Dynamics of Engineering Labor Markets:

Petroleum Engineering and Responsive Supply

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Employers hiring scientists and engineers are once again calling for government to enact policies to increase supply in this labor market. The question about relative supply and demand of engineers has taken renewed importance with the recent call for 10,000 additional engineering graduates a year from a group of technology company CEOs and others on the President's Competitiveness Council. It is also supported by IEEE (The Institute for Electrical and Electronics Engineers) President Ron Jensen who asserts that engineers drive innovation and create jobs. CBS News recently featured Andrew Liveris, president of Dow Chemical, lamenting the scarcity of qualified engineers in the U.S., causing his company to open R&D labs in Brazil, China, India, and Eastern Europe instead of the U.S.

The call for government to increase the number of engineering graduates follows a decade-long series of reports and policy statements noting shortages of science and engineering graduates. It also follows a decade of debate about whether there is a shortage and the evidence about such shortages and impacts. It is claimed that a market failure to supply adequate numbers of scientists and engineers calls for government intervention to alter the dynamics of this labor market.

Increasing the number of engineers is also offered as a cure for the current economic crisis and persistent unemployment. Additionally, increasing the supply of engineers responds to fears of foreign competition fueled by claims about the production of hundreds of thousands of engineers in China and India. These claims are repeated in numerous reports arguing that the U.S. is losing technological competitiveness to China, India and other countries because of weaknesses in our K-12 math and science education system. One consequence of this weakness, it is claimed, is a shortage of Americans well enough educated to succeed in university engineering programs.

The need to increase the number of engineering graduates is based on a number of assumptions that are worth examining before enacting government policies that alter the normal functioning of this labor market. Government intervention is predicated on assumptions that demand outpaces supply; the increasing offshore supply of scientists and engineers constitutes a "competition" with the U.S.; the size of the stock of engineers drives innovation (which, in turn, drives economic growth and social prosperity); supply will depend on (a) stimulating interest and achievement of domestic students; (b) increasing foreign supply/guest workers. In particular, there are three issues that we will examine in this paper: (1) the supply of engineers in other countries is a "threat" to U.S. innovation and competitiveness; (2) that labor markets do not function adequately to produce the requisite supply of engineers to meet industry demand; (3) that guestworkers/students are necessary to meet U.S. employer needs for their permanent workforces.

The Engineer Race

One concern about the health of the economy is that the United States is losing a race with other countries in the number of engineers it is educating and thus our ability to innovate and foster growth. Numerous reports point with alarm to statistics that show rapid increases in the number of engineers being trained in India, China, and other countries. The implication is that if China and India have more engineers than the United States, this somehow puts the United States at risk. The proposed solution to this “problem” is to train more Americans to be engineers (partly by increasing Americans’ interest in science and engineering and partly by improving science and math education in grades K-12). Although increasing the numbers of educated workers is intrinsically a laudable goal, does the engineering workforce size in other countries provide useful guidance for U.S. workforce development policy? To answer that question, we need to examine what engineers do and what drives the market for engineers.

In our analysis of engineering occupations and the nature of demand for engineers (Lynn and Salzman, 2010), we find that engineers make up just over 1 percent of the civilian workforce. Nearly half of all engineers are civil, mechanical, and industrial engineers, with 56 percent of all engineers working in either manufacturing or construction. Not quite 5 percent (4.8 percent, or just over 75,000) are in “scientific research and development services,” and it seems likely that only a few percent more are involved in key innovation activities (Bureau of Labor Statistics, 2010). Thus, most engineers are not creating new technology or developing “breakthrough innovations.” Instead, they are designing bridges, roads, power plants, factories, and buildings, or running day-to-day manufacturing operations.

China is rapidly developing, and its engineers are doing what a rapidly developing country needs its engineers to do. Chinese engineers are building new manufacturing facilities and power plants, expanding cities, and constructing new bridges, railways, and highways. In comparison to the more than 30,000 miles of new interstate highway China built in the past decade, for example, the United States added only 608 additional miles (Lynn and Salzman, 2010). While China is building thousands of miles of additional rail and waterway transit, the United States has actually seen a decline in its total mileage of both. As a proxy of construction and manufacturing activities, it is illustrative to compare the national consumption of cement and steel, two key inputs for construction and manufacturing. As Lynn and Salzman (2010) show, in Table 1 and Figure 2, China is ravenously consuming these inputs while U.S. consumption has remained flat.

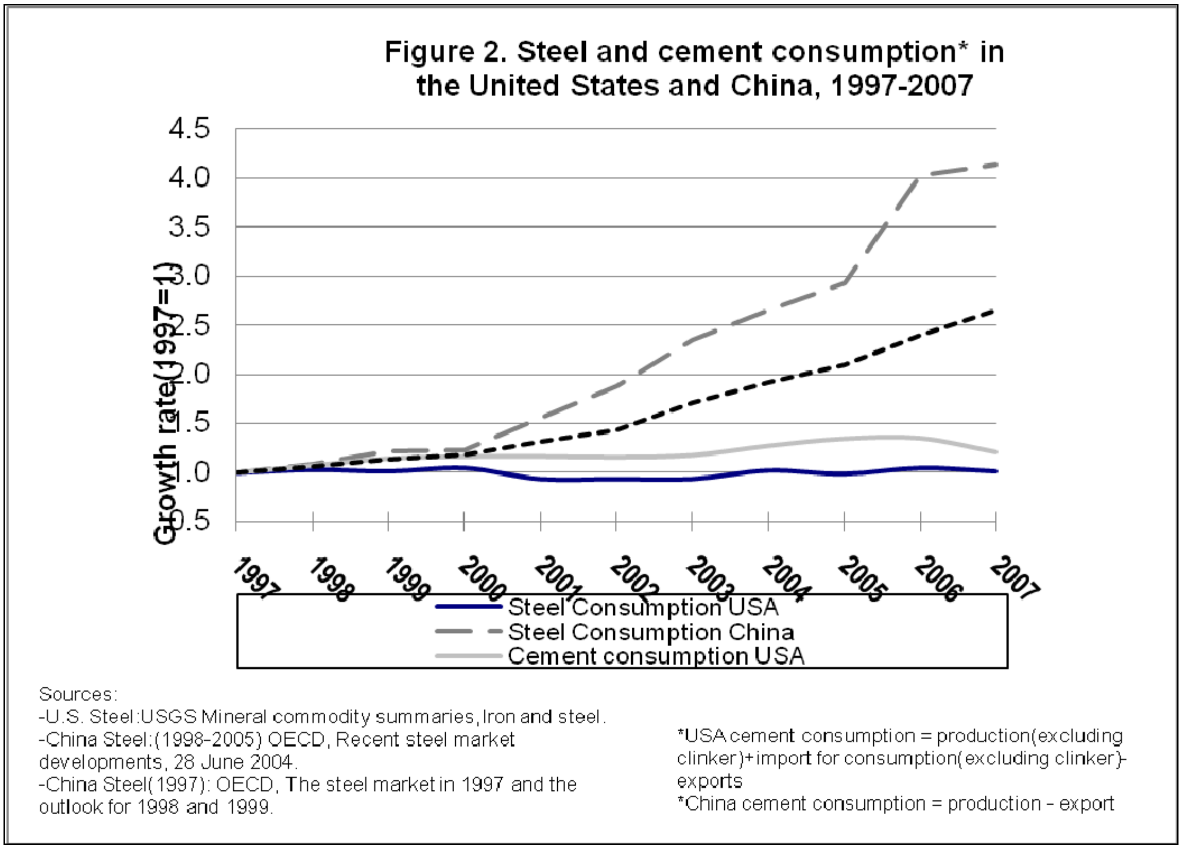
Table 1.
Growth of infrastructure between 1997 to 2007

Length, Miles	**United States[1]**	**China[2]**
Interstate/Expressway	608	30,519
Navigable Channels	(680)	8,510
Rail	(4,030)	7,436

(From: Lynn and Salzman, 2010) Sources:

1. National Transport Statistics, 2009. Bureau of Transport Statistics, U.S. Department of Transportation.

2. China Statistical Yearbook, 2008. National Bureau of Statistics of China.



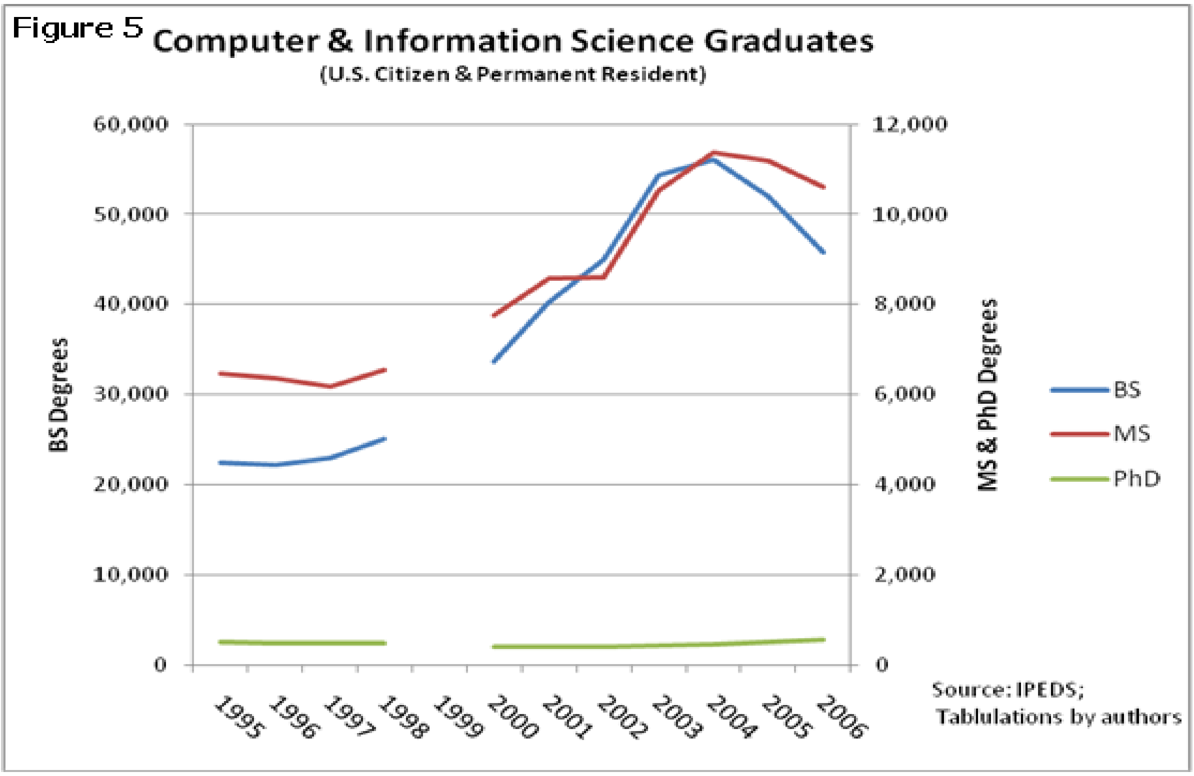
Consequently, we should expect parallel trends in the production and employment of human resources used for that building and manufacturing. In China, it is the rapid development of the economy from a relatively low level that is generating the demand for engineers. Thus, it hardly seems remarkable that in 2008 China felt a need to graduate approximately 660,000 engineers from a population of 1.3 billion people to add to a total workforce of over 780 million. The vast increase in the number of engineers in China is focused on meeting rather basic infrastructure and natural resource needs. It is not indicative of an engineering arms race that threatens the relative U.S. ability to innovate or to compete.

Beyond the numbers, however, is the question of skills. There is no doubt that China can recruit huge numbers of bright students to its universities and then outpace the United States in the number of engineers it graduates. But, what of the skills these engineers graduate with, and what of their employability? The one serious study of engineering supply in China and India (Gereffi, Wadhwa, Rissing, and Ong, 2008) looked beyond the aggregate numbers and examined the types and quality of engineering graduates in these countries. They find that a small number of graduates from the elite universities are in high demand, but the vast majority do not have the skills or qualifications that global firms need. They make a further distinction in "type" of engineer, between "transactional" and "dynamic" engineers. The former are those who have technical expertise but not the "experience or expertise to apply this knowledge to larger domains (p. 21)." It is dynamic engineers that have those latter skills and there are very few of those graduating from Chinese and Indian universities. A McKinsey study finds that only 10 percent of China's engineering graduates are considered employable in global firms, compared to over 80 percent of U.S. engineering graduates (as cited in Farrell and Grant, 2005). Adjusting for quality, then, China is graduating fewer internationally qualified engineers than the United States (66,000 qualified Chinese engineering graduates compared to more than 80,000 American bachelor's and master's engineering graduates [National Science Board, 2010a]). This is what should be expected at this stage in China's history. Without the depth of faculty who have engineering experience or involvement with firms doing leading-edge engineering, it would be difficult to quickly develop the ability to provide large numbers of engineering students with the skill needed to reach global standards.

Are U.S. colleges and universities responsive to market demands for engineers?

An underlying assumption of the government intervention advocates is that increasing the extent and breadth of K-12 math and science education would eventually result in an increase in engineering graduates. The logic is, apparently, that there is an insufficient number of U.S. high school graduates with adequate math and science skills to satisfy the “demand” of U.S. universities for qualified engineering students. Our analyses, however, suggest that whatever weaknesses there are in U.S. K-12 math and science education, these weaknesses do not hinder the development of an ample supply of top-performing students available to pursue engineering degrees (e.g., Lowell and Salzman, 2007; 2009; Salzman and Lowell, 2009). Another possible problem might be that our colleges and universities are too inflexible to respond to changing market demands for graduates coming from the various different engineering disciplines, educating too many in a declining field and not enough in a growing field. If so, this could partially account for the low employment of engineering graduates. To provide some evidence related to this question we examine the trends in two engineering fields where there were significant rapid changes in demand.

As we entered the 21st century, the demand for IT workers was rapidly increasing. This sudden increase was in part the result of a technology bubble, largely in the dot-com sector, combined with a temporary confluence of industry-specific factors related to the Y2K conversion, implementation of new software systems, and the growth of several new software languages and technologies (e.g., see Salzman, 2000, and Salzman and Biswas, 2000). As Figure 5 shows, in response to the spike in demand, the number of graduates rapidly increased in the first years of the century. Conversely, in response to the technology bust and the remediation of Y2K problems and system conversions, the number of graduates rapidly declined.



[Source: IPEDS; Tabulations: Kuehn and Salzman]

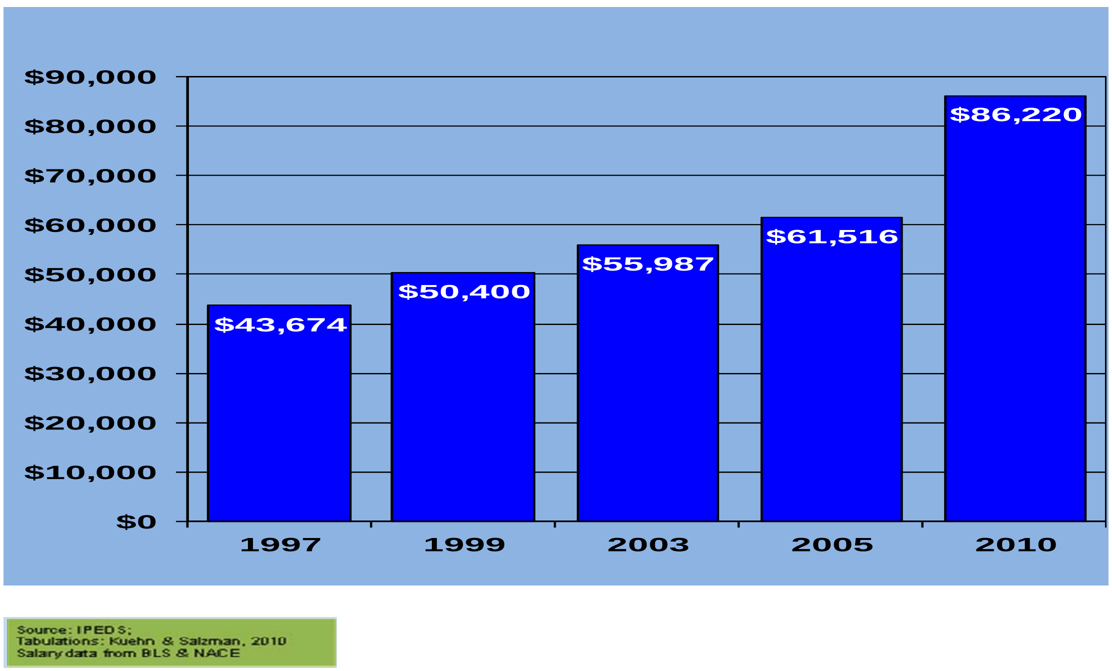
A second case is that of petroleum engineers. In the 1970s, the building of the Trans-Alaskan Pipeline and increased oil exploration in other regions led to rapidly increasing demand for petroleum engineers. By 2002, the Occupational Outlook forecast an employment decline "because most of the petroleum-producing areas in the United States already have been explored" (BLS, 2004) and this continued to be the forecast through the 2008 edition of Occupational Outlook. In the most recent edition, 2010-11, however, the BLS forecast changed to an employment *increase* of 18 percent over the coming decade because "petroleum engineers increasingly will be needed to develop new resources, as well as new methods of extracting more from existing sources."[2] The shift to greater exploration followed the 2008 oil price spike, which also increased the returns to investments in types of oil extraction that were previously cost-prohibitive (e.g., tar sands), thus increasing the demand for petroleum engineers, especially those with new skill sets

In terms of employment, however, the job openings began to exceed the number of graduates around 2002, even though there was no overall workforce growth. This was because of retirements. In some interviews with managers in oil companies, we found high levels of concern about the large cohort of retiring engineers just as they were launching large development and maintenance projects. This underlying demand was then exacerbated by the oil price spike, which intensified exploration efforts, in part because higher oil prices would make previously unprofitable exploration profitable. The earlier shortage had already led to increases in starting salaries, but with the oil price spike, petroleum engineering starting salaries rose further, becoming the highest

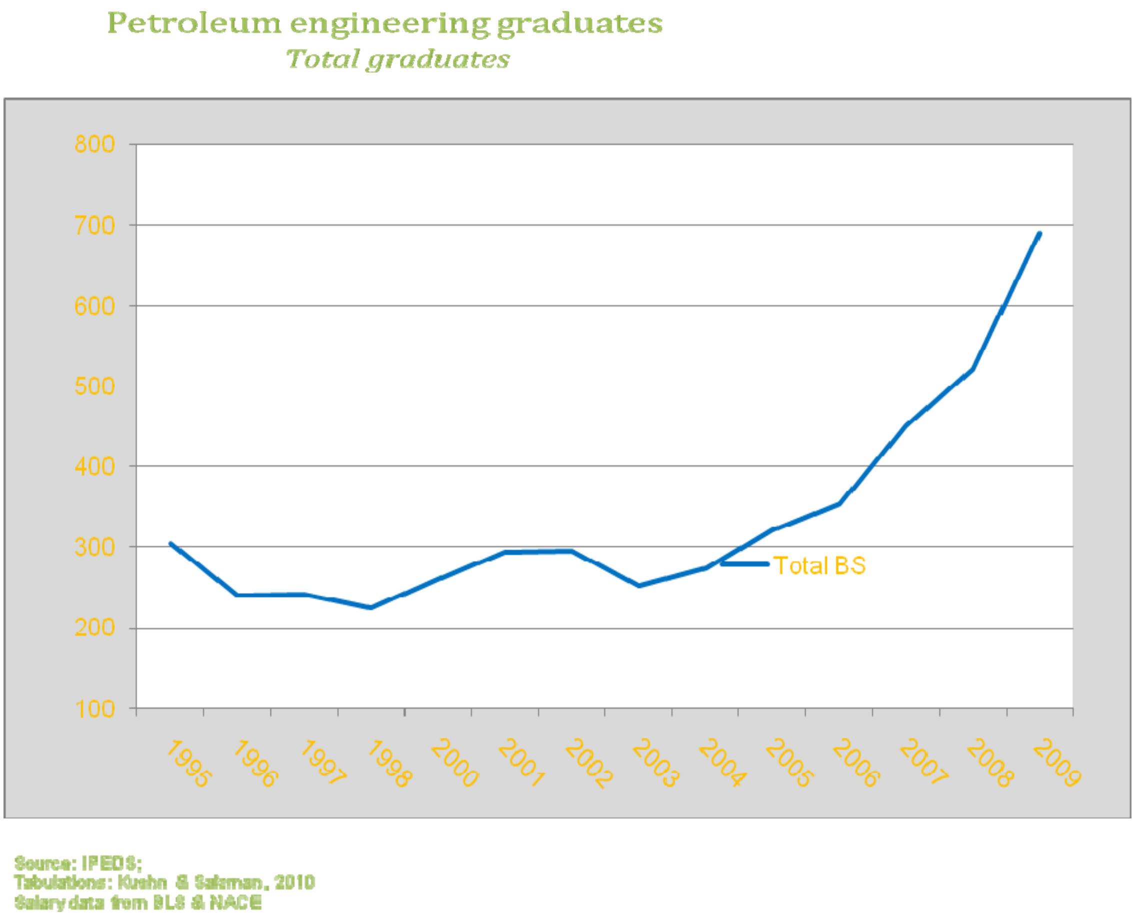
[2] (http://www.bls.gov/oco/ocos027.htm)

of all fields of engineering for new bachelor's degree graduates (National Association of Colleges and Employers, 2010). Starting salaries jumped from an already high $43,674 in 1997 to $50,400 in 1999. Starting salaries rose further to $55,987 (Bureau of Labor Statistics, 2004) in 2003, $61,516 in 2005 (Bureau of Labor Statistics, 2006), and $86,220 in 2010 (National Association of Colleges and Employers, 2010). In all these years, petroleum engineering salaries were higher than other engineering salaries but, until recently, the petroleum engineering starting salary premium was small. For example, the 1997 $43,674 starting salary for petroleum engineers was only marginally greater than that for the second highest paid engineering field, chemical engineers, who received an average starting salary of $42,817. In 2010, however, the starting salary of $86,220 for petroleum engineers was much higher than that of the second highest field, still chemical engineering, which was only $65,142 (National Association of Colleges and Employers, 2010).

Petro(B.S.) Engineers Starting Salaries 1



The result of rapidly increasing starting salaries was that the number of graduates more than doubled over four years. Reports from some petroleum engineering programs show an even greater increase in demand in the past two years (TTU, 2010). As shown in Figure 6, the dramatic increase in petroleum engineering following a steep rise in starting salaries, which in turn reflected an observable increase in industry demand, is a textbook case of efficient and responsive market functioning. While unremarkable in one respect (i.e, that supply increased in response to demand as expressed through increases in price), it stands as a notable case given the calls for government intervention to alter engineering labor markets. The evidence from this case of petroleum engineers shows industry can use normal market mechanisms, namely wage increases, to rather dramatically and quickly increase supply.

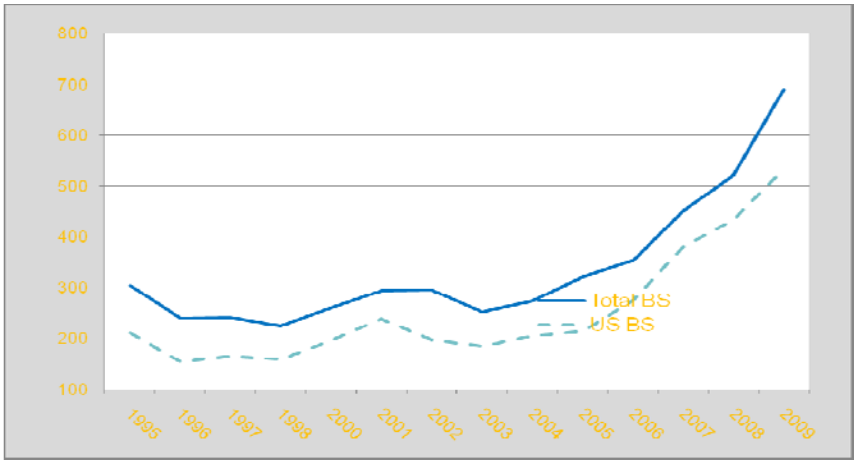


Guest workers: Are foreign students and workers sought to address workforce shortages or high wages?

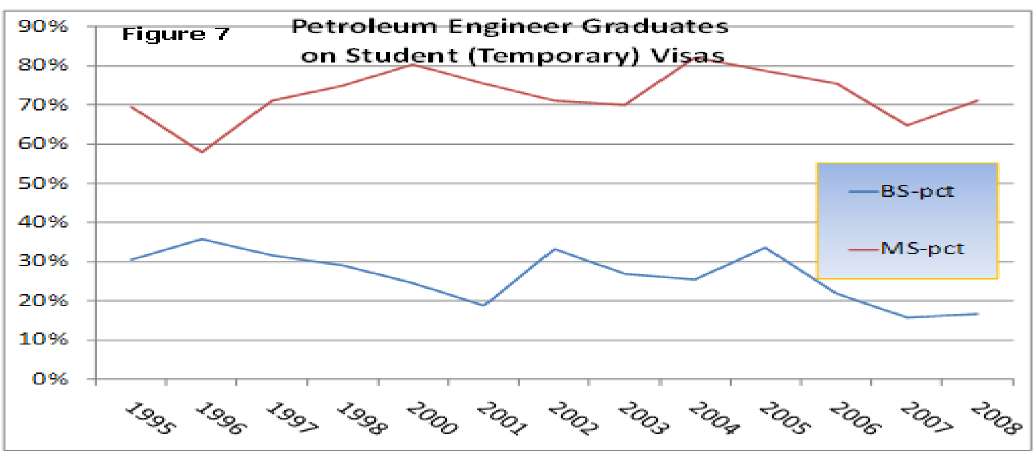
A key claim is that the U.S. S&E workforce is dependent on foreign students and workers because it is not possible to find sufficient domestic supply. However, when we examine the dramatic increase in petroleum engineering graduates we find that, interestingly, it is not just the overall supply of petroleum engineering graduates from colleges that appears to be responsive to demand and wages, but it is the domestic supply (U.S. citizens and permanent residents) in particular that supplies the increased pool of graduates. As wages increase and job demand in the United States increases, there is a shift in the relative share of domestic and foreign students in the graduating pool; the percentage of foreign petroleum engineering graduates in the U.S. on student visas, the highest of any of the engineering fields at the bachelor's level, declines as the domestic supply increases (Figures 7 and 8). At the Bachelor's level, the number and percent of total graduates who are on student visas dropped to the lowest proportion of total graduates in the past 15 years. The share of graduates on student visas dropped from slightly more than half of the proportion from 13 years ago (17 percent in 1995 vs. 31 percent in 2008; though the actual number of student visa graduates increased or held steady). The increased demand was largely satisfied by American students.

Petroleum engineering graduates

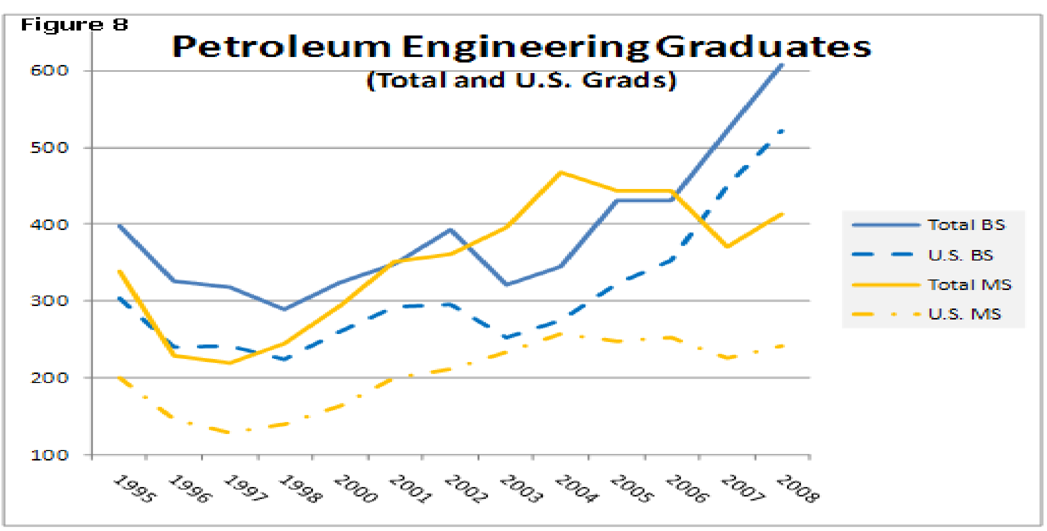
Total and U.S. [citizen & perm. resident] grads



Source: IPEDS;
Tabulations: Kuehn & Salzman, 2010
Salary data from BLS & NACE



[Source: IPEDS; Tabulations: Kuehn and Salzman]



The other component of the argument that more graduates are needed is the argument that we need foreign workers to expand our workforce supply. In particular, the H1B visa program is viewed as crucial to adding to the U.S. workforce in the IT sector. Critics of this program argue that it is merely a guestworker program that functions to lower salaries and generally serves as a Federal government industrial policy that undermines the normal functioning of the labor market (i.e., as a market in which demand and supply determine wages and labor force size). Since the H1B program is a temporary visa program with a six year limit, it is not the ideal mechanism to expand the labor force to meet long-term shortages. The green card, which grants permanent residency is, however, one means of meeting longer term workforce needs. Though not the perfect natural experiment to test competing claims about whether the H1B is a guestworker program that serves as a government policy intervention into the labor market or whether it is providing needed workers that can't be found through unfettered labor markets, an analysis of H1B visas conducted by Ron Hira of RIT does provide some useful evidence. Hira looked at the rate at which companies sponsored H1B visa holders for green cards as an indication of whether companies were seeking to expand their workforces or merely viewed it as a guestworker program without seeking a longer term workforce expansion. His findings are quite striking: there is a dramatic segmentation of companies using H1B visas into those who appear to be seeking long-term workforce expansion and/or searching for the "best and brightest" to add to their workforce and those who seem to be using the H1B visa program as a guestworker program, in which limited tenure serves their workforce strategy (see Table). These data are consistent with other research finding that the H1B visa program is part of a business strategy for at least some IT business segments to rely on government policies to create a guestworker programs to facilitate offshoring and lower labor costs (e.g., Hira, 2010; Salzman and Biswas, 2001)

Immigration yield for Top 10 H-1B employers:
FY07-09 (From Hira, 2010)

H-1B Rank	Company	H-1Bs FY07-09	Greencard Apps FY07-09	Immigration Yield
5	Tata	2,368	0	0%
3	Satyam	3,557	37	1%
2	Wipro	7,216	125	2%
10	Accenture	1,396	28	2%
1	Infosys	9,625	476	5%
9	Intel	1,454	163	11%
8	IBM	1,550	382	25%
6	Deloitte	1,896	588	31%
7	Cognizant	1,669	702	42%
4	Microsoft	3,318	2,214	67%

Source: DHS USCIS: Initial H-1B I-129 Petitions FY07-09 & PERM Data FY07-09/ Ron Hira RIT, 2011.

Conclusion: Market response vs. market distortion

In summary, this evidence suggests that concerns about the supply of engineers, and/or concerns about the ability of U.S. schools to provide an adequate supply of students with the qualifications to become engineers in response to demonstrated demand, are ill-founded. Colleges appear to have been quite able to increase their production of IT and engineering graduates (and domestic students) when there is sufficient market demand and incentives, at least in the cases of computer/information sciences and petroleum engineers.

If the U.S. does need to have more engineers creating new technologies and jobs, why doesn't our current economy demand more engineers? Where is the evidence that employers have tried to use market mechanisms to attract more engineers and have failed to do so? It would seem that such a test should be required before calling for government policies that alter labor market dynamics. Otherwise, if there is government intervention in labor markets to dramatically increase the number of engineers graduating each year without concomitant increases in demand, fewer will find engineering jobs. Those who do will get lower salaries. The U.S. technology system will be damaged in the long run as future cohorts are discouraged from pursuing an engineering education.

Perhaps, before we worry unduly about how many engineers we are graduating, we need to worry about how many our economy can productively employ. We need to worry about why many engineering graduates are unable to find jobs in engineering, and what signals that sends to current students deciding what careers to pursue. Perhaps our economy cannot productively use many more engineers than we are now educating. Or perhaps we have a shortage of engineering graduates with the skills that make them valuable to firms and effective as entrepreneurs. Before making any dramatic changes in our supply of engineers, we need a better understanding of the demand side of the equation. Otherwise, we risk unintended outcomes that can distort labor markets and the attractiveness of these fields for years to come. The boom–bust cycle of engineering employment following Sputnik made engineering an unattractive career opportunity for many years following the dramatic employment declines in the late 1960s and through the 1970s (Kaiser, in preparation; Freeman, 1976). More recently, the expansion of science doctorates has led to a decline in the appeal of those degrees to prospective students (Teitelbaum, 2008). Conversely, the tight control over the number of medical degrees offered in the United States has kept that field highly desirable to qualified young people, but at the cost to society of physician shortages. Thus, while restricting the number of degrees may come at an immediate social cost of shortages, artificially inflating the numbers, and thus distorting the market, ultimately devalues the longer-term attractiveness of the profession and exacts a high social cost as well.

The lessons learned from past decades of demand and supply in the science and engineering labor market are that disequilibria have significant consequences and that market-driven adjustments seem to occur reasonably well, albeit with a short lag given the years of preparation needed before workforce entry (Freeman, 1976; Teitelbaum, 2008).

REFERENCES

Bureau of Labor Statistics (1996) *Occupational Outlook Handbook*, 1996-97, UM-St. Louis Libraries Edition, derived and modified by Raleigh Muns July 20, 1996, from http://stats.bls.gov/ocohome.htm

Bureau of Labor Statistics (1998) *Occupational Outlook Handbook*, 1998-99, UM-St. Louis Libraries Edition, derived and modified by Raleigh Muns April 14, 1998, from http://stats.bls.gov/ocohome.htm

Bureau of Labor Statistics (2004) *Occupational Outlook Handbook.* 2004-05 ed. United States Department of Labor.

Bureau of Labor Statistics (2006) *Occupational Outlook Handbook.* 2006-07 ed. United States Department of Labor.

Bureau of Labor Statistics (2010), *Occupational Outlook Handbook, 2010-11 Edition*, Engineers, on the Internet at http://www.bls.gov/oco/ocos027.htm (visited *January 15, 2010*). U.S. Department of Labor.

College Board (2006) "Table 2: Mean SAT Scores of College-Bound Seniors, 1967-2006" http://www.collegeboard.com/prod_downloads/about/news_info/cbsenior/yr2006/table2-mean-SAT-scores.pdf

Council on Competitiveness (2004). *Innovate America*. Washington, D.C.: Council on Competitiveness.

Farrell, Diana, and Andrew Grant (2005). "China's Looming Talent Shortage." *McKinsey Quarterly* No. 4, p. 72

Flecker, J. and Meil, P. (2011) "Organisational restructuring and emerging service value chains - implications for work and employment," In*: Work Employment & Society* January 6, 2011 vol. 24 no. 4 680-698.

Freeman, Richard B. (1976). "Cobweb Model of the Supply and Starting Salary of New Engineers." *Industrial & Labor Relations Review*, Vol. 29, no. 2, pp. 236-248.

Gereffi, Gary, Vivek Wadhwa, Ben Rissing, Ryan Ong (2008) "Getting the Numbers Right: International Engineering Education in the United States, China, and India" Journal of Engineering Education

Gomory, Ralph E., and William J. Baumol (2000). *Global Trade and Conflicting National Interests*. Boston: Massachusetts Institute of Technology.

Hill, Christopher T. (2007). "The Post-Scientific Society" *Issues in Science and Technology*, Fall.

Hira, Ron (2010) "Bridge to Immigration or Cheap Temporary Labor? The H-1B & L-1 Visa Programs Are a Source of Both" Economic Policy Institute, Briefing Paper, #257

Hira, R. and Hira, A. (2005). *Outsourcing America*, New York; Amacom.

Kaiser, David (in preparation) *American Physics and the Cold War Bubble*. Chicago: University of Chicago Press.

Lowell, B. Lindsay, and Harold Salzman (2007). "Into the Eye of the Storm: Assessing the Evidence on Science and Engineering Education, Quality, and Workforce Demand." Paper presented at the annual meeting of the Association for Public Policy Analysis and Management, Washington, D.C.

Lowell, B. Lindsay, Harold Salzman, Hamutal Bernstein, and Everett Henderson (2009). “Steady as She Goes? Three Generations of Students through the Science and Engineering Pipeline.” Paper presented at the annual meeting of the Association for Public Policy Analysis and Management, Washington, D.C.

Lowell, B. Lindsay, Harold Salzman, Hamutal Bernstein, and Renato Busquets (forthcoming) “Career Attrition Among Scientists And Engineers: Comparing Demographic Groups And Fields Of Education, 1993 And 2003” Working Paper.

Lynn, L. and Salzman, H., (2002), “What makes a good engineer? U.S., German and Japanese perspectives.” *Proceedings of the European Applied Business Research Conference.* Rothenburg, Germany. June

… (2004). “Third Generation Globalization: The New International Distribution of Knowledge Work”, in *The International Journal of Knowledge, Culture and Change Management*, 4, pp. 1511–1521. Republished in J. Westover (ed.), *Globalization, Labor, and the Transformation of Work*.” Common Ground: 2010.

… (2006). “Collaborative advantage” *Issues in Science and Technology*, Winter” 74-82.

… (2007). “‘Innovation Shift’ to the Emerging Economies: Cases From IT and Heavy Industries.” *Sloan Industry Studies* (Occasional Paper WP-2007-22)

… (2009). “The ‘New’ Globalization of Engineering: How the Offshoring of Advanced Engineering Affects Competitiveness and Development.” *Economics, Management, and Financial Markets*, Vol. 4, no. 1.

… (2010), “The globalization of technology development: Implications for U.S. skills policy,” *A US Skills System for the 21st Century: Innovations in Workforce Education and Development* Finegold, D., M. Gatta, H. Salzman, S. Shurman (Eds.) LERA Research Volume, 2010

Lynn, Leonard, Pamela Meil and Hal Salzman (forthcoming) “Forging new links in the global technology system: cases from China and India” *Journal of Asia Business Studies.*

Meiksins, P. and Smith, C., (1996), *Engineering Labor: Technical Workers in Comparative Perspective*, Verso, London.

Meil, P. and Salzman, H. (2010) “Technology Entrepreneurs in India,” in Lynn, L. and Salzman, H. (eds.). (2010b) *Technology Entrepreneurs in the Emerging Economies: The new shape of global innovation.* Northampton, MA**:** Edward Elgar Publishing

National Academies of Sciences (2007). “Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future.” Washington, D.C.: Committee on Science, Engineering, and Public Policy. National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies. The National Academies Press.

… (2010). Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5. Washington, D.C.: Committee on Science, Engineering, and Public Policy. National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies. The National Academies Press.

National Association of Colleges and Employers (2010) *Fall Salary Survey* http://www.naceweb.org/Home.aspx

National Association of Manufacturers (2005). *The Looming Workforce Crisis*. Washington, D.C.: National Association of Manufacturers.

National Science Board. (2010a). *Science and Engineering Indicators 2010*. Arlington, VA: National Science Foundation.

… (2010b). *Globalization of Science and Engineering Research: A Companion to Science and Engineering Indicators 2010*. Washington, D.C.: National Science Foundation.

Organisation for Economic Co-operation and Development (2003). *Problem Solving for Tomorrow's World: First Measures of Cross-Curricular Competencies from PISA 2003*. Paris: Organisation for Economic Co-operation and Development.

… (2004). *Learning for Tomorrow's World: First Results from PISA 2003.* Paris: Organisation for Economic Co-operation and Development.

Organisation for Economic Co-operation and Development (2006). *PISA 2006: Science Competencies for Tomorrow's World Report*. Paris: Organisation for Economic Co-operation and Development.
Porter, M., Takeuchi, H. and Sakakibara, M. (2000). *Can Japan Compete?* New York: Perseus Press.

Rothstein, Richard (1998). *The Way We Were? The Myths and Realities of America's Student Achievement.* New York: Century Foundation Press.

Salzman, Harold (2000). *The Information Technology Industries and Workforces: Work Organization and Human Resource Issues.* Report for the National Academy of Sciences Committee on Workforce Needs in Information Technology.

Salzman, Harold (2007). "Globalization of R&D and Innovation: Implications for U.S. STEM Workforce and Policy, Testimony before the U.S. House Subcommittee on Technology and Innovation." Statement submitted to the Subcommittee on Technology and Innovation of the Committee on Science and Technology, U.S. House of Representatives.

Salzman, Harold, and Radha Roy Biswas (2000). *The Indian IT Industry and Workforce*. Report for the National Academy of Sciences Committee on Workforce Needs in Information Technology.

Salzman, Harold, and Lindsay Lowell (2008). "Making the Grade." *Nature*, Vol. 453, pp. 28-30.

Salzman, Hal and Leonard Lynn (2010) "Engineering and Engineering Skills: What's really needed for global competitiveness" Paper presented at: Association for Public Policy Analysis and Management Annual Meetings November 4, 2010 Boston, MA.
http://policy.rutgers.edu/faculty/salzman/EngineeringDemandSkills-SalzmanLynn2010APPAM-vx.pdf

Sheppard, Sheri D., Kelly Macatangay, Anne Colby, William M. Sullivan, Lee S. Shulman (2008) *Educating Engineers: Designing for the Future of the Field* San Francisco: Jossey-Bass.

Teitelbaum, Michael. 2008. "Structural Disequilibria in Biomedical Research" *Science*, Vol 321, 1 August 2008

Walker, Joe (2010). "Engineering Grads Earn the Most." *Wall Street Journal*, March 12, 2010, <http://online.wsj.com/article/SB10001424052748703625304575116170339369354.html?mod=djemPJ_t>.

Wadhwa, Vivek (2010). "The Global Innovation Migration." *Business Week*, March 9, 2010.