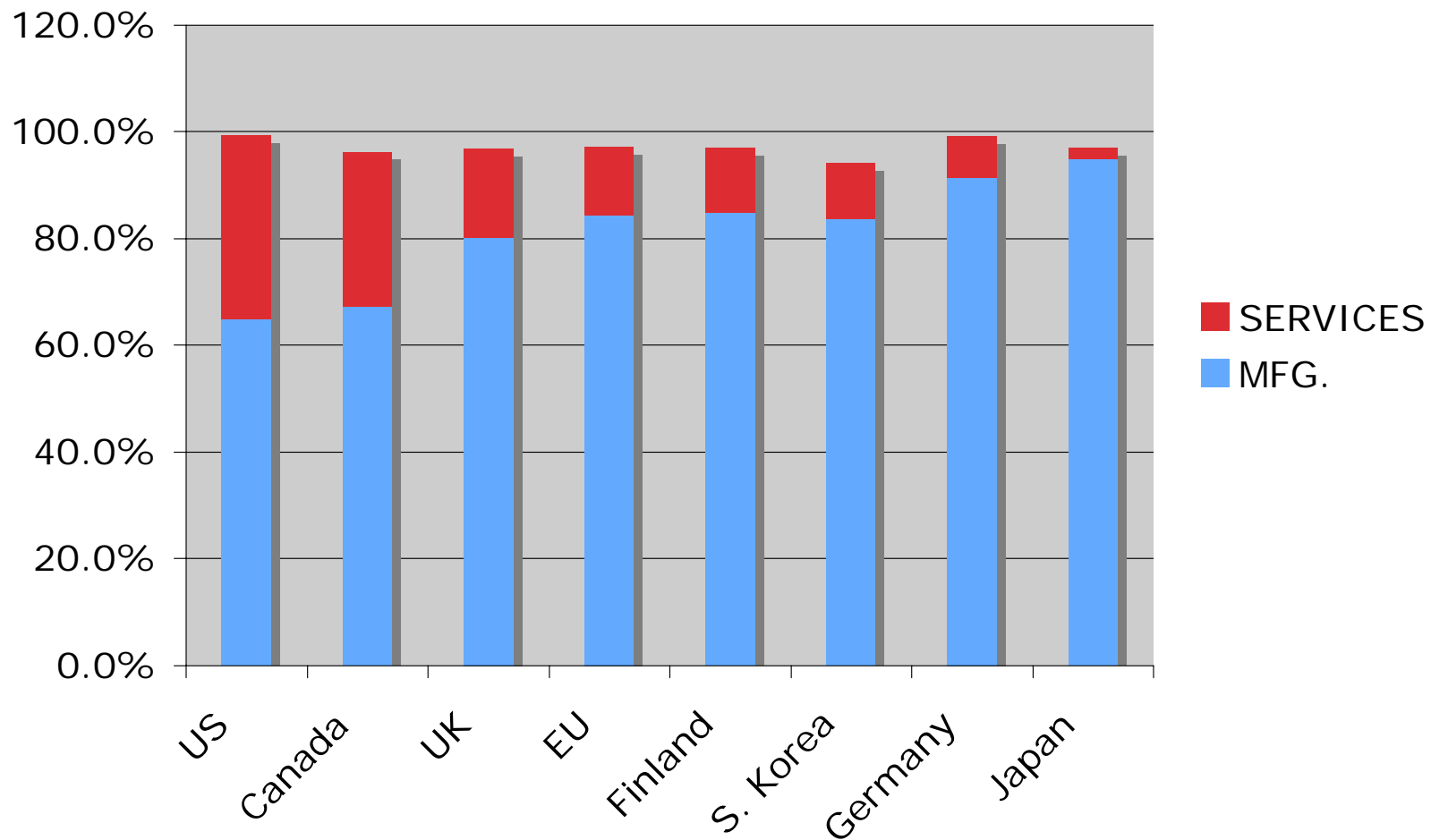
Differences Among Engineering Disciplines 40 Year Trend



Differences

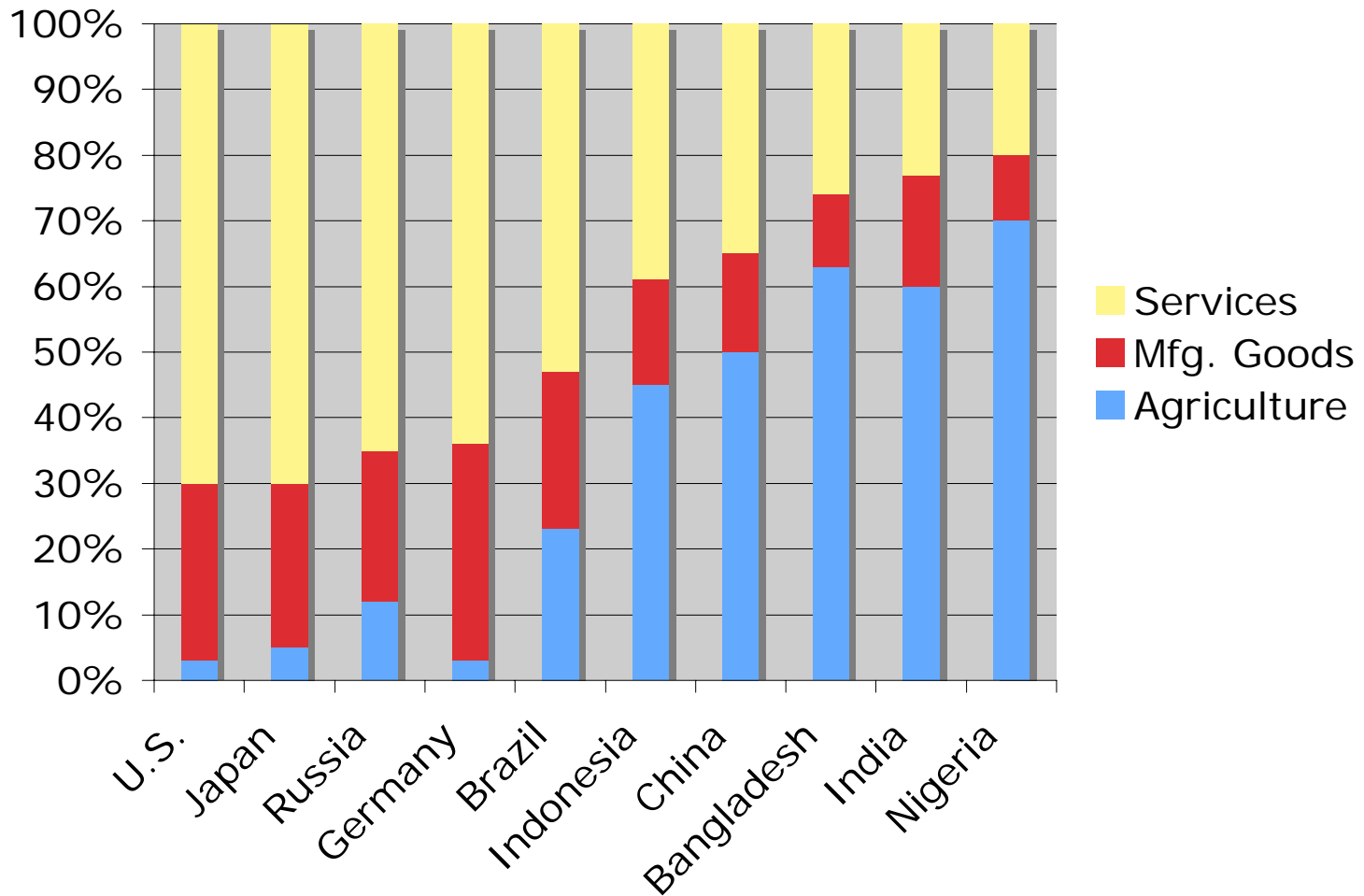
- Alignment of education, research and market needs have been different for different disciplines
- EE/CE – most well aligned
- ME – some alignment
- CEE – ??

Industrial R&D 2000



Source: Science and Engineering Indicators 2004, National Science Foundation, Washington, DC

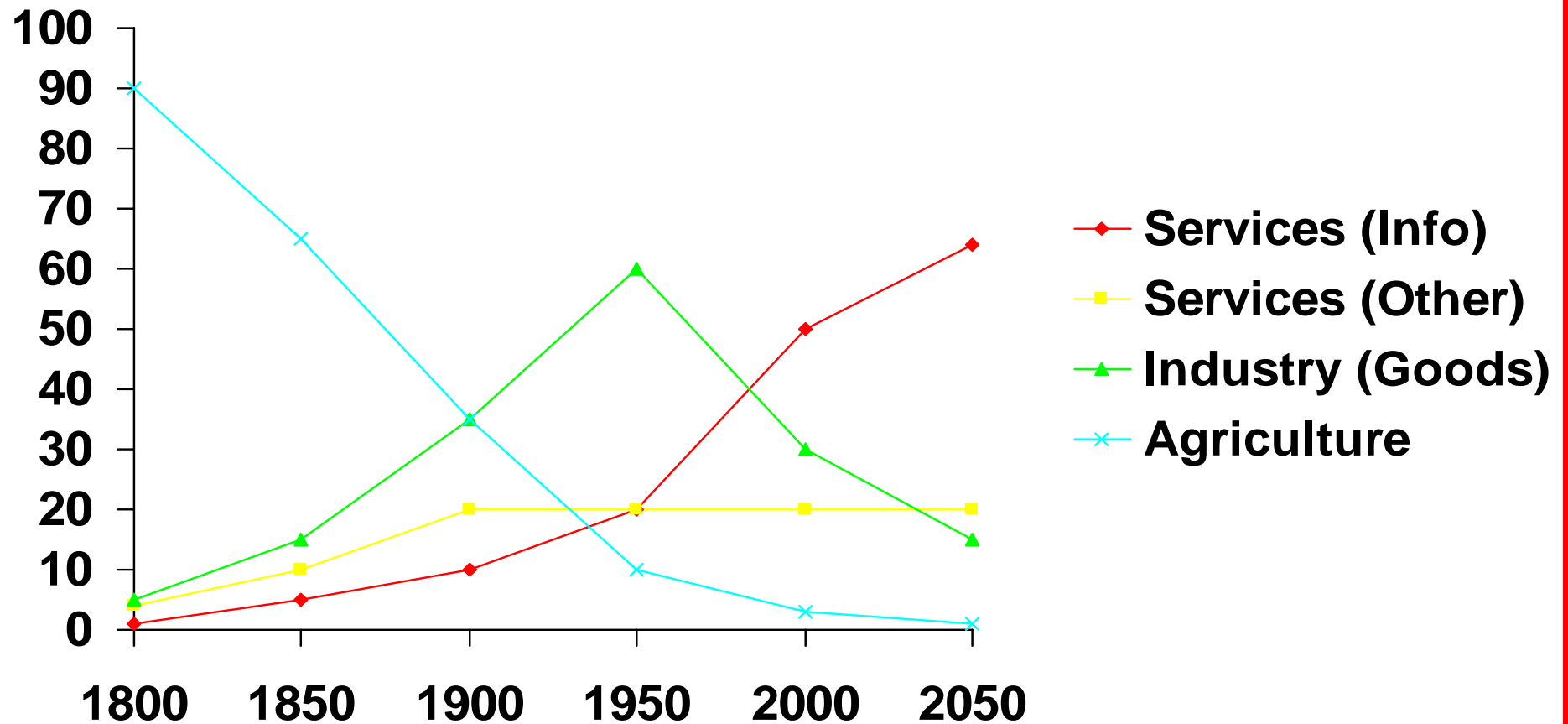
Labor Force by Sector 2004



Source: IBM Research <http://www.research.ibm.com/ssme/>

U.S. % Employment by Sector

History and Projection



Source: Stuart Feldman, IBM Research, Presentation at Carnegie-Mellon University, 29 June, 2005

Trend is to Increase the Distance from Manual Labor

- In agriculture distance is through automation
- In Manufactured goods distance is geographical

What are the implications of these trends for the next generation PhDs?

Desired Attributes of a PhD

Results of an Informal Survey

- World class knowledge in some specialty
- Ability to develop world class knowledge in related areas
- Understanding how their specialized knowledge fits within the larger context of knowing and understanding.
- Aware of *all* effects of globalization and technology – and the price with which it comes.
- Leadership, as reflected in breadth of knowledge and ability to articulate ideas, confidence, poise, and focus.
- Can deal with predicaments and not just problems
- A thinker, a strategist

A Renaissance PhD

Preparing Renaissance Engineers

Value Individuality

- Multiple intelligences*
 - Musical intelligence
 - Bodily-Kinesthetic intelligence
 - Logical-Mathematical intelligence
 - Linguistic intelligence
 - Spatial intelligence
 - Interpersonal intelligence
 - Intra-personal intelligence
 - Naturalist intelligence
 - Existential intelligence

- Customized (individualized) education

- Flexibility

“Train a child according to his way.” (Book of proverbs 22:6)

* H. Gardner

“Blue-collar” PhDs or Thought Leaders

Students and the education providers have
different interests and talents

*PhD Education can to take advantage of
these rich differences.*

Some Suggestions

- Flexible programs – Introduce incentives to faculty and students to include studies in areas of interest and talent
- Minors, modules, apprenticeships – management, sciences, psychology, finance, negotiations.....
- Intensive short training sessions – communications, management, business plan development,.....
- It is imperative for the community to re-examine the current model of PhD Education
- Broaden the basis of incoming students

Impediments to Broader Preparation

- Requires breadth of knowledge and expertise that most advisors may not possess.
- Takes away student time from research project
 - That provides financial aid to student
 - That has to produce to meet deadlines
- No clear incentives or road-map for the education providers to make changes
- Students are self-selected, assisted by
 - Admission requirements
 - Types of perceived employments that await them

Community Responsibility

- Government
 - In proposals require plans for educating PhD students
 - Support systemic changes in PhD education
- Industry/Business
 - Participate in the education enterprise – fellowships, apprenticeships
- Professional Societies
 - Need to go through a Renaissance of their own
- Academe
 - Reduce the conflict between institutional needs (teaching & research) and PhD education
 - Establish clear incentives for PhD education – separate from research
 - Ignore or improve USNWR ranking methods
- Faculty
 - Awareness of how important PhD education is to the well being of the nation.

The best time to improve is when one is still the best – a maxim that Detroit missed in the 1950s.

There is no room for complacency.

*Every morning in Africa a gazelle wakes up.
It knows it must outrun the fastest lion or it will
be killed.*

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*It doesn't matter whether you're a lion or a gazelle -
when the sun comes up, you'd better be running.*

-Richard Hodgetts

Thank you.