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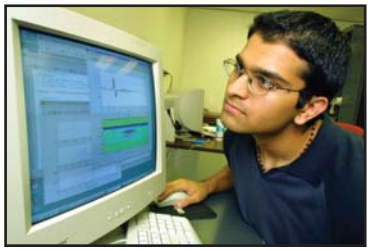

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Framing the Engineering Outsourcing Debate: Placing the United States on a Level Playing Field with China and India

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Acknowledgements

This report is part of an ongoing study to compare the number of U.S. engineering graduates to those in developing nations, particularly India and China. This is a complex issue and requires further study but this preliminary report raises several questions about the numbers quoted in the popular press. This report was developed by graduate students of Duke University's Master of Engineering Management Program under the guidance of Dr. Gary Gereffi, and Vivek Wadhwa with consulting assistance from Katzenbach Partners LLC.

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Abstract

The effect of the dynamics of engineering outsourcing on the global economy is a discussion of keen interest in both business and public circles. Varying, inconsistent reporting of problematic engineering graduation data has been used to fuel fears that America is losing its technological edge. Typical articles have stated that in 2004 the United States graduated roughly 70,000 undergraduate engineers, while China graduated 600,000 and India 350,000. Our study has determined that these are inappropriate comparisons. These massive numbers of Indian and Chinese engineering graduates include not only four-year degrees, but also three-year training programs and diploma holders. These numbers have been compared against the annual production of accredited four-year engineering degrees in the United States. In addition to the lack of nuanced analysis around the type of graduates (transactional or dynamic) and quality of degrees being awarded, these articles also tend not to ground the numbers in the larger demographics of each country. A comparison of like-to-like data suggests that the U.S. produces a highly significant number of engineers, computer scientists and information technology specialists, and remains competitive in global markets.

The Engineering Outsourcing Debate

The impact of engineering outsourcing on the global economy is a discussion of keen interest. Consistent reporting of problematic engineering graduation data has been used to fuel fears that America is losing its technological edge. Typical articles have stated that in 2004 the United States graduated roughly 70,000 undergraduate engineers, while China graduated 600,000 and India 350,000. When cited by the popular media, these numbers were rarely documented or verified.[1]

Our study has determined that the above comparison is inaccurate, or tells only part of the story. The commonly quoted numbers are based on reports issued by the Chinese Ministry of Education and the National Association of Software and Service Companies in India, who are generally considered to be the authorities on engineering graduation statistics within their respective countries. However, the statistics released by these organizations have included not only four-year degrees, but also three-year degrees and diploma holders. These numbers have been compared against the annual production of accredited four-year engineering degrees in the United States. Additionally, these numbers include not only engineers in traditional engineering disciplines, but information technology specialists and technicians.

Here we will present a clearer analysis of the number of engineering and engineering-related degrees awarded annually by the United States, India and China. We will define the term “engineer” and the various degree options that exist. We will then offer what we believe is a more accurate and balanced comparison between the numbers of engineering, computer science and information technology degrees awarded in the United States, China and India.

Classifying Engineers

The outsourcing debate has been complicated due to conflicting definitions of the engineering profession. Different statistical survey groups have adopted their own engineering classifications.[2] Additionally, definitions vary greatly internationally. Within academic and professional settings, an engineer is defined as a person capable of using scientific knowledge to solve real-world problems. Engineers utilize their knowledge of math and science to achieve practical ends. However, this definition makes it difficult to count engineering populations. In the U.S., the following definitions have been used in various surveys and reports: *an individual working in an engineering occupation; an individual’s highest or most recent degree; anyone with an engineering degree or occupation*.

Through our research, we have identified two main groups of engineering graduates: dynamic engineers and transactional engineers. Dynamic engineers are individuals capable of abstract thinking and high-level problem solving using scientific knowledge. These engineers thrive in teams, work well across international borders, have strong interpersonal skills, and are capable of translating technical engineering jargon into common diction. Dynamic engineers lead innovation. The majority of dynamic

engineers have a minimum of a four-year engineering degree from nationally accredited or highly regarded institutions.

Transactional engineers may possess engineering fundamentals, but not the experience or expertise to apply this knowledge to larger problems. These individuals are typically responsible for rote and repetitive tasks in the workforce. Transactional engineers often receive associate, technician or diploma awards rather than a bachelor's degree. These subbaccalaureate degrees can be obtained in less than four years, but more than one. Most highly accredited universities in China, India and the United States stress the importance of a four-year education. For instance, master's programs within the United States typically will not admit students with three-year bachelor's degrees unless they have also completed a one-year post-graduate diploma from an AIU- or an AICTE-approved institution. Subbaccalaureate degrees normally are granted at lower-tier institutions that lack the research facilities, dedicated faculty and budgets of accredited universities. Additionally, the quality of curricula varies greatly at these institutions. Due to time and budgetary restrains, subbaccalaureate programs are rarely capable of placing a strong emphasis on research, group work, applied engineering, or interdisciplinary thinking.

It is important to note that while many bachelor's programs produce dynamic engineers and most subbaccalaureate programs produce transactional engineers, this is not a hard and fast rule. In the last 50 years we've seen a number of science and technology leaders with little or no traditional education. Similarly, a degree from MIT, the Indian Institutes of Technology, or Tsinghua University in China doesn't guarantee the recipient is a dynamic engineer.

Study Methodology: The United States, China and India in Comparative Perspective

In this study, we sought to identify credible, well-documented and comparable engineering educational statistics for the U.S., China and India. We also explored the undergraduate graduation profiles for some of the largest engineering universities within each of these countries.

We obtained data from Ministry of Education in China, the National Association of Software and Service Companies (NASSCOM) in India, and the U.S. Department of Education's (DoE) National Center for Educational Statistics (NCES). We corroborated this data by contacting top universities in India and China and analyzing their graduation data and areas of specialization.

We also contacted various journalists, consultants and other industry experts to gain a better understanding of the issues and to validate our methodology.

Findings

To create an accurate and representative comparison between the number of engineers produced annually by the U.S., China and India, we researched the annual production of engineers, computer scientists and information technology specialists at the bachelors and subbaccalaureate levels in 2004. The results from our research can be found in Table 1 and Graph 1 below:

Table 1: Bachelor's and Subbaccalaureate Engineering, Computer Science and Information Technology Degrees Awarded in the U.S., China and India in 2004

Degree Field	United States[1]	India[2]	China[3] *
Total Bachelors and Subbaccalaureate Engineering, Computer Science and Information Technology Degrees	**222,335**	**215,000**	**644,106**
Number of Bachelors Degrees	137,437	112,000	351,537
in Engineering (Excluding CS and Electrical)	52,520	17,000	---
in CS, Electrical and IT	84,917	95,000	---
Number of Subbaccalaureate Degrees **	84,898	103,000	292,569
in Engineering	39,652	57,000	---
in CS and IT	45,246	46,000	---

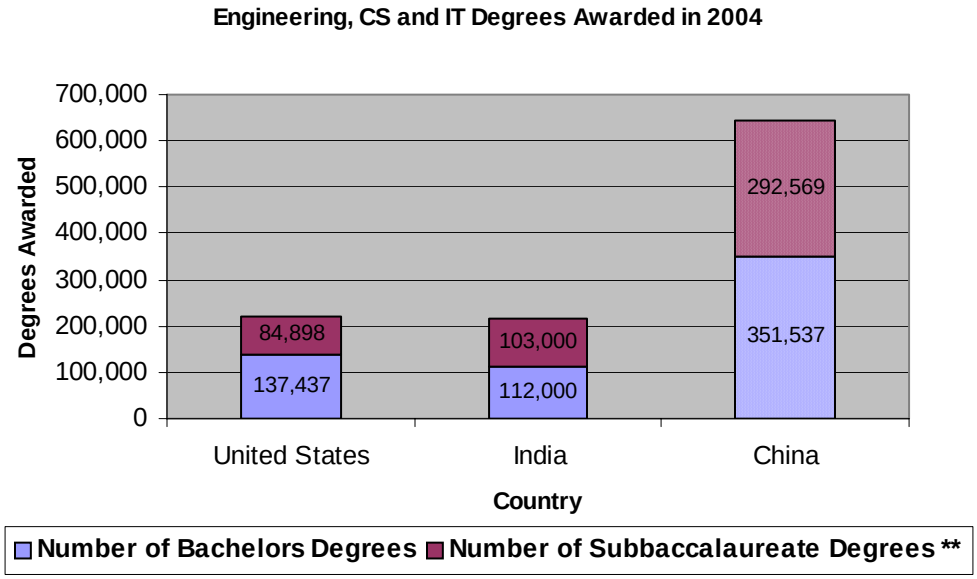
* This data provided by the Chinese Ministry of Education may include additional engineering and technology degrees outside traditional engineering fields, CS majors and IT specializations (example: auto mechanics)

** Subbaccalaureate degrees refer to Associates degrees in the United States, short-cycle degrees in China, and three-year diplomas in India

Note: The National Center for Education Statistics reports the total US engineering bachelor's degrees granted in 2004 to be 63,558. This number differs from the American Society of Engineering Education's (ASEE) 2004 statistic of 72,893. This variation is due to the way each of these organizations classifies and categorizes engineering graduates.

Sources:
1 National Center for Educational Statistics (NCES). 2003-4 Table 249, 2003-4 Table 253. NCES. Obtained from NCES Annual Reports Program Director
2 National Association of Software and Service Companies (2005). 2005 Strategic Review: Chp 6: Sustaining the India Advantage. NASSCOM. Pg 158
3 Chinese Ministry of Education. Number of Students in Regular HEIs by Field of Study. http://www.moe.gov.cn/edoas/website18/info14477.htm

Graph 1: Engineering, Computer Science and Information Technology Degrees Awarded in 2004

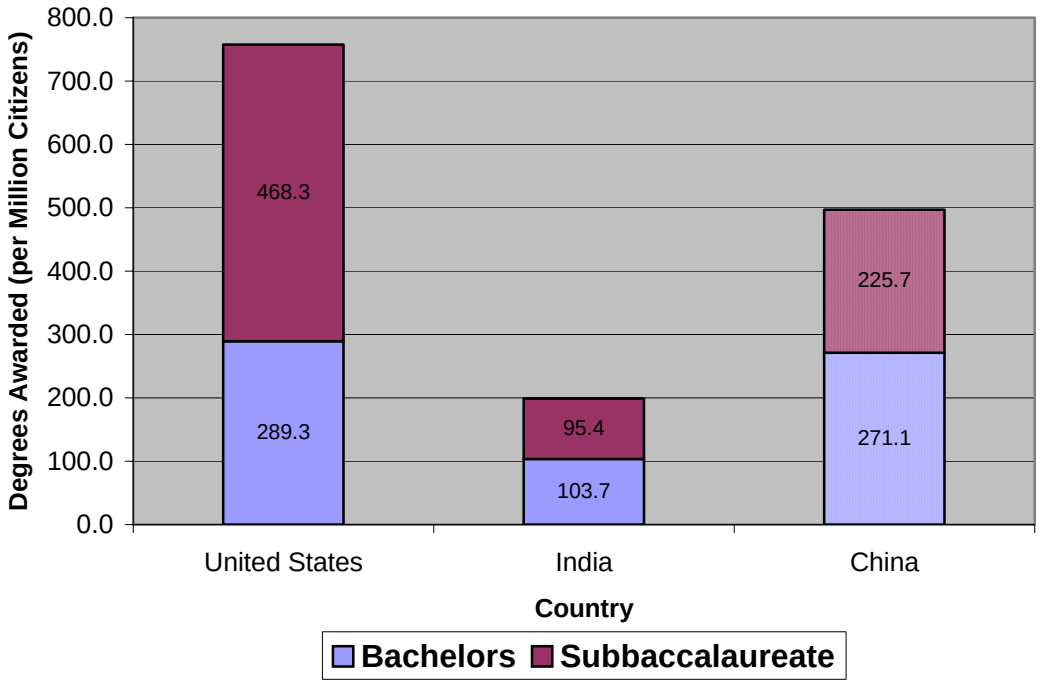


Note: Shaded China data may constitute an overestimate.

This shows that when compared on a level playing field, the U.S. is producing a very significant number of engineers, CS and IT specialists. China has roughly four times the population of the U.S., and India is approximately three times as large. If we take the data from Table 1 and normalize it against country population, we obtain the results presented in Graph 2.

Graph 2 depicts the annual production of bachelor's and subbaccalaureate degrees in Engineering, CS and IT awarded per million citizens. These data imply that per every one million citizens, the United States is producing roughly 750 technology specialists, compared with 500 in China and 200 in India.

Graph 2: The Number of Bachelor's and Subbaccalaureate Degrees in Engineering, CS and IT Awarded Annually per Million Citizens



Note: Shaded China data may constitute an overestimate

Data Background

The Chinese Ministry of Education is considered to be the definitive source for information relating to China's graduation data. We spoke with the Ministry of Education at length and learned several important points about its engineering graduation data. In 2004, the Ministry states that 644,106 engineers graduated, 351,537 of which received bachelor's degrees and 292,569 of which graduated from short-cycle programs. Short-cycle degrees are two-three year degree programs similar to U.S. associate's degrees. However, these statistics are still misleading. There are questions about what qualifies as an engineering program. As a result, any bachelor's or short-cycle degree with "engineering" in its title is included in these numbers, regardless of the degree's field or the academic rigor associated with it. This means that the reported number of engineers produced by China in 2004 may very well include the equivalent of motor mechanics and industrial technicians.

In all likelihood, this 644,106 number may not be comparable to the engineering production in the United States and India. The Ministry of Education told us that their aggregate numbers were obtained by adding the numbers of "engineering" graduates as reported by different provinces. These provinces were not required to report these degrees by major and further there was no standard definition of engineering between the provinces.

The National Association of Software and Service Companies (NASSCOM) provided the engineering graduation statistics on India. In NASSCOM's 2004 Strategic Report, they estimate that in 2004 a total of 215,000 engineering graduates were produced. Of this number, 112,000 individuals received four-year bachelor's degrees, while the remaining 103,000 received three-year degrees. According to this projection, 84.8% of India's four-year engineering graduates received IT-related engineering degrees (Applied Electronics & Instrumentation; Computer Science & Engineering; Electricals & Electronics; Electronics & Communication; Electronics & Telecommunication; Information Technology; Instrumentation Engineering; Instrumentation & Control; and Computer Application). While NASSCOM's engineering graduation statistics constitute projections, these values appear grounded. NASSCOM is currently the de facto authority for these data, given that the Indian national government records engineering graduation data on an erratic, non-annual basis. For example, the most recent official Indian graduation data are from 1993.[3] NASSCOM's projections are based on numbers that are pulled from three locations:

- The Institute of Applied Manpower Research's annual publication, "Manpower Profile India"
- The Ministry of Human Resource Department's Annual Report
- IndiaStat.com

Together, these sources provide data with a three- to four-year lag. To extrapolate 2004 data, NASSCOM estimates labor supply numbers based on historical compound annual growth rates (CAGR). NASSCOM also consistently rechecks its past projections with current numbers, and it believes that in most cases the projections are accurate.

Once we obtained engineering graduation data from China and India, we then sought comparable engineering data for the United States. The American Society for Engineering Education (ASEE) and the Engineering Workforce Commission (EWC) are known for being the definitive sources for such statistics. Unfortunately, neither of these organizations publishes comprehensive reports detailing the graduation rates of IT specialists or individuals receiving subbaccalaureate degrees. As a result, we turned to the DoE's National Center for Education Statistics (NCES). This statistical databank contains comprehensive post-secondary graduation data across all majors and degree types. We accessed this database to obtain bachelor's and associate's level engineering, CS and IT graduation statistics. It is important to note that NCES engineering data differ from those recorded by the ASEE and EWC. This is due to the way NCES classifies various majors and because the NCES does not classify Computer Science as an engineering discipline. However, because we are focusing on Engineering, Computer Science and Information Technology, the NCES data are ideal.

Is America Losing its Technology Leadership?

Today, almost one-third of the globe's science and engineering researchers are employed by the United States. Thirty-five percent of science and engineering articles are published within the U.S. and the U.S. accounts for 40% of the globe's research and development (R&D) expenditure. Over the past two years, politicians, statisticians and policy makers have asked how much longer we can maintain our technological edge

when other nations with greater populations are producing more and more scientists and engineers. Many have argued that we are actively fueling this process by outsourcing American science and engineering jobs overseas.

There is no definitive answer to what the future holds. It is clear that the U.S. is not in the desperate state that is routinely portrayed. The country needs to maintain its focus on improving the quality of education and maintain its momentum, but there is no imminent crisis.

Outsourcing creates a clear threat to certain professions and it is likely that this trend will continue. It seems that the jobs of transactional engineers are easily outsourced and are routinely being taken by relatively low paid engineers in countries like India and China. However, the outsourcing of high-level engineering and IT professions is another story. These jobs often require specialized dynamic engineers: individuals with strong interpersonal skills, technical knowledge and the ability to communicate across borders.

The great majority of engineers involved in outsourced professions hold a minimum of a four-year degree. As a result, one could argue that approximately half of China's and India's annual engineering and IT graduates are capable of competing in the global outsourcing environment. However, a recent McKinsey global labor market study argues that this estimate is far too generous. McKinsey concluded that only 10% of Chinese engineers and 25% of Indian engineers can compete in the global outsourcing arena.[4] McKinsey attributed these figures to limited language proficiency, educational quality, cultural issues, job accessibility and the attractiveness of domestic non-outsourced jobs.

So, the real threat to the United States' science and technology economy exists in a subset of the engineering populations produced by China and India. Foreign dynamic engineers trained by accredited universities with high language proficiencies and close proximity to their country's industrial and commercial centers are the most likely to compete with U.S.-based engineers for offshore engineering jobs, and they also will be central to innovation drives in their domestic economies.

America: Innovating and Evolving

Many of the studies and articles published to date paint a grim picture for the future of American science and technology. Fortune magazine argued that a restructuring of the global economy is an unprecedented event, and no one knows for certain what the impact of such an event might be.[5] A recent article in *Finance and Development* showed that in 2003 the rest of the world outsourced more to the United States and the United Kingdom than the other way around. The article went on to argue that despite U.S. outsourcing activities, a net loss of jobs within the United States has not occurred.[6] However, McKinsey Global Institute believes that in a worst-case scenario, 49% of packaged software, 44% of infotech services, 25% of banking services, 19% of insurance jobs and 13% of pharmaceutical jobs could be outsourced.[7] These again are services that can be produced by transactional engineers.

So how can America rise to meet the threat of a global overhaul? Many believe that education is the answer. Dynamic engineering jobs are difficult to outsource; individuals with these skill sets are virtually always in demand. However, to begin producing more dynamic engineers, we need a primary educational system that is on par with international standards. We also need to increase the enrollment rate within our engineering colleges. Our engineering population is not stagnating, but it certainly could be growing faster.[8]

Final Thoughts

Today's global economy is technology driven. As a result, innovations within the engineering and science sectors are of principal importance. Engineers will continue to play a prominent role in this process; the real question is where these engineers will be located. We have shown that when evaluated on a level playing field, the United States is producing a competitive number of engineers, computer scientists and information technology specialists. The challenge for the United States over the next decade will be to retain its role as a global pacesetter in the education of engineering and scientific talent and thereby to sustain its legacy as a preeminent technological innovator.

Appendix:

Duke Outsourcing Study: Empirical Comparison of Engineering Graduates in the United States, China, and India
URL: http://memp.pratt.duke.edu/downloads/duke_outsourcing_2005_appendix.pdf

Works Cited

[1] Bialik, C. (2005). "Sounding the Alarm with a Fuzzy Stat." The Wall Street Journal Online, October. http://online.wsj.com/public/article/SB113028407921479379.html?mod=2_1125_1
[2] U.S. National Science Board (2004). Chapter 3: "Science and Engineering Labor Force." Science and Engineering Indicators, pp. 3-6. http://www.nsf.gov/statistics/seind04/c3/c3h.htm
[3] Government of India, Department of Education. Table 56: "Estimated Stock of Engineering Degree Holders in the Working Age Group by Selected Disciplines." http://www.education.nic.in/htmlweb/iamr6.htm
[4] Farrell, D, Laboissière, M, Rosenfeld, J, Stürze, S, and Umezawa, F. (2005). "The Emerging Global Labor Market: Part II – The Supply of Offshore Talent in Services." McKinsey Global Institute, June, p. 24.
[5] Colvin, G. (2005). "America Isn't Ready [Here's What To Do About It]: In the Relentless, Global, Tech-Driven, Cost-Cutting Struggle for Business…" Fortune, July, p. 70.
[6] Amiti, M., Wei, S. (2004). "Demystifying Outsourcing: The Numbers Do Not Support the Hype Over Job Losses." Finance and Development, December, pp. 36-39.
[7] Farrell, D, Laboissière, M, Pascal, R, Rosenfeld, J, de Segundo, C, Stürze, S. (2005). "The Emerging Global Labor Market: Part I – The Demand for Offshore Talent in Services." McKinsey Global Institute, June, p. 22.
[8] U.S. National Science Board (2004). Chapter 3: "Science and Engineering Labor Force." Science and Engineering Indicators, pp. 3-30. http://www.nsf.gov/statistics/seind04/c3/c3h.htm