RUTGERS
THE STATE UNIVERSITY
OF NEW JERSEY

SOAR Scholarly Open Access at Rutgers

SOAR showcases Rutgers scholarship and makes it freely accessible to the world

The 'New' Globalization of Engineering: How the Offshoring of Advanced Engineering Affects Competitiveness and Development

Rutgers University has made this article freely available. Please share how this access benefits you.
Your story matters. [https://rucore.libraries.rutgers.edu/rutgers-lib/46552/story/]

This work is the **VERSION OF RECORD (VoR)**

This is the fixed version of an article made available by an organization that acts as a publisher by formally and exclusively declaring the article "published". If it is an "early release" article (formally identified as being published even before the compilation of a volume issue and assignment of associated metadata), it is citable via some permanent identifier(s), and final copy-editing, proof corrections, layout, and typesetting have been applied.

Citation to Publisher Version: Salzman, Hal & Lynn, Leonard. (2009). The 'New' Globalization of Engineering: How the Offshoring of Advanced Engineering Affects Competitiveness and Development. *Economics, Management, and Financial Markets 4*(1), 11-46.http://www.addletonacademicpublishers.com/contents-emfm#catid142.

Citation to *this* Version: Salzman, Hal & Lynn, Leonard. (2009). The 'New' Globalization of Engineering: How the Offshoring of Advanced Engineering Affects Competitiveness and Development. *Economics, Management, and Financial Markets 4*(1), 11-46. Retrieved from doi:10.7282/T39P33C3.

Terms of Use: Copyright for scholarly resources published in RUcore is retained by the copyright holder. By virtue of its appearance in this open access medium, you are free to use this resource, with proper attribution, in educational and other non-commercial settings. Other uses, such as reproduction or republication, may require the permission of the copyright holder.

Article begins on next page

SOAR is a service of RUcore, the Rutgers University Community Repository
RUcore is developed and maintained by Rutgers University Libraries

OFFICIAL JOURNAL OF THE CONTEMPORARY SCIENCE ASSOCIATION • NEW YORK

Economics, Management, and Financial Markets

VOLUME 4 • NUMBER 1 • MARCH 2009

ADDLETON ACADEMIC PUBLISHERS • NEW YORK

THE ‘NEW’ GLOBALIZATION OF ENGINEERING: HOW THE OFFSHORING OF ADVANCED ENGINEERING AFFECTS COMPETITIVENESS AND DEVELOPMENT*

LEONARD LYNN
Case Western Reserve University
Leonard.Lynn@case.edu

HAL SALZMAN
Rutgers University
HSalzman@rutgers.edu

ABSTRACT. Changes in the strategies of multinationals and in the global distribution and movement of technologists have accelerated a “new” globalization of engineering. Field studies with our colleagues in China, Germany, India, Japan, Mexico, South Korea, the UK, and the U.S., lead us to consider in this paper aspects of the recent offshoring of advanced engineering to emerging economies. We examine the potential consequences for multinationals and their home countries of the new globalization of engineering, many of which are unintended, suggesting the need for greater attention by managers, government policymakers and scholars.

A generation ago the typical multinational (MNE) was vertically integrated and hierarchically organized. Key functions were headquartered in one of the triad economies of the U.S., Japan or Europe. In the case of technology development, for example, more basic R&D work might be conducted by central research laboratories, with more applied work done at triad production facilities. Some engineering activities were conducted in emerging economies, but these had little to do with the core engineering programs of the firm.

At a Whirlpool facility in India, for example, washing machines were redesigned to keep out rats, to survive shipment on bad roads, and to cope with power ebbs and surges in electrical current (*WSJ*, June 12, 2004). At an automobile plant in an emerging economy, we found, as part of our study, that engineering activities during this earlier period had consisted of such things as developing oil pans that could survive severely potholed roads. Engineering managers at an electronics firm we studied did not consider doing work on their more advanced technologies at a site in India because, until recently, there was no market in India for products based on the newer technologies, and no sense that India provided a viable export platform. Further, according to Indian law at the time the multinational could not own a controlling interest of the Indian subsidiary. Engineering teams in the emerging economies worked in relative isolation from their counterparts at triad facilities and provided little that was useful in the triad economies.

In the past decade, however, the geography of technology development has undergone profound shifts as multinationals disperse core activities, “unlocking” them from longstanding forms of organizational integration. Geographic embeddedness that, only a few years ago, seemed to confer unassailable advantages to areas such as Silicon Valley must be examined anew now that the “developing countries” are developing some of the world’s leading-edge technology. Triad multinationals are racing to shift cutting-edge work on cellular telephones and other aspects of telecommunications to China. They are moving software development and some pharmaceutical research to India. Advanced aerospace work is being done in Brazil. Increasingly, specialized firms in a variety of countries are providing key design and research services to multinationals (Lynn and Salzman, 2004). We call this the “new globalization of engineering.”

This ongoing transition represents an extraordinary “unlocking” of longstanding organizational forms. The reduction of international trade barriers and the development of new technologies allowing globally dispersed work on engineering have coincided with the push by firms to cut costs by dispersing engineering activities globally and the pull of growth markets in the emerging economies that requires new engineering and technology development, and offers the availability of highly skilled human resources. The result has been a massive transfer of technological capacity to the emerging economies. Although the transition is not yet complete, and its full ramifications are as yet poorly understood, it is clear that firms are undergoing profound organizational change. It is not just the magnitude of change but the change in how firms organize core activities that is remarkable.

This paper addresses the processes of organizational change and makes a preliminary analysis of the specific impact on engineering activities. Based on on-going field studies carried out at technology development sites in nine triad and emerging economies, we examine the nature of the transformation, and the factors that have converged to create and facilitate these changes. We conclude with an analysis of the possibilities and threats posed by this evolving pattern of global engineering, of where the boundaries might exist between change that is adaptive and change that risks the loss of control over essential functions.

The "dis-integration" of technology value chains

In the 1980s and 1990s, the key to success in the face of Japanese competition and Wall Street pressure was to unlock the organizational bonds that kept all manner of activities, from manufacturing screws to managing IT infrastructure, bound together in one firm. It was only necessary, according to management theorists, to keep "core competencies" locked up in order to achieve competitive advantage. Everything else could be dispersed to other firms and locales. In the U.S., the great downsizing and outsourcing movement led to fundamental changes in concepts of organization. Longstanding assumptions about how the firm should organize its activities gave way to new theories about efficient firm functioning, ranging from the virtual corporation to the networked firm (e.g. Askenas et al., 1995). Some segments of the workforce suffered from these new organizational models, by being downsized when the work left for low-cost areas or when the jobs were shifted to a low-wage firm, but the consensus among economists was that the nation, as a whole, benefited from the decrease in the cost of goods and the increase in productivity (e.g. Bhagwati, 2004). It was argued that the country was economically secure as long as the high value added work remained onshore, and firms would prosper as long as they kept tight control over their essential activity – in the case of manufacturers, the development of new products and processes, and marketing.

But in the latest phase of globalization, some firms are dispersing their core competencies around the globe, seemingly tempting fate by locating them in countries that may build on those activities to launch competitors. Some are even outsourcing R&D and design activities to firms in Taiwan and other countries. Is this just the next evolutionary step in organizational restructuring that continues a decades-old trend, leading to greater efficiency in the triad economies, as well as creating new economic opportunities to those hosting the new activities? Or is it becoming something entirely new?

In our study of engineering globalization, we find that the organizational change that led to corporate restructuring in the 1990s shifted the conceptual framework of what constitutes a "firm" and, combined with technology and population shifts, has become a disjunctive, or qualitatively new phase in organizational form and globalization. At the same time, in the history of firms that successfully made organizational transformations, often overlooked are the accounts of those firms that stumbled not because they didn't transform their organizations but because they "unlocked" too much, they gave away too much of the firm's functions and were unable to recover. Although the dominant focus of much management literature is on how organizations suffer because they resist change, it is also important to consider the risks of stumbling during organizational transformation, the dangers of making too many changes, or changes of the wrong type, that lead to failure.

It is often only in retrospect that the distinction can be drawn.

A well-known illustrative example is provided by IBM. As IBM developed the PC in the 1970s and 1980s the company decided to give up development of PC operating systems and microprocessors. These activities were taken over by Microsoft and Intel, respectively. IBM managers apparently believed that their special competency was the design and assembly of the PC itself combined with their marketing ability and brand name. It soon became apparent, however, that the strategic links in the value chain leading to the production of a PC were the operating system and the microprocessor. Microsoft and Intel, not the PC assemblers, were the only firms to consistently make a profit from the PC (Borrus and Zysman, 1997).

Our analysis of the profound changes underway in the organization of MNEs is within a framework of change occurring through the convergence of multiple factors over time, of an iterative process that occurs outside the explicit view of actors, and thus is not the result of a “strategy.” This model of the process of change follows the processes of structuration as developed by Giddens, and views organizational change and decision making as a process of experimentation, of often “stumbling” through change rather than a process of implemented and well-articulated planning (Ortmann and Salzman, 2002). How the unlocking of engineering within organizations occurred is the culmination of a decade of small changes in a number of different areas rather than a strategy that appeared fully formed to be implemented. Dispersed engineering may be launched as a cost cutting strategy but is now developing into a transformation of technology development strategies and of the role of different nations in the value chain.

In this paper we consider two aspects of the current organizational transformation and globalization of engineering work: (1) the antecedents to organizational change comprised of changes in population and migration dynamics, the policy and market changes in emerging economies, the technical and organizational changes in the practice of engineering, the changes in the capabilities of communication technologies, and the role of previous organizational changes in transforming conceptual models of the firm; and (2) the possible consequences, some unintended, of unlocking engineering from the core organization including, for example, the possible loss of capabilities by the firm and the implications of severing the ties between company and country.

The antecedents of organizational change and engineering globalization

The new globalization of core engineering activity by Multinationals is a very recent phenomenon, just beginning in most firms, and less than a decade old in the pioneering firms. This is the engineering that involves core product development, different from the localization engineering that has been conducted for many years. The new globalization of engineering is the result of a confluence of factors: in organizational models and engineering practice, in politics and national policies, in technology, and in migration. We consider, in turn, each of these factors and then the impact of their confluence to create a new stage of globalization, built on a new form of engineering organization.

Organizational changes and the globalization of the firm

Although MNEs have long had manufacturing facilities for local production in the newly emerging economies (NIEs), often because host governments required them to meet a specified level of domestic content to gain market access, core development activities were tightly controlled in the MNEs' home countries. The transformation of MNEs into true global firms began in a few firms such as ABB and GE a decade or more ago, but much more recently it has spread to most MNEs. In one of the MNEs we are studying, a manager remarked "ten years ago we were all strangers," referring to his globally distributed product development teams. This MNE has been multinational in its operations for decades, but the global distribution of its closely-knit engineering activities is relatively new.[1]

For many years it was thought that engineering and manufacturing had to be co-located, at least in the launch stages of most new product lines, and much longer for very sophisticated processes. Thus, the highest-level manufacturing that was tied to engineering was not located offshore. Even the companies that did develop strategies for running sophisticated manufacturing without high levels of direct engineering support, such as Intel in its "CopyEXACTLY!" method, were limited in the amount of offshoring they did (and Intel continued to build U.S. plants).

This new globalization of engineering often began at the bottom, starting with manufacturing and low value-added activities. As these activities became dispersed, engineering activities began to follow. For example, in one of our automobile cases, a German company tried to run its state-of-the-art manufacturing plant in Mexico by staffing it with German engineers. However, this turned out not to be feasible because the company couldn't retain enough German engineers in Mexico. Meanwhile both the products and the manufacturing processes required some local adaptation. The company turned to a local university to develop a manufacturing engineering program that could educate and train engineers to support this high-technology automobile plant. In another case, developed by our collaborator in Mexico, a French company producing automobile parts in Mexico found it needed to involve local engineers familiar with local conditions (such as low atmospheric air pressures at the high altitudes where the plant was operating) to address manufacturing problems (Acosta, 2004). The technology developed as a result, also proved useful in numerous other parts of the world.

Through this process, engineering capacity was transferred to remote locations. As a result both local engineering capacity and local human resources were developed. Thus, physical and human infrastructure was initially developed to support the manufacturing of leading-edge technology. The location of this high-end technology eventually led to the development of high level engineering capability.

From Closed to Open Systems:
The Transformation of Engineering Practice within MNEs

Engineering work in technology-focused firms has always been considered a core activity that had to remain tightly controlled within the home country location of a firm, and conducted within the boundaries of the firm. In a classic article on core competencies, Hamel and Prahalad (1996 and elsewhere) emphasize that firms should protect their core competencies at all costs by, for example, making sure they are difficult to imitate. This was a prevalent view at the time. For many years, firms sought to keep each key link of the value chain within their organization. A large literature notes that engineers are much more organizationally oriented than their counterparts in other professions (e.g. Meiksins and Smith, 1996). Perhaps as a consequence of this, engineering developed dominant practices consistent with this desire to keep all engineering activities within the firm.

Sometimes these efforts to protect technological competencies became dysfunctional. Some research in the 1980s concluded, for example, that an unwillingness to share technological information with venders, undercut the competitiveness of U.S. industry (Bolton et al., 1994; Lynn, 1982). U.S. firms in many industries developed the “Not Invented Here” syndrome, a tendency of engineers to invent, or reinvent, technology rather than buying or copying it from others. The conceptual framework and ingrained practices of engineering seemed to constrain designers from even considering the use of components designed outside of their firm.[2] For example, as late as the mid-1990s, companies producing very sophisticated medical electronics went so far as to design and produce the screws for their machines rather than buy them.

There were other reasons for MNEs to keep their advanced engineering close to home. In industries in which informal and tacit knowledge were important components of the engineering process, physical co-location was considered crucial for successful projects. Microsoft consolidates nearly all development in one physical location to facilitate knowledge transfer, typically even transferring staff of acquired companies to their Redmond campus.[3] In seeking access to basic science and technology, MNEs located major R&D activities near major academic institutions, especially in the United States, though also in Europe (Dalton et al., 1999). As a manager of software development at a firm in our study explained in an interview, “it was always thought that all the developers had to breathe the same air, be under the same roof.” Or, as expressed by a software executive: “Microsoft used to believe that development was a contact sport; "You needed people bumping into each other. In Redmond, you wanted your entire development team in the same building. Ideally, they'd be on the same floor." (Kirsner, 2005)

In the 1980s, in part because of the competitive challenge of the Japanese, U.S. and European firms began to rethink their organizational models. A feature of the Japanese system that attracted considerable attention was the trust-based enduring relationships between firms and their suppliers (e.g. Womack, et al., 1990; see Sydow, 2005, on the role of trust in ‘systems’). Japanese firms were portrayed as outsourcing many of their engineering functions to affiliated suppliers (the so-called “keiretsu”). Firms like Toyota were shown to be far faster than their U.S. counterparts at developing new products because from early on they involved suppliers in the design process (e.g. Clark and Fujimoto, 1991). In learning from the Japanese model, U.S. firms transformed it somewhat. The U.S. firms greatly increased the depth of their relationships with suppliers, but not to the extent of the Japanese. Conversely, the U.S. firms did not restrict their network of suppliers as tightly as the Japanese (keiretsu ties typically endured for decades and involved extensive long-lasting cross ownership of equity). Firms like GM and Ford spun off key divisions to create major new firms like Delphi and Visteon. Increasingly, the preferred model was to seek economies by allowing (and, as we learned in some of our interviews, sometimes coercing) suppliers to contribute to technological development.

When a component or activity was judged to be non-core, and thus was outsourced, that same component became a core competency of the firm to which it was outsourced. Naturally the sourcing companies sought to develop their own core competencies by engineering the component or the processes for manufacturing it. Increasingly, contract manufacturers, to whom manufacturing activity had been outsourced, found they could expand their activities, and thus their business and profit levels, by providing higher-levels of manufacturing that was engineering-dependent, at lower cost than the OEMs, creating more pressure for the OEMs to buy, rather than make, more and more component parts.

Through this accretion of engineering, these sourcing companies grew their engineering activities and sometimes were able to expand their scope of product supplied to OEMs (this was observed in several of our cases, particularly in the growth of suppliers in NIEs, as will be discussed below).[4] In tandem with these developments were technology shifts in the materials and production technologies used. Additionally, previously unrelated technologies (such as mechanical and electronic) were being brought together in new ways. These developments required the increasing use of cross-disciplinary and cross-boundary engineering teams (Lynn and Salzman, 2004).

As suppliers expanded the scope of their engineering activity, to transform their components from commodities to “engineered” products, there was a new emphasis on strategic alliances. MNEs increasingly relied on OEMs and ODMS in East Asia and elsewhere (Hobday, 2000). Finally, the internet boom and IPO wealth possibilities motivated a number of the best technology and management people to become technology entrepreneurs rather than building careers within large firms. Often the goal was to sell their new technologies to a large firm. The concurrent shift in strategy by major U.S. MNEs to outsource more and more of their technology development helped fuel this trend.

In sum, there was a conceptual shift, beginning with a reconsideration of where the firm added maximum value in developing and making its product. At the most basic level, many component parts were identified as commodity parts where proprietary content did not result in high value added. Engineers pressured by management began to evaluate greater numbers of component parts for their "criticalness" to the proprietary characteristics of the product and the value of in-house design.

These developments led to a re-conceptualization of organizational boundaries (Askenas et al., 1995). Organizational dispersion began with lower level activities, but slowly changed the framework of what an organization is and how activities can be coordinated (e.g., leading to new theories ranging from networked organizations to "hollow firms"). Along with these changes in the technology strategies of MNEs, other important changes were taking place in the relative attractiveness of locations for technology development.

Rethinking geographical lock-in: clusters and regional advantage

Until very recently, innovation and high value-added activity were considered to be the sole province of the triad. Indeed, for some technologies, such as software in Silicon Valley and biotech in California and Massachusetts, it seemed that technology development could effectively be accomplished only in certain regions of the industrial nations. Despite widespread efforts around the world to duplicate innovation clusters, most have so far not been notably successful (the Technopolis programs in Japan, for example, are generally regarded as having been disappointing). Researchers have posited theories about the organic nature of innovation regions due to historical circumstances, path dependencies, unique characteristics that supported a “triple helix” of institutional supports (Etzkowitz and Leydesdorff, 2000), and other factors that led to “geographical stickiness” of this activity[5]. The triad nations, as a matter of policy, viewed the world as highly bifurcated: competition for high value-added work and innovation was a race only amongst the triad nations, and other countries weren’t in the running. There was a global hierarchy in which lower-level (and lower value-added) activities were shed off to NIEs. The NIEs were thought to be limited in their ability to host higher level engineering and innovation activities because of the weaknesses in their infrastructure, human resources, and national policies. The impacts of the advanced global technology systems were mixed for the NIEs. These nations received generally obsolete technology, and in return sent their most talented young people to the triad nations for higher education and work opportunities

Now we are beginning to see trends that may pose challenges for the triad innovation regions. Countries such as China and India are beginning to develop and expand strong research-oriented universities. Indeed, Peter Drucker recently speculated that the medical school in New Delhi may be the best in the world (*Fortune* 2004). In interviews with global engineering managers at an electronics MNE, we were told that engineering graduates from the top technical universities in India were equivalent to the best graduates at major U.S. engineering schools (they said the same is not yet true in China, but that it may be before long). Technological entrepreneurs and financiers from NIEs are beginning to go home, after acquiring intimate knowledge of the functioning of triad innovation regions. For a variety of reasons there have been sharp declines in the numbers of NIE students coming to the U.S. for an education in science and technology.

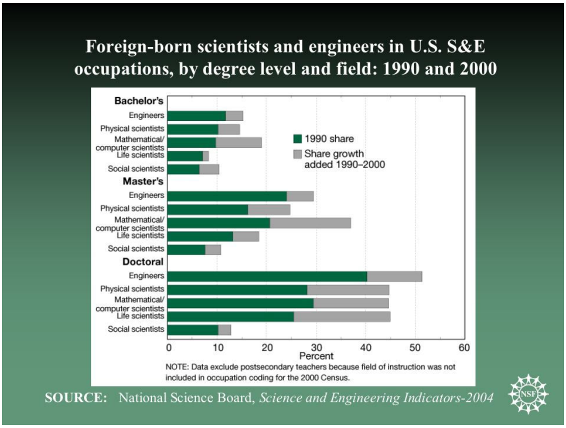
The recently-established “know-how clusters” near Hangzhou and Suzhou, China where such MNEs as General Electric, Samsung, and Philips have established research facilities, are among a number of clusters that are developing in the NIEs, involving firms and universities supported by local government policies, may be developing as rivals to geographic clusters in the triad nations. With our colleagues in China, we have been studying an emergent Chinese MNE that has developed in one of these areas, and now has sites in the United States and Europe. We have also studied an emergent Mexican multinational. This firm used the opportunities provided by NAFTA to become a major supplier of automotive components. It took advantage of a wave of downsizing at multinational auto assemblers and suppliers to acquire high-level engineering talent. It now has engineering facilities in the U.S. and other countries. Our colleagues in China, Mexico, and South Korea are examining other entrepreneurial spin offs in their countries.

We are also finding that, at least for some technologies, geographical proximity is less important now than it was in the past. New electronic communications technologies make it possible to coordinate engineering development on a global basis. We have visited sites at one MNE in the U.S. and China, where a number of projects have adapted global products for the Chinese market, but where products for global markets are also being developed. We are examining how this MNE has coped with a number of challenges, ranging from time differences to unexpected restrictions on travel after the SARS epidemic. A vice president at a chemical MNE in our study explained how the firm no longer needs to send U.S. engineers on long-term assignments to work on global projects. Several engineering managers in a group interview at an electronics MNE found that as global teams get to know each other better, there is less need for exchange.

Organizations not only determine the behavior of those who work for them, but also are influenced by broader trends in the populations that provide their employees. Science and technology human resource trends in both the triad (especially the United States) and emerging economies are shaping the globalization of technology development in very significant ways.

In the 1990s, immigrant in-flows into U.S. science and engineering higher education and the U.S. workforce increased dramatically. Meanwhile, flows of domestic students into these areas remained flat or even declined. Although the prevailing view is that poor American student math and science achievement was responsible for the decline in the domestic supply of science and engineering students, it has also been convincingly argued that poor job quality/career prospects and more appealing opportunities in other areas such as law and finance played a significant role (Teitelbaum, 2003). Whatever the cause, the result was a dramatic increase in the immigrant share of the U.S. S&E workforce, particularly of those with advanced degrees (see Figure 1).

Figure 1



Foreign-born scientists and engineers in U.S. S&E occupations, by degree level and field: 1990 and 2000

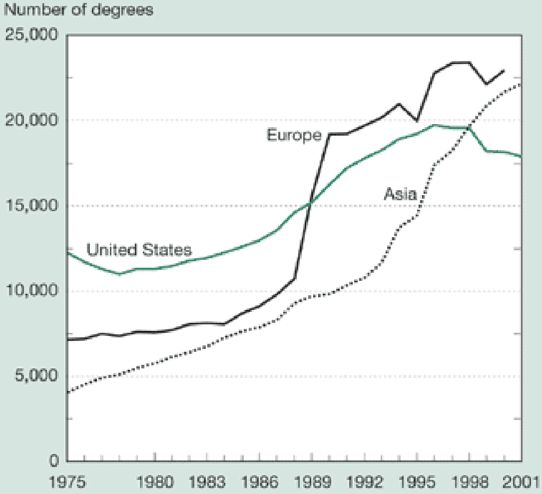
NOTE: Data exclude postsecondary teachers because field of instruction was not included in occupation coding for the 2000 Census.

SOURCE: National Science Board, *Science and Engineering Indicators-2004*

Figures 2 & 3

Figure 2-38

NS&E doctoral degrees in United States, Europe, and Asia: 1975–2001



NS&E natural sciences and engineering

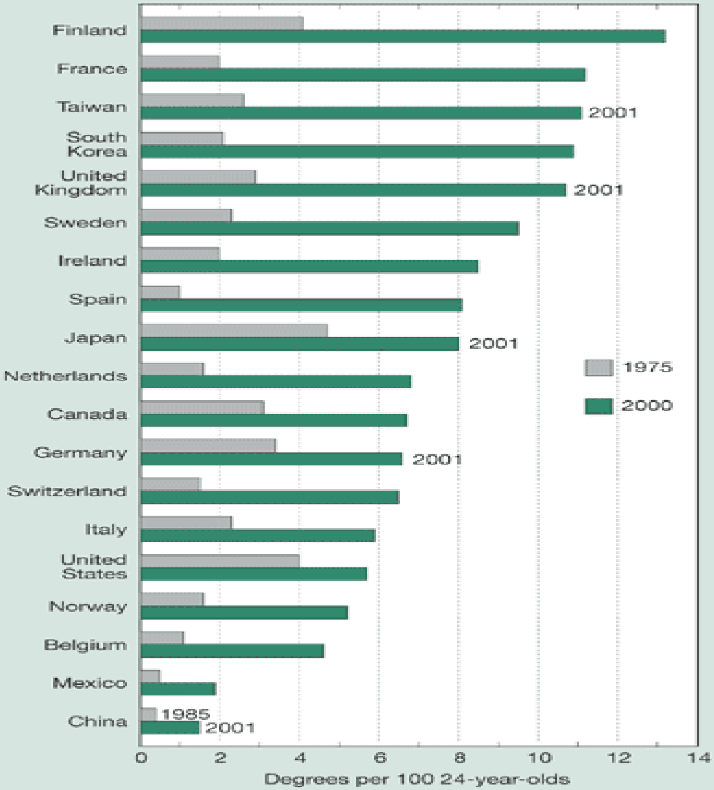
NOTES: NS&E includes natural (physical, biological, earth, atmospheric, and ocean sciences), agricultural, and computer sciences; mathematics; and engineering. Europe includes only France, Germany, and the United Kingdom. Asia includes only China, India, Japan, South Korea, and Taiwan. The jump in the European data in 1989 is due to the inclusion of French data, which were unavailable in this data series before 1989. French data are estimated for 2000.

SOURCES: France—National Ministry of Education and Research, *Rapport sur les Études Doctorales;* Germany— Federal Statistical Office, *Prüfungen an Hochschulen;* United Kingdom—Higher Education Statistics Agency, special tabulations; China—National Research Center for Science and Technology for Development; India—Department of Science and Technology, *Research and Development Statistics;* Japan—Government of Japan, Monbusho Survey of Education; South Korea—Ministry of Education, *Statistical Yearbook of Education;* and Organisation for Economic Co-operation and Development, *Education at a Glance 2002;* Taiwan—Ministry of Education, *Educational Statistics of the Republic of China;* and United States—National Science Foundation, Division of Science Resources Statistics, *Science and Engineering Doctorate Awards*. See appendix tables 2-26, 2-38, and 2-39.

Science & Engineering Indicators – 2004

Figure 2-34

Ratio of first university NS&E degrees to 24-year-old population, by country/economy: 1975 and 2000 or most recent year



NS&E natural sciences and engineering

NOTES: NS&E includes natural (physical, biological, earth, atmospheric, and ocean sciences), agricultural, and computer sciences; mathematics; and engineering. The ratio is the number of earned degrees in these fields per 100 24-year-olds.

SOURCES: Organization for Economic Co-operation and Development, *Education at a Glance 2002;* and national sources. See appendix table 2-33 for most recent data.

Science & Engineering Indicators – 2004

The workforce expansion was largely fueled by the increase in foreign-born graduates of U.S. universities, particularly at the graduate levels (see Figure 1). Within the past five years or so, there has been a sharp increase in the educational science and engineering capacity in emerging economies (see Figures 2 and 3; note that although the percentage attaining university degrees in China is small, the population is so large that China is producing a very large number of graduates). Importantly, unlike the U.S., some of the Western European countries substantially increased their domestic supply of S&E human resources.

The combined effect of these trends over the past decade has been a steady rise in the number of foreign-born scientists and engineers occupying management positions in U.S. multinationals. Unlike European firms, which had an expanding or at least steady supply of domestic engineers and managers, U.S. firms were increasingly populated by foreign-born workers and these firms appeared to integrate foreign-born personnel throughout their ranks.

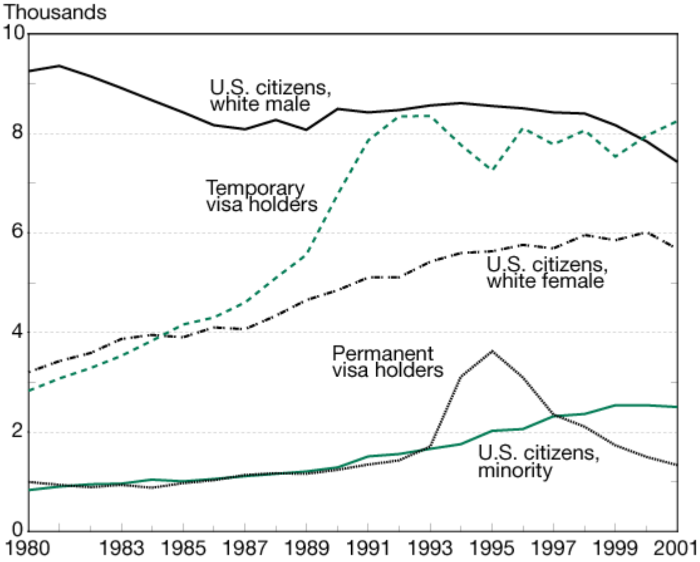
It is important to note, however, that it is not just U.S. firms that are developing "global managers." Our research finds that as firms expanded their reach around the globe, they began to develop a cadre of managers who had experience managing outside the firm's home country. One, large European firm began in late 1990s to make international experience part of management development, with the expectation that all senior managers would have spent some time working outside of their home country. Honda of Japan has also done this. In fact, we find that, typically, domestically-born managers in non-U.S. firms are more "international" in terms of languages spoken and cultural experiences than their U.S. counterparts. However, in the cases we have studied, U.S. firms integrated foreign managers into their highest level positions, particularly in the home country office, to a much greater extent than European or Japanese firms (despite the high profile foreign CEO at Nissan and, recently, at Sony).

This difference may have historical roots in the culture and experiences of each country (e.g., the U.S. has long been a country of immigrants), but it was the immediate supply of personnel that appears to have had the most direct effect in changing the composition of personnel.

The high influx of immigrants into the science and engineering fields in U.S. universities (with a third to nearly a half of all engineers and computer science students enrolled in U.S. graduate programs coming from outside of the U.S.) infused firms with staff who were familiar with NIEs. In our study, an electrical equipment manufacturer that was relatively early to establish higher-level manufacturing and engineering facilities in China reported two factors that helped them recognize the potential advantages of locating in China, and to assess the risks. One factor was the CEO's experience as a manager in Asia. The other was the presence of a senior Chinese engineering staff member who had gone to graduate school in the U.S. Firms initiating the movement of IT work to India were often led to the opportunities there by employees who were Indian nationals. These were managers who could bridge the two cultures. They had assimilated into the MNE at its home country, and had local knowledge of India. Among the "U.S." managers we have interviewed at MNEs, some were originally citizens of China, Egypt, and India.

By comparison, in one European firm that had established production operations and some engineering activities in Mexico, all of the senior managers in Mexico were from the company's home country. The Mexican engineers believed that the firm's executives and governing board would not consider a non-European for a high-ranking management position.

Figure 4: S&E doctorates earned by U.S. citizens and non-citizens: 1980–2001 (NSF mmo-21)



Source: NSF Science & Engineering Indicators 2003

Some preliminary observations

We believe our research is pointing toward three sets of conclusions: first that the new globalization of engineering is likely to have a series of unanticipated consequences that may be unfavorable for MNEs, the triad nations, and possibly others. Second, that while some of these consequences are suggested by theory, in some cases current theoretical concepts may prove to be no longer relevant. Finally, we also conclude that there are many signs of more positive outcomes of the new globalization of engineering that go beyond the possible reduction in global inequalities.

Unintended consequences of the new globalization of engineering

In our descriptive analysis of the extension of the globalization of higher level engineering to include emerging economies, we have noted the role of multiple factors, the iterative process of change over time, and the interactions between these different factors. Although the multinational corporations are major actors in our analysis, we do not see corporate strategies as having been particularly important. It is not as though corporate leaders articulated a strategy of locating engineering activities in emerging economies, or even that such strategies came up from middle management in accord with corporate values. Nor do we see the process as having been guided by reflective national and local political leaders in the triad or the emerging economies.

We see the triad MNEs as having come under increasing pressures to cut costs: first manufacturing costs and then, increasingly, engineering costs. These pressures have come from shareholders, customers and competitors. Wall Street has always demanded good quarterly financial results. Now retailers like Walmart are better able to demand low costs than ever before. MNEs are increasingly free to enter each others' markets, and are being joined by new MNEs from countries where production costs are lower. Use of the internet and new management analytic techniques make it easier than ever for MNEs to identify high cost links in value chains. The pressures are such that there seems little latitude to consider the longer-term ramifications to the cost-cutting frenzy.

In parallel fashion, as MNEs are "unlocking" their core engineering activities, policy-makers in the emerging economies recognize the opportunities, and are under increasing pressures to make themselves attractive hosts for the higher valued added activities of MNEs. The various political pressures by WTO agreements, and other policy changes that leave less latitude for emerging economies to control the behavior of the MNEs, are developing in tandem with the change in MNE actions. Policy-makers in the triad also have a diminished capacity to control events. They too face increased competition from other regions in both the Triad and elsewhere, and more restrictions on the policies they can follow.

Because of the perceived need for policy-makers and MNE leaders to act quickly, or risk losing out, there has been a kind of herd mentality. If other regions are aggressively seeking MNE foreign direct investment, or if other MNEs are aggressively locating engineering activities in emerging economies, it seems more prudent to reflexively do the same than to undertake an analysis of the longer term consequences of such actions.

As a result, we have argued, the globalization of engineering defies many taken-for-granted principles inherent in concepts/strategies and theories such as core competencies, geographical stickiness or embeddedness, communities of practice, or requirements for proximity for tacit knowledge exchange. This leads us to pose the question of whether or not the various actors might face a series of unintended consequences. These include the loss of key competencies by the MNEs, the unwitting creation of formidable new competitors, the "hollowing out" of Triad technology regions (if not, perhaps, of Silicon Valley itself, then of less prominent but still important regions), and the disinvestment in human resource and innovation capacity in the Triad. We first turn to a brief discussion of each of these issues that may involve costs to the Triad. We then discuss the positive implications of the inclusion of the emerging economies in the globalization of engineering by MNEs.

Loss of core competencies. As we have noted, two cost-cutting strategies that firms have vigorously pursued over the past decade have been the *outsourcing* of non-core work to other firms and the *offshoring* of some of their activities to countries with low labor costs. For lower value added work, primarily in manufacturing, the two strategies were often combined, for example, MNEs would transfer activities offshore to contract manufacturers.

The development of the Indian IT sector provides an example of the transfer of development capabilities via a combination of offshoring and overseas outsourcing. The Indian IT industry received its first boost by performing low-cost legacy and maintenance programming for triad firms. But, given the shortage and cost of labor in the triad during the IT boom, and the shortage of IT specialists as the world prepared for the Y2K problem, there was an explosion of demand. Given its talent base and the knowledge transfers that it had received through contracting and joint venture relationships, the Indian IT industry was able to develop higher skilled capabilities. The offshoring of work by U.S.-based IT firms to India had a similar consequence. Given the customer relationships they had built doing legacy work, and thanks to the flows of Indian IT professionals back and forth between India and the Triad nations, the Indian companies have been very successful at marketing their services directly to U.S. and European firms.

The surrender of certain competencies is not always harmful to the long term interests of the multinationals and their triad home countries. Indeed, it is often beneficial. Two decades ago GE lost its microwave design and manufacturing capabilities to Samsung and other lower cost foreign firms. GE was able to successfully respond by re-deploying its assets in more profitable areas. But when the spinning off of competencies is not thought out, or the firm is unable to respond nimbly, the results may turn out to be disastrous. Our concern is that there has been little strategic thought about the new globalization of engineering and the possible shifts in organizational focus may be more limited than in the past.

Triad automobile assemblers have increasingly outsourced systems of components to “tier one” suppliers. Generally the tier one suppliers have themselves been triad MNEs. This outsourcing of what might once have been considered core competencies did not lead to the development of new competitors in the triad for the assemblers. A factor here is that both the formal systems, such as legal constraints on intellectual property and contracts, and the informal social systems of trust and long-term relationships, led to a symbiotic co-evolution of OEM and supplier networks (see Sydow, 2005, on the role of trust and social context). However, such formal and informal systems may not control important suppliers from emerging economies. A Chinese manager in the automobile components industry expressed the view to us that the existence in the U.S. of what we would characterize as such systems of trust showed that the U.S. was moving away from true capitalism. This manager believes that China is now the world's most capitalistic economy.

New competitors from emerging economies. In past waves of the globalization of business, new competitors challenged U.S. and European firms in the automotive, consumer electronics, semi-conductor and other industries. Such firms as Toyota, Samsung, Sony, and less-known producers in Taiwan of lap-top computers, cell phones and electronic components seemed to come out of nowhere. We expect this to be a growing occurrence in coming years with the difference that China and India combined have more than ten times the combined population of Japan, South Korea, Singapore and Taiwan. It may well be that the influx of new competitors to today's MNEs will be correspondingly larger and, because of their large domestic economies, may be less reliant on Triad nation markets, and thus less constrained by Triad norms of business practice Two Chinese firms in our study, one in electronics the other in automotive parts, originally grew into major firms as suppliers to foreign MNEs. Both are now themselves becoming MNEs, and have subsidiaries in the U.S. and Europe. One has already become a global OEM and the other is quickly moving to do so.

Another trend is what might be called "value chain creep." Many NIE firms begin by supplying commodity parts and other activities that do not require high-level engineering to MNEs. Some of these firms develop strategies for growth that involve moving up the value chain, to provide more highly engineered products. This is a well-documented phenomenon with many contract manufacturers developing into OEMs. In the case of an NIE automobile components firm in our study, opportunities became available as the automobile assemblers increasingly outsourced systems of components. This first was able to use these opportunities to move to the position of a Tier 1 supplier (perhaps with government assistance), and thus greatly upgrade it engineering capabilities.

A variation on this pattern was seen at another firm, which moved up the value chain by expanding its engineering capability through a partnership with an MNE. There was some disagreement between the two companies about how the emerging economy firm developed its engineering expertise (including allegations by the MNE of IP infringement). Nonetheless, the NIE was able to build up its engineering capability and develop products at the global standard, eventually forming an alliance with a different MNE.

“Hollowing out” of the Triads. A half century ago Charlie Wilson, then CEO of GM, was famously quoted as saying “what’s good for GM is good for the USA.” Less controversially at the time, Wilson also said that what was good for the USA was good for GM. There may have been differences of opinion about the extent of benefit GM provided versus the subsidies or preferential treatment it received, but no one would have argued that GM provided some other nation a greater benefit. Now, however, national identity is not nearly as clearly defined as, perhaps, is exemplified by GM’s competitor, Chrysler when it was part of Daimler Chrysler or Nissan which is partly owned by a French automaker. The national identity of company and employees changes many of the organizational dynamics. The new global, industrial order can no longer be characterized by simple formulations based on the national identity of companies.

The premise for companies investing in the triad nations has always been that there is a combination of unique human and technology resources in those nations. As emerging economies develop pools of high level science and technology human resources (and, for some countries, that may just mean retaining more of their students that are now coming to the U.S.), and as firms locate their engineering/R&D work in the emerging economies, the implications for the triad are uncertain. Mutual gain scenarios would mean that, in aggregate, all parties benefit. However, scenarios of global oversupply of personnel or development capacity might imply that emerging economies with their advantages of lower cost and greater proximity to growth markets might draw science and technology capability away from the triad. We believe the outcomes are not yet clear. However, the internationalization of firms at multiple levels, in their personnel and in their core activities, does appear to be loosening the geographic lock-in that has historically shaped firm’s activities.

From the stand point of the triad nations and certain triad regions, the implications may be ominous. The United States, for example, has relied on talented science and technology students and professionals from emerging economies to fill its classrooms, and provide a major part of its capability in technological innovation. These human resources are no longer flowing to the United States in as great numbers and perhaps not of the same quality, and many who have built S&E careers in the U.S. are leaving to return home. The result is a potentially weakening of the U.S. science and technology programs in universities, as well as of the human resource aspects of the U.S. technology system.

By pointing out possible unanticipated consequences of the new globalization of engineering work our intent is not to denounce this globalization, but rather to suggest areas where problems may occur for certain firms, regions and nations, and the types of problems or dilemmas that are likely to spur further organizational changes as firms and nations grapple with the impact of this stage of globalization. The point is to better anticipate and deal with the possible negative consequences of this new globalization of engineering. It is important to note that a number of new opportunities that may provide wide-spread benefits are also suggested by our research.

Enriching aspects of the new globalization of engineering

Some of the potential benefits of the new globalization of engineering are fairly obvious. It may decrease poverty in the emerging economies, and decrease global inequalities. For citizens of the triad nations it may offer such benefits as a more stable international political environment, new markets and new investment opportunities.

Less obviously, we also believe the new globalization of engineering will result in a richer set of engineering solutions to various problems. In a number of our interviews we were given examples of what we call "context-dependent engineering." This refers to the direct and indirect factors particular to a region that shape engineering practice and product development. As we noted above, MNEs have long carried out the localization of engineering in emerging economies. This typically included end-stage modifications and changes in production processes that made a product better suited for production and sale in a region. Sometimes engineering changes occurred that went further than anticipated. An automotive parts company in our study was producing a global product in Mexico that had been designed in Europe. The company's Mexican engineers found that the part wasn't suited for the high altitudes and rough roads of Mexico. Since it was a global product, designed in and for the advanced industrial nations, the MNE had not intended to re-design it for the Mexican market. However, because production was located in Mexico, and Mexican engineers were involved in the process, as the product was redesigned these concerns took on greater weight than the expected market share in the NIE might have warranted. As it turned out, re-designed product found a larger than expected market as high altitudes and rough roads were also common in other parts of Latin America, in Alaska, and other parts of the world.

Context-dependent engineering in NIEs has become more important as the level of engineering activity and product development increases. Engineering in NIEs becomes more important because of five factors. (1) As market potential increases in the NIEs, particularly when it moves beyond commodity non-durable consumer goods, the market requires a localization of products that involves higher levels of engineering and R&D (e.g. the development of global-standard automobiles, rather than local or end-of-life-cycle cars, the development of new electronic devices, and work on large-scale infrastructure products). (2) As the types and extent of localization increase in quantity, there is also an increase in the "quality" of engineering. In one of our cases a minor project to adapt electrical equipment to local power standings expanded into a redesign of components to lower costs. Then, local NIE engineers proposed a more fundamental redesign to advance the core technology to better address local needs. As it happened, the redesign has the potential to support radical advances in the technology, and to result in a new global product. (3) As NIE engineers are educated in the NIEs, and practice advanced engineering there, the NIE context shapes a more general framework or approach to engineering practice and problem solving that may differ from that of engineering in the triad nations (just as engineering practice in each of the Triad nations has its own distinctive features[6]), so that an indigenous engineering approach develops. (4) NIEs, because of their particular regional characteristics (geographical, social, industrial development) are "intermediate markets" that often provide the basis for incremental and/or "proving ground" engineering. (5) Operations in NIEs put MNEs into new supply chain networks. One of our interview respondents mentioned how much his MNE had saved because its globalization of engineering development made it aware of new potential suppliers in countries it would otherwise have known nothing about in countries ranging from Thailand to Turkey.

For a variety of reasons, we have found that products that would not have been developed for MNE home markets in the triad economies are developed in NIE facilities of the MNEs. Factor costs (e.g. for engineering labor, energy, raw materials) may be different, allowing different engineering solutions to problems. Regulatory standards may be different, requiring or allowing products that would not initially be attractive in MNE home country markets. Demand conditions may be different because of differences in life styles.

One company in our study sold an electrical product for commercial use in the triad nations. Some engineers believed the product had potential residential applications, but only if there were a significant amount of further development. It did not seem worthwhile to invest in that development given the costs involved, the uncertainty of success at the level required for the market, and the possibly limited market. However, an engineer who was championing this product development was able to obtain approval to develop it at an NIE facility. Adapting the product for the NIE market required far less effort than would have been true for the triad markets because required performance standards were lower and interfaces with existing electrical control systems were simpler. Interestingly, the lower cost of engineering in the NIE was not cited as a factor, probably because the company had a backlog of engineering projects. It would have been easy to keep all the engineers busy on other projects. The priority given this project depended more on the promise of developing a marketable product than cost. As a result of the successful adaptation of its commercial product for the non-commercial market in the NIEs, the company is now supporting the further development of this intermediate product into a more advanced product for the triad nation markets (i.e., an intermediate product that could be developed with incremental development and funding levels was marketable in an NIE country and, once proved, would justify further investment for further incremental development to meet global standards).

Other factors of context-dependent engineering concern the nature of the engineering approach itself. The importance of NIE context-dependent engineering is that the framework shaping engineering in these countries has the potential to give them global leadership in certain areas of technology and innovation. One of the dominant factors shaping engineering practice in NIEs is that many of the engineering problems concern development under severe resource constraints. This leads to an approach to engineering, and thus often to types of engineering products and innovations, that differs from those historically undertaken in the triad countries, where there have been fewer resource constraints. The economic historian Nathan Rosenberg gives numerous example of how the development of technology in the U.S. took unique paths because most natural resources were cheap, whereas human resources were expensive (1976). Europeans were appalled at how wasteful of trees 19th century American sawmills were – not noting how economical they were in their use of skilled labor. U.S. automobiles until the 1970s, for example, differed from their European and Japanese counterparts in the degree to which they were designed to emphasize power and performance, with little regard for fuel economy. Gasoline, of course, was much cheaper in the United States. Conversely, to take another example from automobile production, Toyota's early development and use of just-in-time inventory control systems is generally attributed to the inability of the company in the 1950s and early 1960s to finance large parts inventory stocks and a lack of warehouse space to store them (Cusumano, 1985). What is often lost in history is that innovations sometimes start as necessities that only later become virtues as market conditions change.

At one of the electrical equipment companies in our study, engineers at a site in an emerging economy were working on a technology that would reduce the energy used in an electrical device. The company's U.S. engineers had not pursued development of this innovation because the energy savings that would result in the relatively small scale devices predominantly used in the U.S. did not add significantly to the attractiveness of the product. In Southeast Asia and Western Europe larger scale versions of the product were sold, and energy costs were much higher. It paid to develop this new technology for these markets. Later the technology was used to add incremental value to the version of the product sold in the U.S. At a pharmaceutical company we visited, research on infectious diseases is centered in India, and is primarily done by Indian scientists, rather than by Western scientists at centers in Europe and North America. Markets, motivations and experiences all support having South Asian scientists doing this work in South Asia. Although these projects are addressing needs that are most pressing in NIEs, we expect that the results of many such projects will quickly come to be applied on a global basis.

An IT company in our study, first began the localization of its products to increase sales in the triad nations. Its internal engineering staff, a team composed of members who were foreign-born and/or had extensive international experience, argued that localization efforts should also be undertaken in some of the NIEs, all of which had been previously ignored markets. Localization teams were set up, initially at the company's home office, but later small offices were opened in several NIEs to do the localization. The localization was confined to language and minor adjustments that were done after the launch of the product in triad nation markets. Soon, however, the engineers in the NIEs began to contribute to development of the product beyond their limited assigned tasks. They suggested product improvements and even some engineering advances, which were welcomed by the core product development team at the corporate headquarters. The managers we interviewed believed that this resulted from a certain "eagerness" by the

NIE engineers and Quality Assurance (QA) testers to prove themselves. It may also have been the result of hiring staff in the NIEs who were more technologically advanced, or at least had attained higher education levels. People with these qualifications applied to work at the MNE because it was considered prestigious, and the MNE could hire workers with this qualification premium in the NIE because their salaries were relatively low. Although the level of work being done was considered lower level in the Triad nations, it was relatively higher level in the NIEs (and thus attractive to those with higher skills). Similar accounts were given to us at other companies as well.

Globally distributed engineering teams commonly mix managers and engineers from the triad and the NIEs. Often things are even more complicated, because the NIE citizens may have been educated and socialized in the MNE home country, and the Triad citizens may have extensive global experience. At an American MNE site we visited in China, the three “American managers” included a Chinese American whose family had come from the region of the site, a Chinese citizen of Taiwan who had worked with the MNE in several countries, and a Chinese who had also worked around the world for the MNE. All three clearly identified much more with the MNE than with their countrymen (The younger manager from Taiwan expects to move to some other part of the world after a few yeas in this assignment. He is happy to go wherever the company needs him as he rises in the management ranks). When we asked about culture, these managers immediately responded in terms of the MNE culture. As was noted above, citizens of other countries are often part of the MNE management and engineering staff.

Although, as one manager put it, “our citizenship doesn’t matter we are all part of [the company],” different histories of cultural and occupational socialization lead to different norms and values. For cooperative action to occur, ways of acting have to be negotiated from these differences. We are finding that at the managerial level, cross-cultural conflict and regional/country allegiances are not prominent issues. This is partially a result of self-selection — those managers who work in global projects are those who are most comfortable with such projects (and those who are not may be placed in other projects, or may be less likely to rise through the managerial ranks). In addition, the internationalization of the manager ranks over the decade has led to increased numbers of managers who come from the regions to which the engineering work is being located (and in many cases, it appears, these managers are driving or supporting the globalization to those regions, as discussed above, in part because they are comfortable with, and recognize the capabilities in/of those regions). As we have noted, this internationalization of managers often seems to result in a strong company identity that at times may be stronger than country identification. Decisions that outsiders might see as harmful to their home country are brushed aside as less important than what is best for the company. Indeed, it often seemed that such considerations had not occurred to them.

Concluding observations

The location of advanced engineering activities in emerging economies is a relatively recent phenomenon, and the research this particular report is based on is still underway. Nonetheless, although our conclusions here must remain tentative, we believe they are well-grounded.

First of all, it must be emphasized that we see many benefits coming from the dispersion of state of the art science and technology work. There is the obvious potential benefit of just having large numbers of additional science and technology workers addressing the world's needs. There is also the perhaps less obvious benefit that science and technology workers socialized in different cultures, working under different economic conditions, and having experienced different issues in their life will take new approaches to old problems and will define new problems that need to be worked on. The result will be new technologies that would have been unlikely to come out of the Triad nations, but that offer benefits around the world. We have given some examples where this has already occurred. The spread of the world's wealth to a much larger share of the world's population is also an obvious benefit, as is the potential result of reducing international conflict through increasing interdependency.

We also see challenges arising from the globalization of engineering development – challenges for today's multinationals, challenges for the triad economies, challenges for the triad universities and knowledge regions, and also challenges for the emerging economies and the regions in them that host engineering development. The multinationals are under growing pressures to globalize to the point that they are at risk of losing sight of their longer term interests. They need to re-evaluate what distinctive competencies they can maintain or develop in the face of new competitors from new places. The triad economies need to examine their science and technology systems. What defensible strengths do they have and how can they maintain them? Universities and knowledge creation regions in the U.S. and other triad nations will have to undertake a similar exercise of defining roles for themselves in a new global environment. Just to give a quick example of one dimension of the challenge: U.S. policymakers will need to evaluate how U.S. needs for S&E workers will be met as fewer S&E immigrants come from emerging economies; U.S. universities need to determine what changes in educational programs will be needed to train the new global technology managers; U.S. universities and communities will need to assess what they have to offer each other that will lead to joint competitiveness at a time when new university-centered communities will be developing around the world.

A final challenge might be mentioned: scholars will need to adapt old theories, or perhaps develop new theories, on such topics as core competences, geographic stickiness of technology, strategic alliances and other areas.

* This project is supported through grants from the National Science Foundation, the National Science Foundation, (Human and Social Dynamics Program, #SES-0527584; Social Dimensions of Engineering, Science and Technology #0431755), and from the Kauffman Foundation. We would like to thank the NSF and our program officers, Rachelle Hollander and Pat White, for their support. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the NSF. An earlier version of this paper was presented at 21st European Group for Organizational Studies (EGOS) Colloquium "Unlocking Organizations" Berlin, June, 2005.

NOTES

1. Westney (2001) provides a good summary of the earlier stage globalization of R&D by MNEs.

2. Even within a firm there was sometimes resistance to using someone else's solution or design; Intel, which developed an explicit manufacturing strategy called "copyExactly!" had to confront this problem internally. One Intel engineer explained: " …engineers are typically trained and rewarded for making improvements, which in the semiconductor industry implies orchestrating change. Even the educational system stresses independent work, and copying is seen as cheating." (McDonald, 1998) "Another Intel engineer said that "Engineers hate copying exactly. 'Engineers by nature don't fall into this mode easily,' said Intel Fellow Gene Meieran. "They're bright; they're innovative; they want to make an impact. When you tell them, 'No, you're not gonna do that,' it's like you're taking away their livelihood." Bruce Goldman, (n.d.) "Global Enterprise Management" Stanford University Alliance for Innovative Manufacturing http://www.stanford.edu/group/AIM/AIMPrograms/EventsArchives/wkshparchives/globalmgmt.html

3. In an analysis of Microsoft by Cusumano and Selby (1995), the account of the company's strategy is to "learn by doing" rather than have formal training programs, supposedly a necessity in "a fast moving industry" (p. 12; p. 105ff, p. 244ff). Salzman and Biswas (2000) found the lack of training programs or systematic work processes to be characteristic of many IT companies, but attribute it more to the relative youth of the firms and technology that had not matured into organizations that had developed formal structures or processes to manage skill development and knowledge transfer. The need for proximity was thus a necessity of the tacit knowledge transfer processes and lack of systems for technology development in many of these IT companies.

4. One published example similar to some of our cases is the shift of Flextronics from contract manufacturer to provider of engineering functions: "Flextronics has spent more than $800 million on acquisitions in the past three years to assemble a 7,000-engineer product-design force spanning India, China, Southeast Asia, Ukraine, Europe, and Latin America." (*Business Week Online*, March 21, 2005).

5. See Saxenian (1996), Von Hippel (1994); and, for a critical review and argument that the empirical evidence is mixed about the extent to which spatial proximity is necessary for tacit knowledge exchange, innovation, learning, and entrepreneurship in regions, see: Cumbers, A. and D. MacKinnon, (2004) "Clusters in Urban and Regional Development" *Urban Studies*, 41 (5-6), May, pp. 959-969.

6. Salzman and Rosenthal (1994) discuss the process of the social shaping of engineering in software design (consistent with others who have examined the social construction of technology; Latour; Hughes, et al); they find there is technical latitude in design within which engineers shape the technology, influence by social factors that shape design outcomes apart from strictly technical considerations. It is within this "action space" that social and cultural factors shape engineering practices. We thus begin by focusing on how the "action space" for NIE engineers might evolve differently from that of engineers in triad nations or from the past in NIEs. The factors we discuss here are those that combine to shape engineering practice, and the resulting designs, in ways that reflect local conditions and diverge from engineering and design in other regions.

REFERENCES

Acosta, C., (2004), "Product Locational Strategies in the Mexicon and German Automobile Industries", paper presented at Workshop on Technology Entrepreneuership and Globally Distributed Engineering, Zhejiang Unversity, Hangzhou, China. December.

Askenas, R. et al., (1995), *The Boundaryless Organization*, Jossey-Bass, San Francisco, CA.

Bhagwati, J., (2004), *In Defense of Globalization*, Oxford University Press, Oxford.

Bolton, M.L. et al., (1994), "The Organization of Innovation in the United States and Japan: Neoclassical and Relational Contracting", in *Journal of Management Studies*, 31 (5), pp. 653–679.

Borrus, M. and Zysman, J., (1997), "Wintelism and the Changing Terms of Global Competition: Prototype of the Future?", Brie Working Paper 96B, Berkeley.

Business Week on Line (2005), "Design Is a Commodity." March 21. For overall discussion and examples of outsourcing engineering, see "Outsourcing Innovation", *Business Week Online*, March 21.

Clark, K. and Fujimoto, T., (1991), *Product Development Performance*, Harvard Business School Press, Cambridge, MA.

Cumbers, A. and MacKinnon, D., (2004), "Clusters in Urban and Regional Development", in *Urban Studies*, 41 (5-6), pp. 959–969.

Cusumano, M., (1985), *The Japanese Automobile Industry*, Harvard University Press, Cambridge.

Cusumano, M., and Selby, R., (1995), *Microsoft Secrets*. Touchstone, New York.

Dalton, D.H. et al., (1999), *Globalizing Industrial Research and Development.* U.S. Department of Commerce, Washington, D.C.

Etzkowitz, H. and Leydesdorff, L., (2000), “The Dynamics of Innovation: From National Systems and ‘Mode 2’ to a Triple Helix of University-Industry-Government Relations”, in *Research Policy*, 29, pp. 109–123.

Hamel, G. and Prahalad, C.K., (1996), *Competing for the Future*, Harvard Business School, Cambridge.

Hobday, M., (2000), “East versus Southeast Asian Innovation Systems: Comparing OEM- and TNC-led Growth in Electronics”, in *Technology, Learning, and Innovation*, Kim, L. and Nelson, R., (eds.), Cambridge University Press, New York.

Kirsner, S., (2005), “Hub Catches Microsoft's Eye”, in *Boston Globe*, June 6, p. B1.

Lynn, L., (1982), *How Japan Innovates*, Westview, Boulder.

Lynn, L. and Salzman, H., (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.

McDonald, C.J., (1998), “The Evolution of Intel’s Copy EXACTLY! Technology Transfer Method”, in *Intel Technology Journal*, 4 (1).

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

Moss, P. et al., (2001), “Limits to Market-Mediated Employment”, in Carre, F. et al., (eds.), *Nonstandard Work: The Nature and Challenges of Changing Employment Arrangements*, Industrial Relations Research Association, Champaign, IL, pp. 95–121.

Günther, O. and Salzman, H., (2002) “Stumbling Giants: The Emptiness, Fullness, and Recursiveness of Strategic Management”, in *Soziale Systeme. Zeitschrift für Soziologische Theorie*, 8 (2).

Ouchi, W. and Bolton, M., (1988), “The Logic of Joint Research and Development”, in *California Management Review*, 30, pp. 9–33.

Rosenberg, N., (1976), *Perspectives on Technology*, Cambridge University Press, Cambridge.

Saxenian, A., (1996), *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*, Harvard University Press, Cambridge.

Sydow, J., (2005), “How Can Systems Trust Systems? – A Structuration Perspective on Trust-Building in Interorganizational Relations”, in Zaheer, A. and Bachmann, R. (eds.), *Handbook of Trust Research*, Edward Elgar, Cheltenham.

Teitelbaum, M.S., “Do We Need More Scientists?”, in *The Public Interest*, Fall 2003, pp. 40–53.

Von Hippel, E., (1994) “’Sticky Information’ and the Locus of Problem Solving: Implications for Innovation“, in *Management Science*, 40 (4), pp. 429–439.