**The New Global Invention Machine: A Look Inside the R&D Networks of U.S. Multinationals**

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**Abstract:** We present evidence showing that US multinational firms are creating a global division of R&D labor akin to global value chains in goods production, where activities are located in regions where production is most efficient. We argue that this system, properly managed, brings global benefits by increasing the innovative capacity of the global economy. These benefits may become increasingly important in the context of a global innovation slowdown many experts believe is already underway. Unfortunately, policy trends in the U.S. and elsewhere complicate the operation and increase the risks associated with this globalization of R&D.

**Acknowledgments:** The statistical analysis of firm-level data on U.S. multinational companies was conducted at the Bureau of Economic Analysis (BEA), United States Department of Commerce under arrangements that maintain legal confidentiality requirements. We thank Bill Zeile, Jim Fetzer, and Ray Mataloni for helpful discussions on the BEA data. All errors and omissions remain our own responsibility. The views expressed are those of the authors and do not reflect official positions of the U.S. Department of Commerce.

## 1. Introduction: The Rise of Overseas R&D

For decades, U.S. multinational companies (MNCs) performed nearly all of their R&D activity within the United States, even as they expanded overseas production and sales of goods and services. The relatively small amount of R&D that was conducted outside the U.S. tended to be concentrated in a small number of advanced industrial economies. Over the past two decades, however, the amount of R&D conducted overseas by US MNCs has grown nearly 4-fold and its geographic distribution has undergone a substantial expansion, now including parts of the developing world. U.S. MNCs have developed an innovation system that spans the globe.

Like many aspects of globalization, the globalization of R&D offers opportunities and may pose risks. Some observers fear that the increasing globalization of R&D activity might lead to a loss of U.S. technological leadership. However, we observe that US innovators remain involved in important ways in US MNCs' global R&D activities for decades – suggesting fears of hollowing-out may be overstated. Furthermore, we note that the large and growing pool of highly educated scientists and engineers in the developing world offers the possibility of increasing the rate of global productivity growth. Our research suggests that the best way to productively utilize this resource is by combining emerging market talent with MNC innovation experience through the globalization of MNC R&D.

However, several challenges could limit these benefits from the globalization of R&D. The global rise of economic nationalism poses a potential risk to progress in this area, particularly if the United States retreats from international trade policy leadership. The aggressive use of tariffs is already signaling to companies that the US government no longer supports the internationalization of commercial activities. It may take years to measure the impact on global R&D activity with any precision, but it is not difficult to imagine current policy moves and public statements by government officials resulting in a decrease in overseas R&D activity by US MNCs or, potentially worse, decreasing integration and collaboration between US MNCs' domestic R&D labs and their foreign affiliates.

In addition, some important developing countries are resisting effective protection of intellectual property rights and openness to foreign direct investment (FDI), preventing MNCs from taking full advantage of these nations' potential as R&D sites. As the locus of R&D effort shifts from manufacturing to services and digitally traded services become a greater component of global consumption, global trade in services must be liberalized to achieve progress in innovation. The global effort to restrict (or tax) international data flows is another potential impediment. Because movement of skilled workers is a vital element of this system, rising opposition to immigration is another risk. Finally, growing US-China tensions pose a special challenge because of the important role these two economies play in the system. Appropriate public policies are needed to strengthen intellectual property rights, encourage labor mobility, and liberalize trade in services so that innovation can flourish to improve living standards and fuel economic progress.

This chapter begins by motivating the study of R&D globalization as a possible (partial) response to one of the global economy's most pressing challenges – the significant and persistent slowdown in productivity growth in the advanced economies. As we argue in the next section, the mobilization of human talent enabled by R&D globalization may be essential to revive and sustain innovation and productivity growth. This makes it not just an interesting phenomenon but something potentially foundational for future growth.

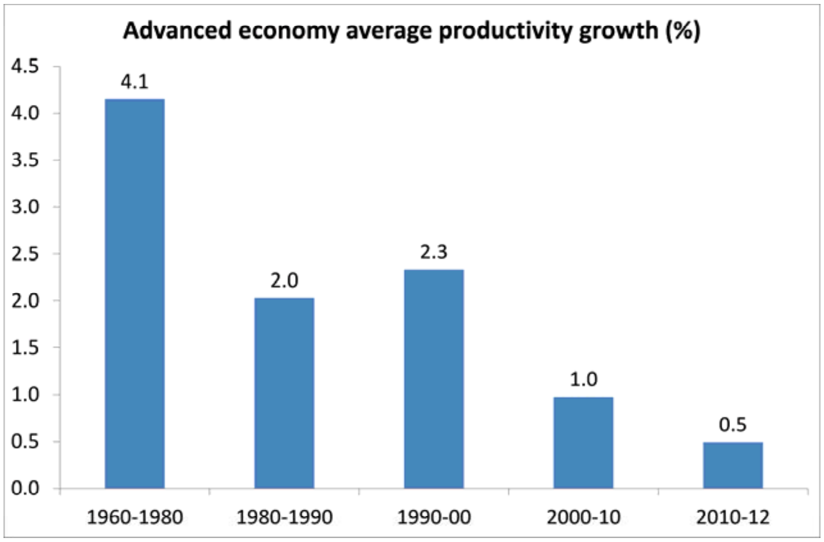
We move on from that initial motivation to describe the data we use to create a statistical portrait of this phenomenon, at least with regard to the actions of U.S. multinationals. These data point to some important shifts in the distribution of multinational inventive activity across geography and across technological fields. We also note that the nature of R&D activity appears to be changing – within multinationals, there appears to be a sharp increase in R&D cooperation across borders, evidenced by a rise in the number of patents that contain inventor teams with both U.S. and non-U.S. addresses. We argue that these movements are all closely related to one another; the sharp increase in the role of IT hardware and software in multinational invention helps explain the significant shift in the geography of U.S. foreign affiliate R&D activity. The most important new hubs of foreign R&D activity are all ones with extensive and growing human resource assets in these increasingly signicant technological domains. As we argue below, the inherent modularity of IT hardware and software facilitates the distribution of inventive activity across geographies, and software-mediated design tools and modern communications technologies help facilitate the intensive information exchange that still must take place.

Having described the forces driving increased R&D globalization, the chapter concludes by noting the policy trends around the world that are limiting its expansion. These policy challenges exist in both developing and developed countries, and appear to be intensifying in the current environment of rising trade friction and antiglobalization sentiment. As always, the benefits of globalization are contingent on pursuing the policies that will enable them to be fully realized.

## 2. R&D Globalization as a Response to the Global Productivity Slowdown

Promoting the effective globalization of R&D may be especially important in light of the challenge posed by the global productivity slowdown (Syverson 2017; Byrne, Fernald, and Reinsdorf 2016). Despite hopeful talk by industry leaders and consultants of an imminent fourth industrial revolution, the available data suggest that the most important hallmark of past industrial revolutions—a significant and persistent acceleration in the growth rate of labor productivity—is still missing. Gordon (2016) argues that the productivity slowdown evident since just before the global financial crisis is only the beginning of a permanent deceleration in the productivity growth rate, a consequence, he argues, of the grim reality that no current or future inventions will have the same impact on human welfare as the "great inventions" of the 19th and 20th centuries. Figure 1 below illustrates the extent of the productivity deceleration in the advanced industrial economies.

**Figure 1 The Decline in Productivity Growth**



Source: Byrne, Fernald, and Reinsdorf, 2016

Many knowledgeable commentators have dismissed Gordon's techno-pessimism, but leading economic theories of endogenous innovation suggest that Gordon's basic tenet has a core of truth—innovation is getting harder.[1] According to the widely cited model of Jones (2009), it is harder to innovate now because of the "burden of knowledge." Human technological knowledge has expanded dramatically, but every generation must first master the knowledge accumulated by previous generations before it can build upon that knowledge. As the amount of prior knowledge grows, it becomes more difficult to master. Increasingly, would-be innovators are forced to specialize in narrow domains of expertise, and innovation requires ever larger and more difficult-to-manage teams that bring this expertise together. Jones (2009) presents persuasive evidence of these increasing costs, and Bloom et al. (2017) provide even starker evidence of apparent diminishing returns to innovative effort in advanced countries.

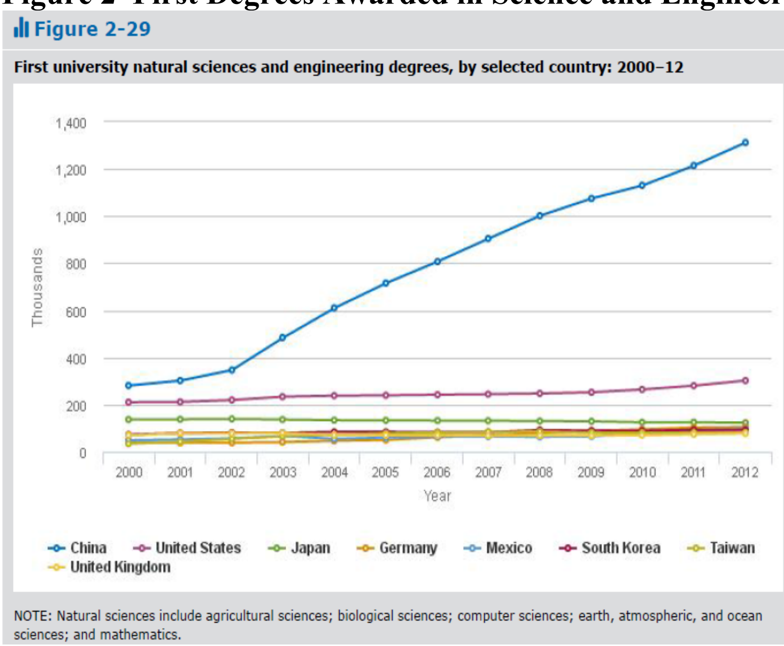
However, there is a silver lining in these pessimistic models of innovation. They all imply that the scale of investment in innovation matters, and the globalization of knowledge creation could be a powerful force for boosting productivity growth. A small number of mostly British engineers, tinkerers, and entrepreneurs produced the breakthroughs of the first Industrial Revolution. The second Industrial Revolution went farther, and it achieved more, because it could draw upon a larger pool of potential inventors that extended beyond Great Britain. This broader mobilization of Western inventive talent had its limits: The research technology of the era required collaborators to be in the same place at the same time. Innovation labor markets were, at best, national in scope, limiting the array of research teams that could be created. Human industrial advance still rested on a narrow foundation, with most of the human race effectively excluded from participation.

Today, this situation is changing in a way that has important implications for future productivity growth. Higher education is spreading rapidly in emerging markets like China and India (Freeman and Huang 2015). In just the past dozen years, China expanded the number of bachelor's degrees it grants in science and engineering by about 300,000, to more than 1.3

[1] For a more optimistic take on America's productivity growth prospects, see Branstetter and Sichel (2017).

million per year (National Science Board 2016).  Figure 2, below, illustrates the extent of China's mobilization of human capital – China now graduates more newly minted scientists and engineers than the technological superpowers of the West put together. By contrast, the United States awards only about 250,000 bachelor's degrees in science and engineering per year. Various sources in the literature suggest that, despite the rapid expansion of the scale of engineering education in India and China, the average quality of an engineering education in China or India may still lag behind that of Western countries, and the ability of either China or India to innovate at the global technology frontier through the efforts of its indigenous firms may still be limited (Arora and Gambardella, 2005a,b; Freeman and Huang 2015).  Nevertheless, ample evidence points to the extremely high level of skill of India and China's top engineering students. Multinationals have responded to this growing talent pool by ramping up the amount of R&D they undertake in emerging-market countries. With computer-assisted design software, internet videoconferencing, and the ability to quickly access terabytes of test data, it is now increasingly possible for Chinese and Indian engineers to collaborate closely, in almost real time, with seasoned technology experts in the United States, Western Europe, and Japan.

**Figure 2  First Degrees Awarded in Science and Engineering**

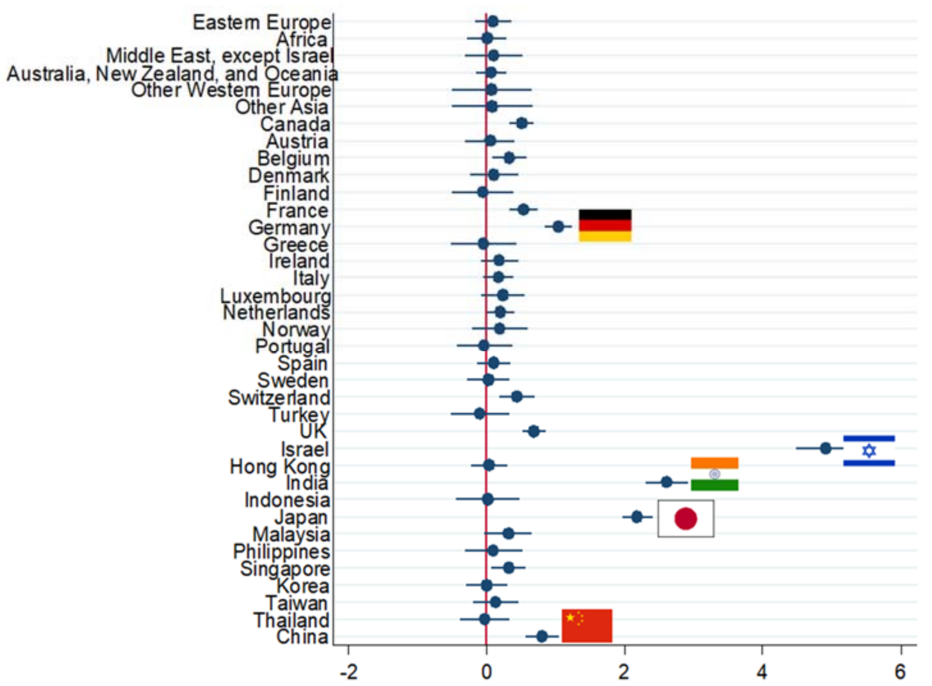



This combination of developed-economy technological experience and emerging-market talent appears to produce impressive results.[2] In a comprehensive study of US patents granted to teams that included at least one Indian or Chinese inventor, Branstetter, Li, and Veloso (2015) find that Chinese engineers working for foreign-based multinationals produced inventions in China that appear to be at least as good as the inventions produced by the same multinationals in their home countries. IBM or Intel engineers in China can be as productive as IBM or Intel engineers in Silicon Valley—and the number of good engineers in China is rapidly growing.  China is not the

[2] For example, Hufbauer, Moran, and Oldenski (2013) report that US MNCs that do not perform R&D outside the United States also do not perform R&D within the United States, suggesting that foreign R&D and domestic R&D are complements, not substitutes, for US MNCs.

only emerging market where US multinationals are finding high returns to their R&D investments. Figure 3 presents results from a comparison of patent output across R&D sites. These results were obtained by regressing patents on foreign R&D expenditure by US MNCs, controlling for firm-country and year effects. The residuals from this regression were then regressed on country dummy, and the figure plots the coefficients of the country dummies.

Figure 3 Patents Generated per R&D Dollar (Controlling for Industry and Firm Effects) by Country




This graph raises the possibility that the foreign engineers US MNCs can access through their global R&D systems could power an acceleration in the rate of productivity growth around the world.[3] Fernald and Jones (2014) estimate that about 1.3 percentage points of the average 2 percent annual increase in US labor productivity from 1950 to 2007 stemmed from higher research intensity (that is, the rising fraction of the population engaged in invention) in the advanced countries. Research intensity outside the traditional developed economies is already increasing rapidly and will likely continue for decades. As investment in higher education spreads through the developing world, it is possible to imagine global research intensity doubling or more than doubling in coming decades. R&D globalization could help ensure that this growing global talent pool is utilized in the most efficient and effective possible way, maintaining the expansion of the global technology frontier even in the face of powerful economic forces that would otherwise slow that rate of expansion. As Nobel laureate Paul Krugman (1992) once noted, productivity is not everything, but in the long run, it is *almost* everything. R&D globalization could be a key contributor to maintaining or increasing global productivity growth.

[3] This paragraph draws from Branstetter and Sichel (2017).

## 3. Data for Measuring the Globalization of R&D

We use a combination of two sources of data to generate a unique panel dataset for analysis of US multinational innovative activity abroad. The first is the Bureau of Economic Analysis's (BEA) annual surveys on U.S. Direct Investment Abroad. BEA is under a congressional mandate[4] to track investment into and out of the United States, and as such, their data comprise the most comprehensive available data on US multinational activity abroad. The database contains financial and operating characteristics of both the US parent companies and their foreign affiliates, including R&D expenditures, which is the primary variable of interest for this paper. We constructed a panel dataset of this activity from 1989 through 2014[5].Each firm may report on a consolidated basis for multiple affiliates in the same country under certain conditions[6]. Therefore, rather than conducting analysis at the affiliate level, we aggregate all foreign affiliate activity up to the country level for a given firm for a given year.

The second source of data is US Patent and Trademark Office (USPTO) patent data, obtained using the PatentsView database[7], and includes all utility granted patent applications through August 2017. We restrict our analysis to USPTO patents, rather than the Japan Patent Office (JPO) or European Patent Office (EPO) patents, for three primary reasons: (1) our sample is US multinationals, (2) the use of USPTO patents ensures a common standard that is close to or at the global technological frontier, and (3) the use of USPTO patents allows a comparable measure across countries. Patents are an imperfect measure of innovation; there is heterogeneity across countries, firms, and industries in the propensity to patent.[8] However, patenting does reflect an important piece of a country's innovative output, and it is highly correlated with other measures of innovation. Because obtaining a patent from USPTO is costly and requires, in principle, a degree of novelty as judged by professional patent examiners, the use of USPTO patents helps to ensure that the counted inventions are close to the technological frontier. It also ensures that a common standard is being applied. While this measure of innovation is not ideal, we believe it is the best available measure of innovation that is consistent for both cross-country comparison and across-time comparison. Furman, Porter, and Stern (2002) provide further support for our use of

[4] The mandate comes from the International Investment and Trade in Services Survey Act. The data are collected for the purpose of producing publicly available aggregate statistics on the activities of multinational enterprises.
[5] The most extensive data are collected in benchmark years: 1989, 1994, 1999, 2004, 2009, and 2014. The reporting requirement threshold varies by year, size of the affiliate, and the parent's ownership stake. BEA estimates values of some variables of some affiliates in non-benchmark years in order to estimate a consistent universe across years. We only use the reported data in this paper.
[6] These conditions are that the affiliates operate in the same country and same industry classification or are integral parts of the same business operation.
[7] http://www.patentsview.org/web/
[8] For instance, the propensity to patent tends to be much higher industries like IT and biotechnology than in less technologically dynamic domains, and it tends to be higher in manufacturing than in services. Simple comparisons of patent counts could therefore obscure changes in the true level of innovation across firms and technological fields. In regression analysis, however, the incorporation of firm and/or industry fixed effects can partially control for time-invariant differences across firms in their propensity to patent that stem from the fact that different firms are inventing in different technological domains characterized by different propensitites to patent. Given our rich BEA data, we can also examine changes in the mix of R&D expenditure across affiliates, industries, countries, and time, which provide us with another window into the changing mix of inventive activities that provides a useful check on the potential biases present in patent data.

patenting as a comparison measure of a country's innovation; they provide an extensive overview of other measures of a country's national innovative capacity and come to the conclusion that patents are "the most concrete and comparable measure of innovative output over countries and time."

There are no numerical identifiers that exist in both the BEA data and the USPTO patent data, so we matched the two databases using firm names. We conducted several rounds of fuzzy matching between BEA multinationals and patent assignees using the "reclink2" Stata command, followed by manual verification to ensure the generated matches were correct. If a firm appeared in the BEA data but not in the patent data in a given year, we assumed that it did not apply for any patents in that year. Following the prior literature, we consider the patent inventors' country of residence as the country where an innovation takes place, and we consider a patent as having originated (at least in part) from a foreign country if any of its inventors list their address as from that country. Using these data, we are able not only to see whether a firm is patenting in a country, but we are also able to see the firm's R&D expenditures there using the BEA data. This means that we are uniquely able to eliminate instances where there are patents that appear to originate in a country where there is no R&D-performing affiliate. Our final dataset is at the firm-country-year level and varies across firms, countries, and time.

## 4. Data Show a Significant Rise in Overseas R&D Conducted by U.S. MNCs

Total US R&D spending as a share of GDP increased slightly from 2.5 percent in 1999 to 2.7 percent in 2016.[9] Multinationals are an important driver of that R&D spending[10] -- their share of the total was 57 percent in 2015[11] -- and the innovation that R&D generates. At the same time, US MNCs have dramatically increased their overseas R&D expenditures. Figure 4a shows that US MNCs' foreign R&D expenditures increased from approximately $14 billion in 1997 to over $55 billion in 2015. In some industries, the growth of overseas R&D has been especially striking. R&D expenditures by overseas affiliates in professional, scientific, and technical services increased by *more than a factor of 18* between 1999 and 2014, and the ratio of overseas R&D to domestic R&D for multinationals in this industry has gone from under 10 percent in 1999 to over 40 percent in 2015. However, this industry is at the extreme end of the distribution. While US MNCs' foreign R&D expenditures have increased dramatically, they still conducted about 83 percent of their R&D in the United States in 2015 (down from 92 percent in 1989, as shown in Figure 4b).

**Figure 4a Growth in Foreign R&D**

[9] World Bank, Research and Development Expenditure data, https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?locations=US.

[10] US Bureau of Economic Analysis (BEA) data, www.bea.gov/iTable/index_MNC.cfm. The BEA is our first principal source of data on US MNCs' global innovation system.

[11] National Science Board, Science and Engineering Indicators 2018, Chapter 4–Research and Development: US Trends and International Comparisons, https://nsf.gov/statistics/2018/nsb20181/assets/1038/research-and-development-u-s-trends-and-international-comparisons.pdf; US Bureau of Economic Analysis, Activities of US Multinational Enterprises in 2015, https://apps.bea.gov/scb/pdf/2017/12-December/1217-activities-of-us-multinational-enterprises.pdf.

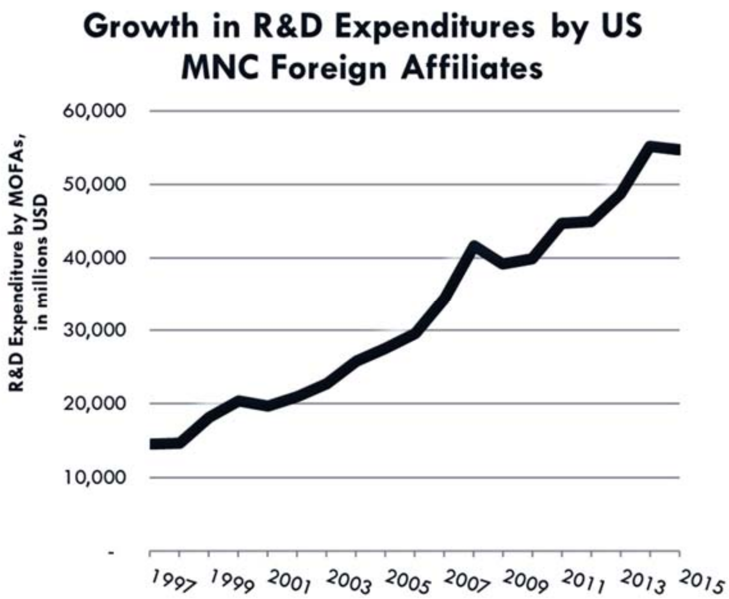
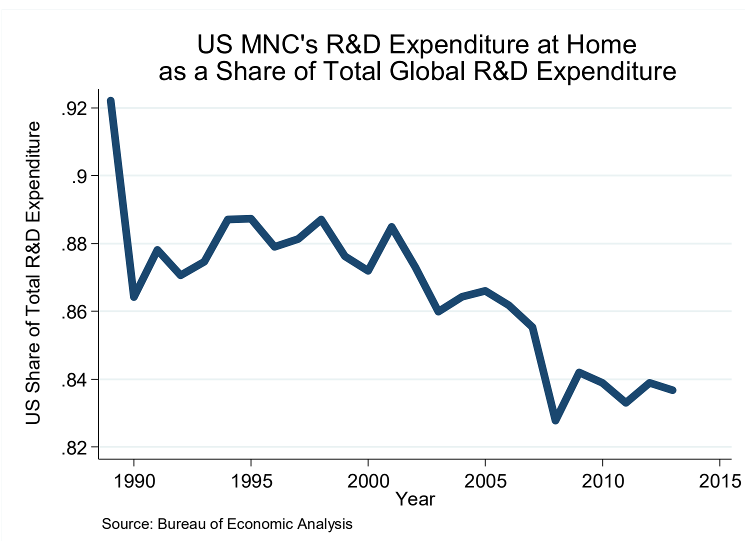



**Figure 4b  The Declining Share of Domestic R&D Expenditure**



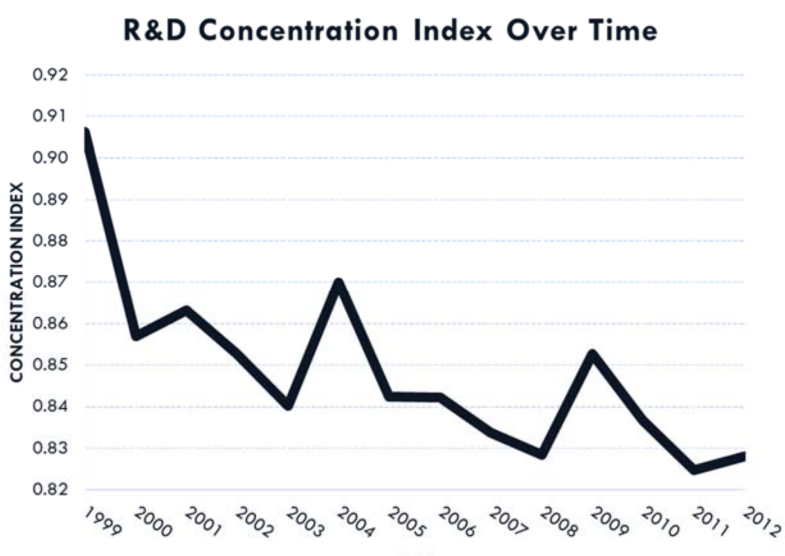

## 5. The Changing Footprint of U.S. MNCs' Overseas R&D

US MNCs' foreign R&D is growing not only on the intensive margin (more spending in existing locations) but also on the extensive margin (conducting R&D in more locations), with an average firm conducting R&D in more places than before. Figure 5a depicts the evolution over time of a Herfindahl index illustrating how concentrated R&D spending is by location. (A Herfindahl index of 1 would indicate all the R&D is being conducted in one location.)

In 1989, US MNCs were conducting 74 percent of all foreign R&D in just five countries—the United Kingdom, Germany, Japan, France, and Canada. They were prominent R&D locations because of their historical importance as global centers of scientific research (and as lucrative consumer markets for US MNC products). By 2014, however, only 43 percent of all foreign R&D was being conducted in these five countries. Figure 5b shows the growing importance of new locations and the corresponding decline in the relative importance of the traditional R&D hubs.

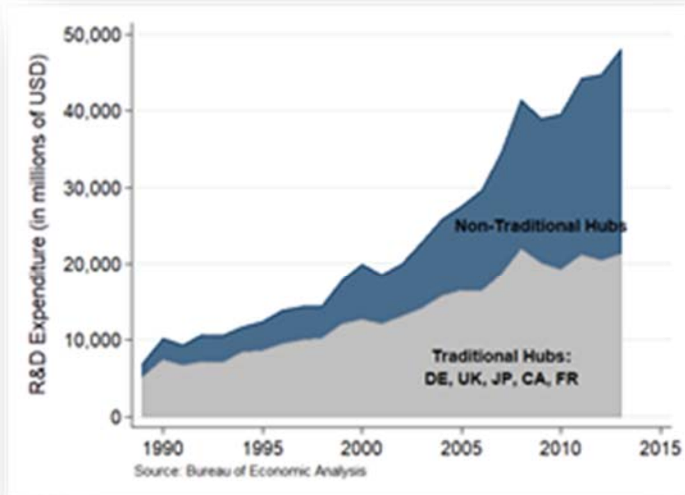
Many of these new hubs have only recently graduated from the ranks of developing countries, and two of the most important new destinations for US MNC R&D, China and India, still have relatively low per capita incomes. Most economists would see only the most advanced industrial countries as possessing a comparative advantage in innovation, so the shift in R&D investment away from traditional hubs appears to challenge traditional views of comparative advantage and economic development. The apparent paradox fades, however, as we examine the inner workings of the global R&D system. In the same way that multinationals have created global value chains that provide low-wage developing countries with the sophisticated inputs they need to manufacture and export technology-intensive products, US multinationals have created a kind of intellectual value chain that combines the impressive engineering talent available in developing countries with sophisticated, specialized knowledge needed to produce frontier innovations for the global market. To see this intellectual value chain in action, we turn to our second principal source of data on US MNCs' global innovation system—patents—and use them to analyze the striking rise in cross-border research collaboration evidenced by patent documents from the US Patent and Trademark Office (USPTO).[12]

Figure 5a




[12] We restrict our analysis to USPTO patents for three primary reasons: (1) our sample is US multinationals and the use of USPTO patents (2) ensures a common standard that is close to or at the global technological frontier and (3) allows for comparison across countries.

Figure 5b  The Rise of New R&D Hubs

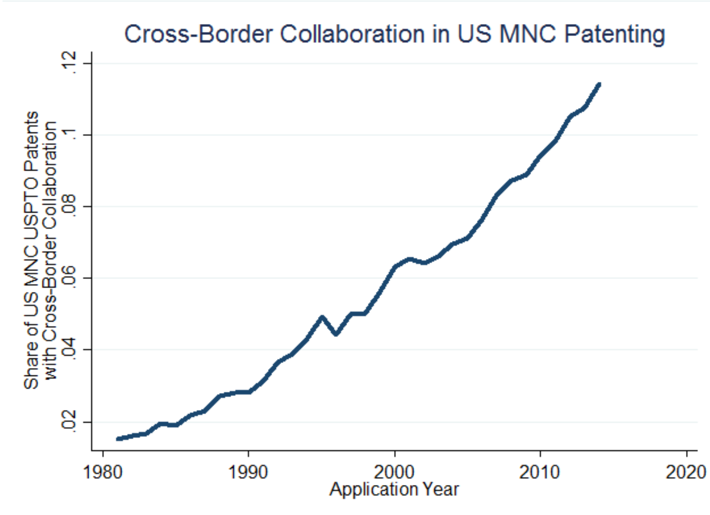



## *6.* US Patents Reveal Rapid Growth in Cross-Border R&D collaboration

US patent law requires that applicants include a list of inventors and their addresses in the patent application. This requirement implies that patents generated with substantive input from scientists and engineers employed by the foreign affiliates of US MNCs will list the foreign addresses of those R&D personnel. Because we know the locations of R&D-performing affiliates around the world, we can match R&D investments made by US MNCs abroad with the patents those investments generate. This matching, however, revealed that many patents listing the addresses of foreign inventors also list the addresses of US-based inventors, suggesting that the patent in question is the work of an international team, collaborating across borders. Branstetter, Li, and Veloso (2015) refer to this phenomenon as "international coinvention."

Earlier research has already noted a rapid rise in international coinvention (Kerr and Kerr 2018; Branstetter, Li, and Veloso 2015). Figure 6 shows that the share of all US patents, including those granted to foreign inventors, that have inventors from more than one country has increased from less than 2 percent in 1980 to more than 10 percent in 2014. For leading multinationals, this fraction is considerably higher.

Figure 6




Further inspection reveals that international coinvention is especially prominent in the sharp rise of patents coming out of developing countries like India and China. Figure 7a tracks the rapid rise in USPTO patents granted to inventor teams with at least one member resident in China. Using information in patent documents, the figure identifies patents owned by all multinationals (not just U.S. multinationals) in which all the inventors have Chinese addresses (depicted in green) and those in which the inventor team contains both Chinese and non-Chinese addresses (depicted in orange).[13] Figure 7b presents a similar breakdown of USPTO patents granted to inventor teams with at least one member resident in India.

It is immediately clear that the dramatic rise of USPTO patent grants to Chinese and Indian inventors was driven disproportionately by multinationals, with a conspicuously large role in patents generated through international coinvention. Branstetter, Li, and Veloso (2015) show that the patents owned by multinationals are of systematically higher quality than patents owned and generated by indigenous Chinese or Indian firms.[14] These authors introduce the idea that the intellectual inputs provided by the rest of the MNCs' global R&D system help make up for the lack of a sufficiently developed indigenous knowledge base in developing countries. In the same way that a developing country can export a complex product because it imports some of the most advanced components, an R&D center based in a developing country can contribute to innovation for the global market because local staff can "import" the R&D expertise of their colleagues who are often based in advanced industrial economies. The high-bandwidth communications technologies enabled by the global internet and, in some industries, the diffusion of design software explicitly engineered to facilitate collaboration by geographically distributed teams, allows for a degree of remote collaboration that was impossible in the 1980s or

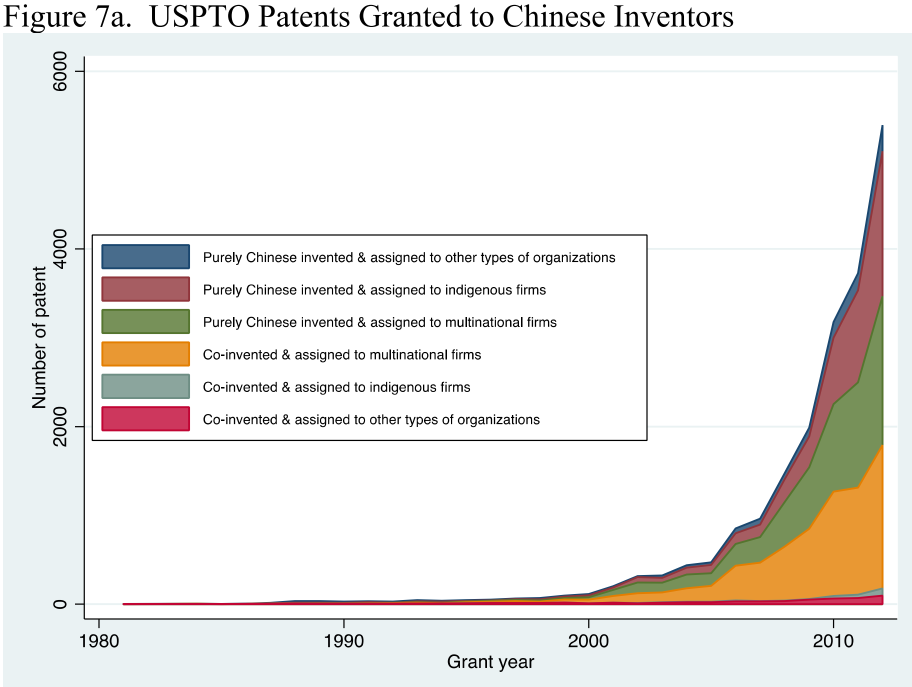
[13] Figure 7 tracks patents assigned to all multinationals, not just those based in the United States. As it turns out, Taiwan-based multinationals generate even more US patent grants through their China-based R&D operations than US-based multinationals do. What is clear, however, is that much of China's recent rapid rise in US patent grants has been driven by the actions of foreign firms, not indigenous ones.

[14] While not included here for reasons of space, Branstetter, Li, and Veloso (2015) show that US MNCs play an even more important role in generating US patents granted to teams with at least one Indian inventor than they do in the case of China.

early 1990s. Further, a series of interviews we conducted with R&D managers in US MNCs reveal that many of the firms with global R&D activities consciously try to create global innovation teams through intentional staff rotation, online collaboration, and other intrafirm networking activities. We believe that these efforts allow US MNCs to tap into the raw talent available in emerging markets in ways that they could not before, and this is a key factor in understanding the geographic shift in R&D activity that has taken place since the rise of the global internet.

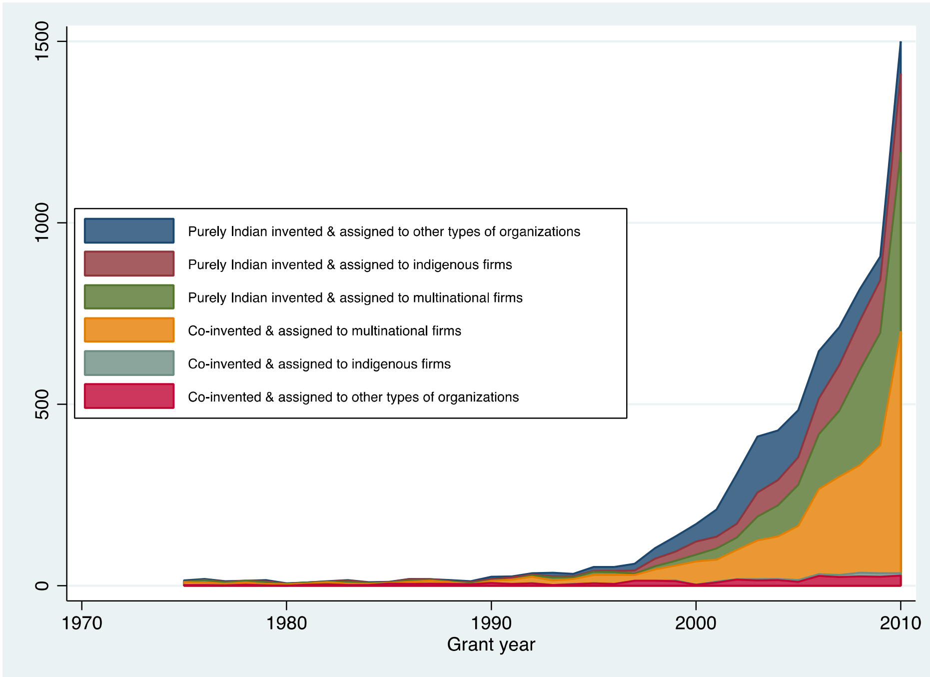
Interestingly, international coinvention not only makes up for the initial absence of frontier innovative capabilities in emerging-market R&D centers but also, over time, can help build up those capabilities. Branstetter, Li, and Veloso (2016) follow clusters of patents generated by foreign MNCs operating in China within particular technological domains and show that these firms are very likely to rely heavily on foreign-based inventors at first, but, over time, the patents become more likely to be invented by teams of indigenous researchers. They suggest that foreign MNCs use international R&D collaboration as a way of sharing advanced expertise with local Chinese teams. Over time, this expertise gets transferred to the local team, and Chinese teams become more intellectually independent, as evidenced by a decline in the number of foreign inventors appearing in the patent documents generated by a given research stream.

Figure 7a. USPTO Patents Granted to Chinese Inventors




Source: Branstetter, Li, and Veloso, 2015

Figure 7b USPTO Patents Granted to Indian Inventors

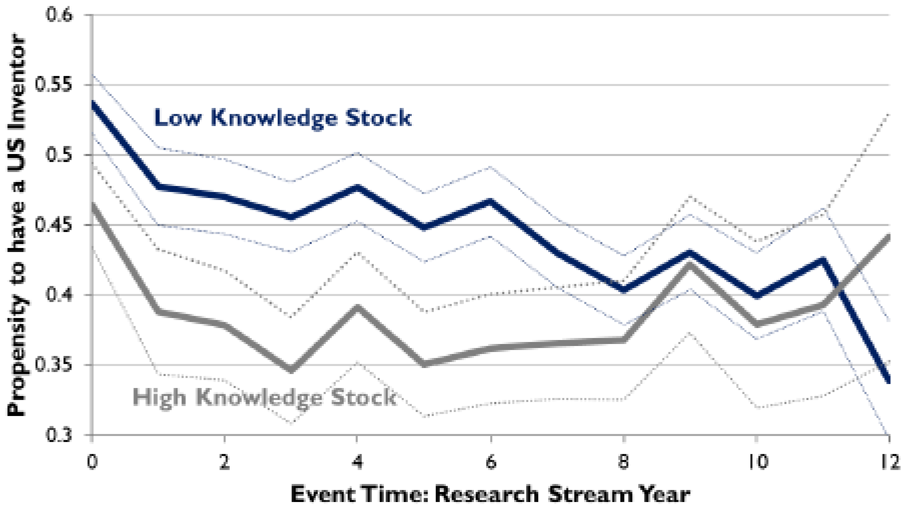



Source: Branstetter, Li, and Veloso, 2015

We expand on this idea in Branstetter, Glennon, and Jensen (2018), using data drawn from all US multinational affiliates that consistently report R&D spending and patenting. We find patterns strongly consistent with the notion that the inception of new research streams in developing countries tends to be more reliant on intellectual input from US-based inventors than is the case in developed countries, though the degree of reliance on US input tends to converge over (long periods of) time. This work further builds out the notion of international coinvention as a mechanism for enabling MNCs to do frontier research in countries with limited indigenous capability for frontier innovation. Our interviews with R&D managers at US MNCs strengthen our interpretation of the declining significance of US inventors in the research streams of foreign affiliates. R&D managers and engineers describe the organizational structures and practices designed to promote knowledge sharing within the firm. International collaboration is deliberately enhanced through short-term personnel exchanges between more and less established R&D subsidiaries, and regular videoconferences help maintain these ties once the exchanges end. Internal systems track networks of expertise around the world, enabling research teams in one location to find necessary expertise elsewhere within the system. All interviewees pointed to the growing capabilities of research teams in emerging markets.

Figure 8, reproduced below from Branstetter, Glennon, and Jensen (2018), illustrates the core finding of that paper. The solid lines trace out the propensity for a patent produced in a given year after the inception of a new research stream to include at least one U.S.-based inventor, and it does so separately for research streams begun in "lower knowledge stock" countries (mostly developing countries and "higher knowledge stock" countries. As is evident from the figure, this propensity starts high – and it begins at a substantially higherpoint for patents generated in lower knowledge stock countries – but it falls quickly, and propensities tend to converge across low- and high-knowledge-stock countries within a decade of the research stream's inception.

Figure 8 Propensity for a Patent Generated by a Foreign Affiliate to Have a US-Based Inventor

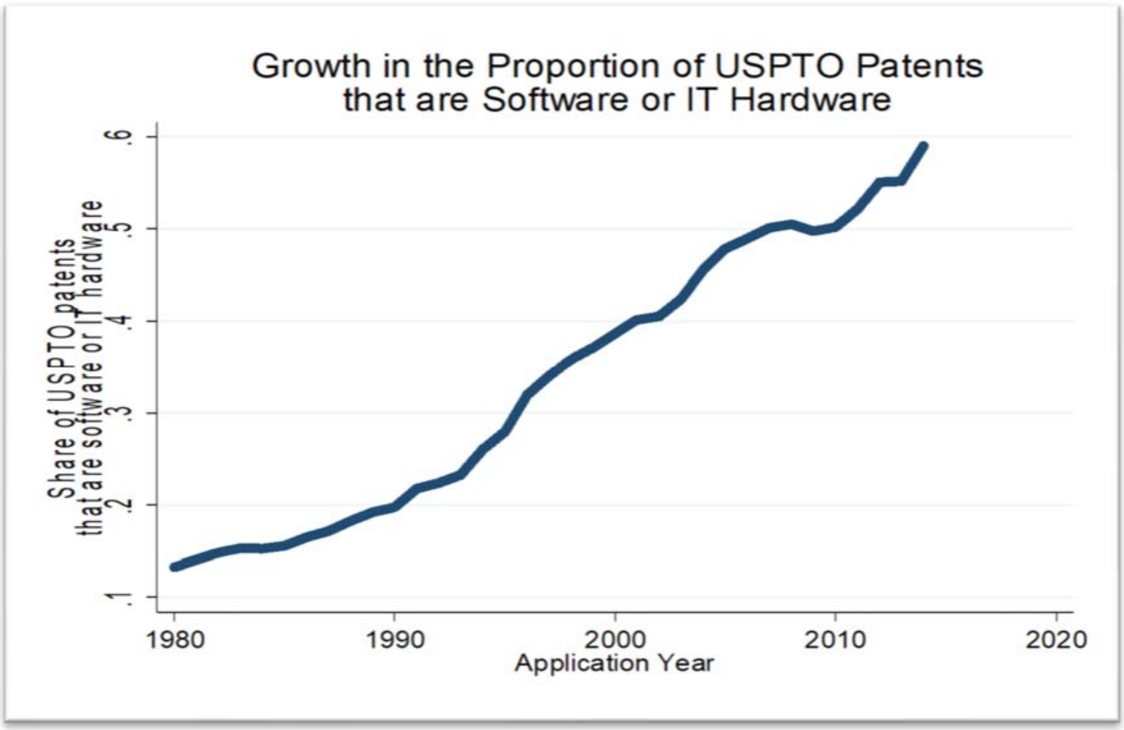



The figure conveys another important message – the apparently enduring reliance of foreign affiliates everywhere on intellectual inputs from U.S.-based research personnel. Examination of the patents generated by even mature, long-running research streams suggests an enduring centrality of US-based R&D facilities within US multinationals' global R&D systems. Patents generated by foreign research streams seem to show that the United States remains an important source of new ideas for all foreign hubs, even in the very long run and even in the most mature research streams. The measure of reliance on US intellectual inputs traced out in Figure 8 generally does not fall below 30 percent, suggesting that those who worry that the globalization of R&D will eliminate demand for US-based engineers might be overly pessimistic. Our results are consistent with those of Macher and Mowery (2008). Arora and Gambardella (2005b) hold a similar view for the India case, arguing that the type of software work offshored to India is software production rather than software design, which continues to be located in the United States.

## 7. The Growing Software and IT-Intensity of U.S. MNC Invention

Software and information technology (IT) patents have been growing in importance since the 1990s; as Figure 9 shows, the share of software patents in all USPTO patents grew from 6 percent in 1990 to nearly 40 percent by 2014. This growth is in aggregate, across all classes and firms, but in some industries, it is even more striking. More important than the simple fact that software/IT intensity in innovation is increasing is the evidence suggesting that firms that do not invest in software and IT are actually left behind. Arora, Branstetter, and Drev (2013) show that in the IT industry, the success of American IT firms relative to Japanese IT firms can be at least partially explained by their difference in software intensity. Japanese IT firms that were less software-intensive were actually less productive than their American counterparts; failing to invest more in software can harm a firm. Branstetter, Drev, and Kwon (2018) document that the importance of software is not limited to the IT sector; they show that innovation in four traditional manufacturing industries (autos and auto parts, aerospace and defense, medical devices, and pharmaceuticals) has also become more software-intensive.; Furthermore, firms that took a more software-intensive approach to innovation outperformed their less software-intensive peers.

Figure 9 Growth in Proportion of USPTO Patents That Are Software or IT Hardware




The increasing use of software and IT hardware in innovation is an important global technological development (Branstetter, Drev, and Kwon 2018). Engineers can now enhance product functionality increasingly through software engineering rather than mechanical, chemical, or electrical engineering. Decades of rapid advance in the computational power of microprocessors had, by the 1990s, created a suite of cheaper tiny computers that could be easily (re)programmed to direct the behavior of very different devices in increasingly sophisticated ways.[15] Advances in microprocessors were complemented by advances in sensors and digital control systems that made it easier for those electronic brains to alter the way these devices worked, often through rapid response to even fairly subtle changes in the devices' environment. As these trends advanced, software engineers built a steadily expanding menu of routines and subroutines in standardized languages that could be used and reused to direct the actions of different devices.

[15] Byrne, Oliner, and Sichel (2018) review the literature on rapid declines in the prices of semiconductor devices and show that these price declines continued through the 2010s.

The economic literature on general purpose technologies (Bresnahan and Trajtenberg 1995, Helpman and Trajtenberg 1998) can help us think about these developments as a new wave of technological change. The suite of basic hardware components that had “arrived” as early as the 1980s—microprocessors, sensors, memory, and digital control systems—was extremely broadly applicable, but every effective application required product- and industry-specific knowledge, embodied in the software that makes these standardized components work in fundamentally different contexts. So, firms across a broad range of industries needed to invest in IT and software engineering capabilities, and the intensity of this imperative increased over time.

The widespread use of software and IT in innovation has enabled and reinforced the globalization of R&D in two important ways. First, the inherently modular nature of IT hardware and software facilitates the division of innovative effort across multiple locations within an MNC. Because different components of a larger system fit together through standardized interfaces, product development of the components can take place simultaneously and, to some extent, independently. This capability allows multinational firms to decompose innovation in these domains into pieces that can be distributed to the location that can perform the R&D most efficiently. The emergence of modern telecommunications technologies centered on a global internet has enabled a richer, faster, cheaper exchange of data than was possible in earlier eras, and in some technological fields, software-enabled collaboration tools have been specifically developed to enable teams of engineers separated by distance to work on the same project. To put it differently, advances in IT and software have created technologies of collaboration that make cross-border R&D far more feasible. Then, a lead R&D center, possibly in the United States, can reassemble the constituent pieces to produce the full innovation.

All of this suggests that technology has partly driven the globalization of R&D documented here—as IT hardware and software have become much more important parts of the R&D portfolios of US firms, research in these domains is inherently easier to distribute across countries, and modern telecommunications and computer-aided design technologies facilitated the dense exchange of information (i.e., data) necessary to support cross-border collaboration in R&D.

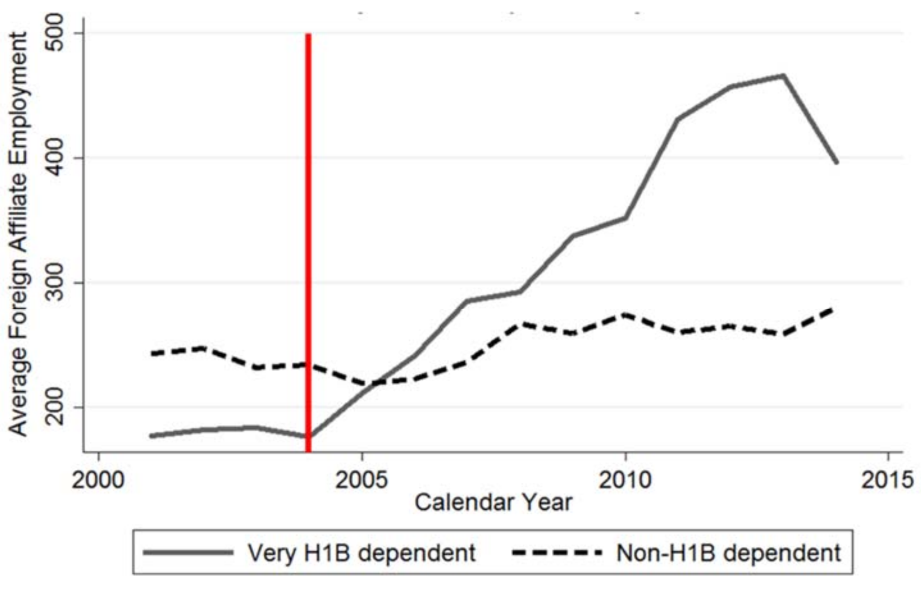
The second way in which the growing importance of software and IT in US innovation contributed to the globalization of R&D is in the human resources required to realize the benefits of the IT revolution. As demand for IT and software engineers expanded in the 1990s, the United States began importing foreign engineers on a large scale. Bound et al. (2015) document the increase in high-skilled foreign-born IT workers in parallel to the rising importance of IT in the United States. According to the National Survey of College Graduates,[16] the US IT workforce, made up of programmers, computer scientists, and electrical engineers, grew by 112 percent between 1993 and 2010, while the overall US workforce grew by only 70 percent. The share of foreign IT workers in total IT workers grew from 16 percent in 1993 to 32 percent by 2010. The H-1B visa program for skilled workers was one of the mechanisms through which foreign engineers were brought into the US labor market. This entire visa program become dominated by workers in “Computer-related” occupations. The annual quotas (i.e., the maximum number of new H-1B visas issued every year to private sector firms) were raised substantially during the internet boom of the 1990s. Arora, Branstetter, and Drev (2013) argue that the ability of

[16] National Science Foundation, National Survey of College Graduates, https://nsf.gov/statistics/srvygrads/.

American firms to access foreign-born software engineers enabled them to respond to technological opportunities much more effectively than their Japan-based rivals, reinforcing the speed and extent of the IT revolution in the United States.

However, while American firms were largely unconstrained in their ability to import foreign talent as needed to meet growing demand for IT and software workers in the 1990s, the H-1B annual quota was cut down to a quarter of its previous size in 2004, beginning a new era in which firms were increasingly constrained in their ability to hire foreign skilled workers. Access to talented engineers and programmers is critical for firms to stay at the technological frontier, and Glennon (2019) documents that many US multinational firms found a creative response to hire the foreign workers they needed anyway: when unable to hire the foreign labor they needed in the US, they simply hired it at their foreign affiliates instead, as shown in Figure 10. The figure, supported by extensive regression analysis, shows how multinational firms highly dependent on the H1-B visa system changed their foreign employment when the H1-B quota was lowered by roughly 75 percent. The relative change is clearly visible in the raw data, and the impact also clearly emerges in a series of careful difference-in-differences regressions.

**Figure 10 Changes in the Relative Foreign Employment of H1B-Dependent Firms**




Source: Glennon (2019)

Glennon also finds evidence that in addition to hiring more skilled labor abroad in response to skilled immigration restrictions, US multinational firms also opened more R&D-performing foreign affiliates and produced more patents abroad, suggesting that restrictions on importing foreign skilled labor were – and continue to be – an important driver of the globalization of R&D. In particular, the shift abroad was concentrated in three main countries: China and India – or those places from which companies had been recruiting engineers and IT workers – and Canada, whose skilled immigration regime made it possible for US multinational firms to easily hire the immigrant workers they needed at their Canadian foreign affiliates. In short, the demand for skilled labor has been a major driver of the globalization of R&D, and a combination of tightened skilled immigration policies and abundant supply of human capital abroad have been important drivers of the foreign R&D location choice.

These changes suggest an extremely large increase in demand for IT/software engineering talent that was partially met by importing talent from abroad in the 1990s, through mechanisms like the H-1B program, then met by moving high-skilled tasks abroad as immigration policy was tightened in the 2000s. A closer examination of the countries supplying this talent suggests that the supply of technically skilled workers is abundant in many of the same countries – notably India and China – where we see a parallel increase in US MNC foreign R&D activity. Applications for Indians made up 62% of new H-1B visa applications in 2016[17], and Indian and Chinese students combined made up 18% of doctorates in science and engineering from US universities in 2016[18], and this share is even larger for some key disciplines. If we view the large number of Indian and Chinese students pursuing graduate education at American research universities as the extreme right tail of a distribution of science and engineering talent, most of which remains at home, then this suggests a massive amount of software- and IT-trained human capital available in China and India. The abundant supply of engineering and technology graduates in emerging economies has also been documented in Arora and Gambardella (2005a) and Arora and Gambardella (2005b).

The evidence also suggests that the talent resident in key emerging markets has been available for hire at wages well below those prevailing in the United States. Within many US multinationals, the rise in demand for IT and software engineers was especially acute and the supply of foreign engineers in these disciplines was especially abundant. This leads to another important finding of our research – software-intensive and IT-intensive US multinationals rapidly expanded their R&D in emerging markets where high-quality human capital was available in relatively abundant supply.

Figure 11a relates the proportion of USPTO patents with developing country inventors to the country's software/IT hardware intensity. Figure 11b illustrates the strong positive correlation between US firm IT and software intensity[19] and their innovative activity in emerging markets.[20] The figure shows the positive correlation between US MNC aggregate R&D activity in a country, obtained from Bureau of Economic Analysis (BEA) aggregate data, and a country's software and IT hardware intensity,[21] conditioning on country fixed effects. These two graphs together suggest that foreign R&D is most pronounced in IT/software-intensive countries and that it is most intensively done by IT/software-intensive firms.

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[17] According to USCIS Fiscal Year 2016 Annual Report to Congress: "Characteristics of H-1B Specialty Occupation Workers."

[18] National Science Foundation, National Center for Science and Engineering Statistics, Survey of Earned Doctorates

[19] US firm IT and software intensity is measured as the firm's USPTO software or IT hardware patent stock, with software and IT hardware patents classified in the same way as described for country IT or software intensity.

[20] We define a firm's innovative activity in emerging markets as the proportion of its USPTO patents with an inventor from a non-high-income country, as classified by the World Bank (see note below figure 7a).

[21] We define a country's software or IT hardware intensity as the share of its cumulative USPTO citation-weighted patent stocks classified as software or IT hardware. We determine the location of a patent using inventor addresses; if an inventor lists their address on a patent in country *j*, we define that patent as originating in country *j*. Software is defined using the Arora, Branstetter, and Drev (2013) methodology, and IT hardware is defined using the Hall, Jaffe, and Trajtenberg (2001) NBER technology classification. We define IT hardware as encompassing the following NBER technology classifications: 21 (communications), 22 (computer hardware and software), 23 (computer peripherals), 24 (information storage), 41 (electrical devices), and 46 (semiconductor devices).

**Figure 11a  Affiliate R&D Expenditure and Host Country Software Intensity**

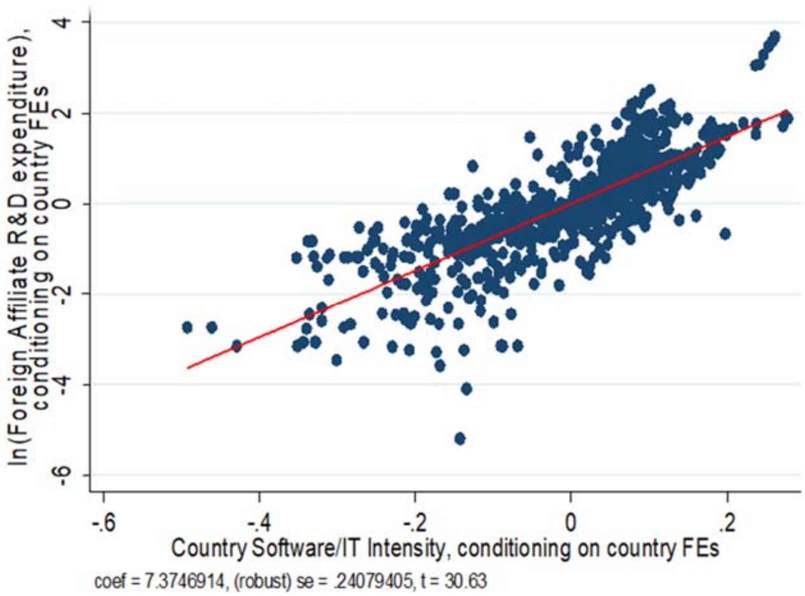
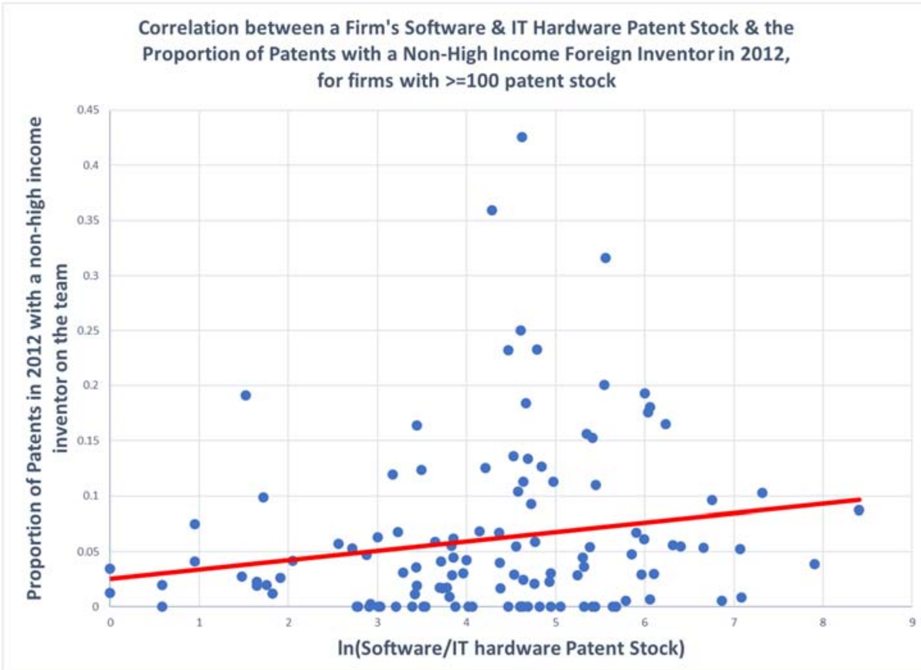


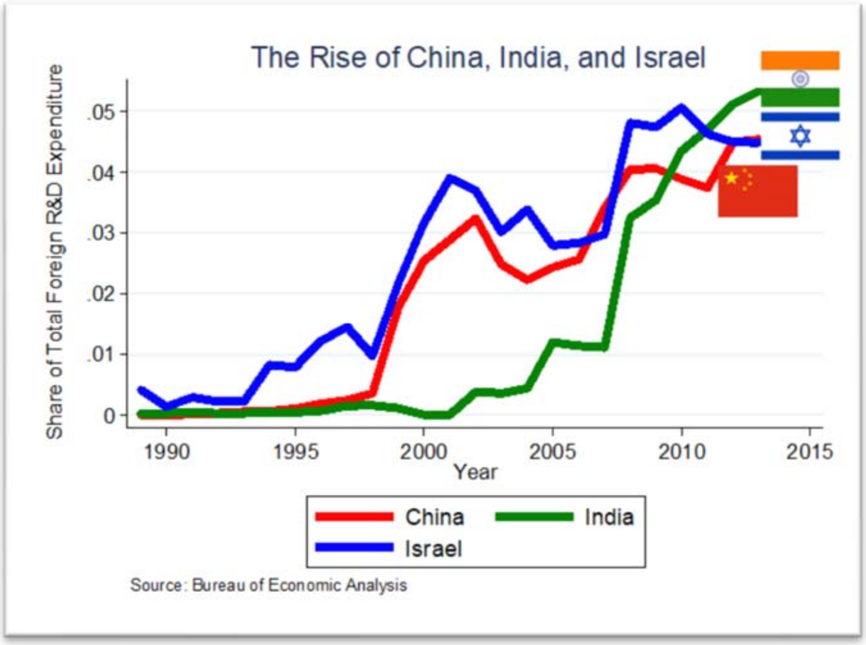

**Figure 11b  Firm Reliance on Developing Country Inventors and Firm-Level Software/IT-Intensity**




## 8. A Tale of Three (New) R&D Hubs

The technological shifts highlighted in the previous section help explain the geographic shift in U.S. MNC R&D activity outside the U.S. All "new" R&D hubs are not created equal – three, in particular, loom especially large in the growing global R&D networks of U.S. multinationals: China, India, and Israel. Figure 12 shows the growth in the fraction of global R&D expenditure accounted for by each of these three countries over time. This section draws upon both our empirical analysis and a series of interviews with country-based MNC R&D managers to illustrate how and why these particular nations have become disproportionate drivers of the market shift in the distribution of U.S. MNC R&D spending across countries. In all three places, local human resources in the IT/software domain were an important attractor.

**Figure 12: The Rise of China, India, and Israel**

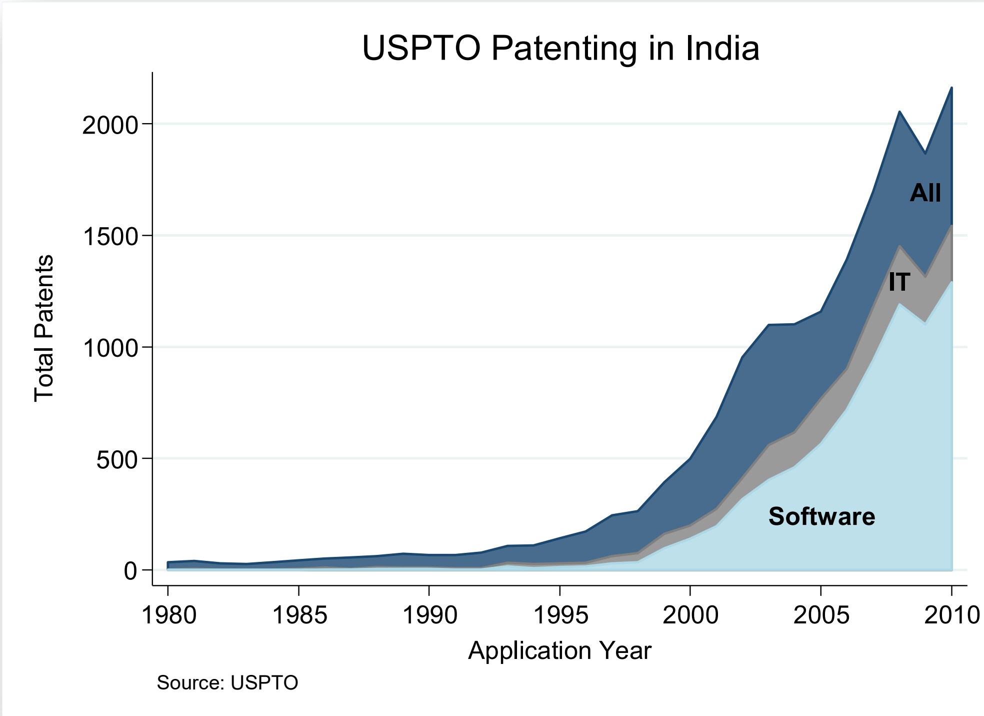



*A Passage to India*

Software invention looms large in the patents generated by U.S. MNC R&D affiliates in India, as indicated below, in Figure 13, and the abundance in India of relatively low-cost software engineers[22] was repeatedly emphasized in interviews as a reason for U.S. multinationals to expand their R&D activity in that country. India's success in exporting software and business process outsourcing services established the quality of Indian software engineers, and U.S. firms in these service sectors were especially aggressive at shifting some research and development activities to India. Largely because of that country's growing role, professional services is the U.S. industry with the most globalized R&D. In recent years, the ratio of R&D performed by foreign affiliates in professional services relative to that undertaken by the U.S. parents is over 40%, and India makes up an important component of this. Because software has increasingly become a critical input to innovation across the entire product space, manufacturers have joined services firms in meeting some of their demand for software engineering skill with Indian labor.

**Figure 13 USPTO Patents with Indian Inventors**

[22] Arora and Gambardella (2006) have described the sequence of developments that enabled India to produce such a large number of software engineers.




The Indian case also casts a particularly strong light on the difference between the "knowledge-seeking" motivation described in the earlier management literature and the search for talent we highlight here. U.S. multinationals were not investing in India to tap new technologies developed autonomously by indigenous Indian firms or to learn frontier science from pioneering Indian academic institutions. For the most part, the innovative capabilities of indigenous Indian firms are still viewed as quite limited compared to those of the multinationals resident in India. Therefore, one can draw a distinction between the knowledge-seeking FDI explored in the empirical literature of the 1990s and early 2000s and what seems to be happening in India. Multinationals are not seeking to tap into an indigenous body of knowledge, in the same way that they might have sought to tap into German chemical engineering capability or Japanese expertise in cutting edge consumer electronics in earlier decades. Instead, many multinationals were tapping "raw" Indian talent and integrating that talent into multinational R&D systems in which a significant amount of the intellectual leadership and direction still came from outside India (Branstetter, Glennon, and Jensen 2018). In the more mature and developed R&D centers, Indian staff are beginning to exert more intellectual leadership in some domains, but there is still a gap between indigenous and multinational innovation. Our interviewees consistently emphasized the importance of a common language and the role of the Indian diaspora in the United States in successfully integrating Indian talent into U.S. MNC R&D systems.

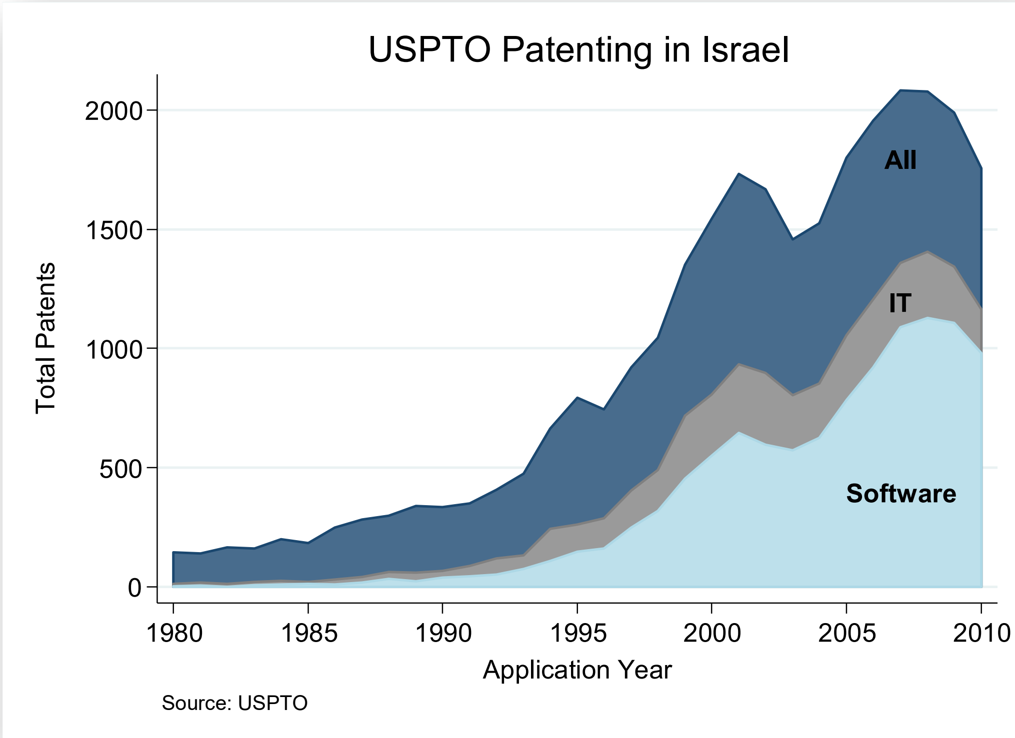
*Israel, the (R&D) Promised Land*

Figure 14, below, breaks USPTO patents with Israeli inventors down into various technology categories, with software and IT looming large, but not as large as in the Indian case. The attraction of human capital was also a major theme of our interviews in Israel, although the nature and genesis of that human capital differed in significant ways from the Indian case. Universal conscription of the Jewish population places much of the nation's human capital endowment under the authority of the military, and a rigorous battery of tests sorts the most intellectually gifted recruits into elite groups like Unit 8200, a signals intelligence unit that is often compared to America's National Security Agency. At a formative stage in their lives, young Israelis assigned to these units receive intensive exposure to high level computer science concepts and skills, and they are tasked with high-level, challenging software engineering tasks critical to Israeli national security. This experience often exerts a profound influence on the education and career choices of conscripts recruited into these units after their return to civilian life. American readers are invited to imagine the impact on the nation's software engineering workforce if the top one tenth of one percent of U.S. high school graduates could be locked in the basement of the National Security Agency for several years, given a crash course in digital intelligence, cyberwar, and cybersecurity, and required to produce mission-critical software products.

Almost by accident, the Israelis have created a unique set of institutions that steers a disproportionate fraction of their most gifted citizens into computer science related careers, and the stock of veterans of these elite units was growing to significant levels just as the global trajectory of innovation shifted in a way that made software more central to nearly every domain of technological innovation. Israeli per capita GDP still lags that of the U.S, but Israeli wages are not cheap. Nevertheless, MNCs are investing because the quality of Israeli human capital is distinctively high. Not surprisingly, domains of Israeli strength like cybersecurity and machine vision often have a connection to the military or intelligence functions that are the focus of investment by Unit 8200. Some Israeli firms in these domains have gone on to become major global leaders in their fields, and previous IPO success helped induce an impressive flow of energetic and creative Israeli start-ups. However, acquisition by a U.S. multinational is now a far more likely outcome for these start-ups than an IPO in the U.S. or elsewhere. Upon acquisition, the most successful start-ups often become Israel-based R&D hubs for the acquiring U.S. firms.

These acquisitions and the successful integration of the firms into the R&D operations of U.S. multinationals are partly enabled, once again, by a prominent Israeli diaspora in the United States. The interaction between Israeli and American financiers, scientists, and engineers is quite intense, especially when scaled to the size of the Israeli economy. Many Israeli senior managers of U.S. MNC R&D operations in Israel have family connections to the United States, received part of their education at an American university, and spent years in Silicon Valley before returning to Israel. On the other side, many prominent American managers, venture capitalists, and scientists have strong personal/family ties to Israel and have spent substantial time in that country. American multinationals are investing in Israel to take advantage of distinctive Israeli competencies, but we argue that these competencies have been jointly developed by Israel's unique human capital institutions, American firms, and the Israeli corporate entities they have established or acquired, rather than wholly developed by a cluster of indigenous firms.

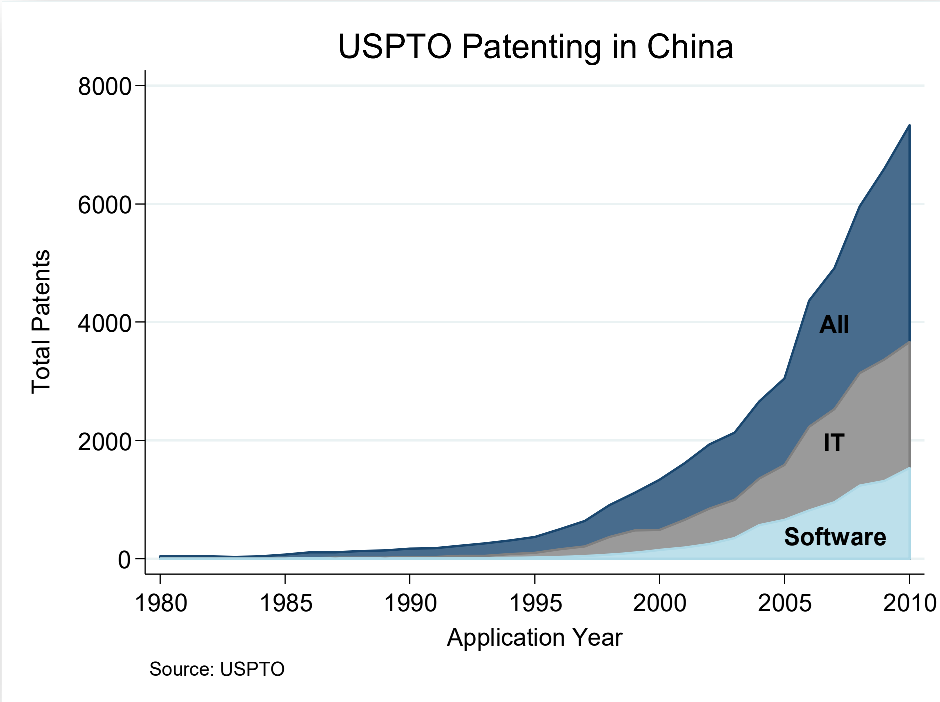
Figure 14 USPTO Patents with Israeli Inventors




*China: Enter the Dragon*

Multinational investment in China is a more complex phenomenon, as evidenced by the distribution of patents across technology classes, depicted in Figure 15 below. Interviewees maintained that the scale, cost, and quality of Chinese engineering talent was an important draw, and that Chinese engineers were involved in international teams creating inventions for the global market. Unlike in Israel or India, though, it was also apparent that multinationals conducting R&D in China were often seeking to (re)design Western technology for a Chinese market that is large and rapidly growing, but distinctive and different from high-income Western markets. In this new hub, there are clearly some older motives (market adaptation) for MNC R&D investment, as well as the newer ones we stress in this paper. It is also the case that Chinese R&D is more hardware-focused than Israeli or Indian R&D, reflecting China's emergence as the leading producer and exporter of IT hardware and components. As in Israel and India, the Chinese diaspora in the United States played an important role in helping U.S. multinationals recruit talent and navigate the complex business environment of contemporary China.

Figure 15 USPTO Patents with Chinese Inventors



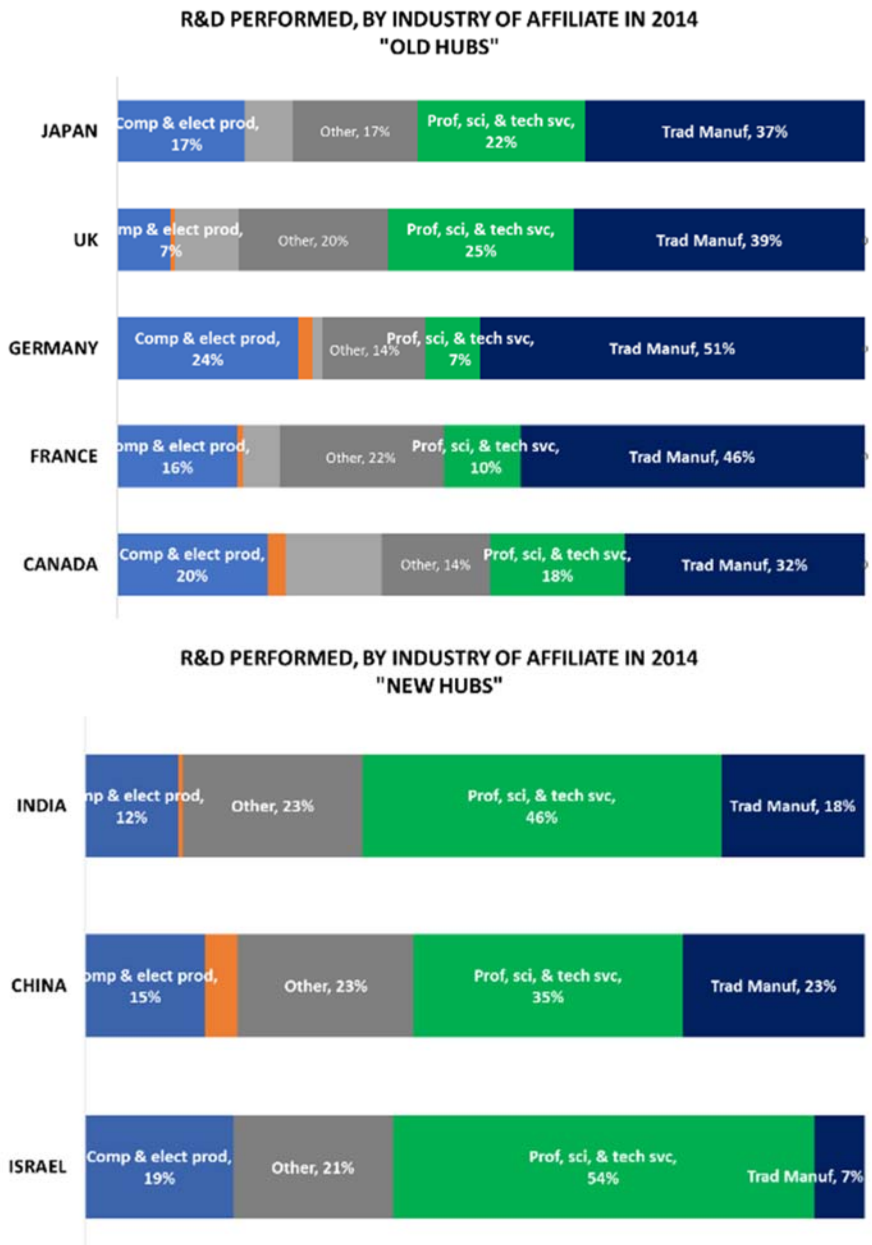

The presence of strong diasporas for all three of our new hubs is significant when considering findings from Kerr and Kerr (2015) and Foley and Kerr (2013), which show that the ethnic composition of a firm's inventors is associated with increases in the share of that firm's affiliate activity in countries related to that ethnicity.

## 9. R&D Globalization, Comparative Advantage, and the Role of non-U.S. MNCs

The growth in R&D in new hubs has been a significant driver of the overall increase in overseas R&D spending, but traditional hubs still remain an important component of the global R&D system created by US MNCs. Nevertheless, R&D performed by US MNC affiliates in the "new hubs" of China, India, and Israel is concentrated in different industries than in the traditional R&D hubs. R&D by affiliates in Germany, Japan, Canada, the United Kingdom, and France is concentrated in traditional manufacturing sectors such as chemicals, good, and machinery, while R&D by affiliates in China, India, and Israel is in professional, scientific, and technical services (a category dominated by software engineering). Figure 16 presents the breakdown of recorded expenditure across broad industry categories. It is a crude reflection of specialization in different kinds of R&D in different host nations, but it is hard to reconcile the number with the notion that R&D-performing affiliates are doing the same thing in these different countries. An alternative perspective, provided in Figures 10-11, revealed the distinctively high fraction of software and IT patents invented in Israel and India – these technological (as opposed to industry) domains are much less prominent in the patents generated in the traditional hubs.

No particular hub completely specializes in one domain, and, as we noted earlier, US-based coinventors play an important role in the innovative activities of all hubs. Nevertheless, the data reveal a clear pattern of specialization, with US MNCs clearly focusing their R&D investment in ways that reflect the distinctive relative strengths of the countries in which they are investing. The ability to access this broad range of strengths through a global R&D system helps maintain the innovative dynamism of US MNCs.

**Figure 16 Specialization According to Comparative Advantage?**




We now seek to relate this evidence to the problem of the global innovation slowdown noted in section 2. Regardless of whether the reader agrees with Robert Gordon (2016) that the inventions of our present and near future will fail to pack the productivity-enhancing punch of past inventions or aligns with the beliefs of Brynjolfsson and McAfee (2017) that we are on the verge of a new series of dramatic technological revolutions, in the long run, the compelling endogenous growth models of Jones (2009) and supportive evidence put forward by Bloom et al. (2019) suggest that innovative progress will require that an ever-increasing fraction of the human race be recruited to support human innovative efforts. If these efforts relied solely on brainpower already resident in the advanced industrial countries, the potential limits to these human resources would seem to be relatively proximate in time. Educated workers talented enough to participate in the advance of the technological frontier have many alternative, equally remunerative potential uses of their human capital and ability, and an ever-increasing fraction of talented workers could only be procured for the purposes of invention at an ever-increasing cost.

The recent massive expansion of higher education outside the advanced industrial countries – and particularly in China – raises the possibility that the developing world's innovation may be about to shift into overdrive at the same moment that the Western world's invention engine is faltering. Unfortunately, despite intense (and WTO-illegal) efforts to promote it, China's indigenous innovation abilities appear, at least so far, to fall short of those that exist in leading Western countries. The work of Jones (2014, 2015) suggests that highly specialized skills are complements for one another, but that the incentive to specialize only exists in "thick" markets for human capital, and it could plausibly take years or even decades before China's enterprises acquire the full stack of inventive capabilities patiently crafted over decades by the world's leading multinationals.

One of the central messages of this paper is that the world does not have to wait for Chinese or Indian enterprises to (re)invent this full stack of capabilities. The technological and organizational capabilities of the leading U.S. multinationals provide mechanisms and frameworks through which the growing ranks of talented Chinese, Indian, and Israeli engineers can be plugged into globalized R&D systems that already possess this full stack. While our exposition and figures have emphasized the interaction of U.S.-based inventors with foreign teams in a particular country, U.S. MNCs can also pair an Indian software engineer with a German mechanical engineer or a Japanese electrical engineer, as the circumstances warrant. The matching possibilities and achievable team configurations within these MNC networks could have first-order implications for future research productivity, because the sobering models of Jones (2009) suggest that it is not only the scale of R&D teams, but also their diversity that contributes to R&D outcomes.

An extensive, though mostly descriptive literature on national "innovation systems" has already made the point that different nations tend to involve different R&D systems with different strengths and weaknesses (Nelson, 1992; Okimoto and Rohlen, 1988; Mansfield, 1988a,b, Branstetter and Kwon, 2018). Because the components of these systems co-evolve over long periods of time and tend to cohere together in mutually reinforcing ways, it often proves quite difficult to transplant a conspicuously successful element from one national system into another. Germany, the nation that invented research universities and dominated the earliest science-intensive industries, has struggled in the postwar era to incubate a start-up infrastructure like that associated with Silicon Valley in the U.S. – a particular painful setback came in the early 2000s with the collapse of Germany's Neuer Markt. Around the same time, the nation's efforts to lure immigrant engineers from source nations like India generated a significant backlash and yielded little in the way of results. Conversely, the U.S. has struggled to transplant German institutions like the vocational training systems and applied Fraunhofer Institutes that have contributed significantly to the export strength of Germany's mittelstand. The rise of globalized R&D networks within MNCs means that no single nation – not even the most advanced – needs to contain within its borders the full stack of capabilities in order for enterprises to utilize them. These international systems broaden the array and diversity of invention teams that can be created, raising the productivity of R&D investment.

This essay has emphasized the role of U.S. MNCs in the creation of global R&D networks, but existing research makes it clear that U.S. firms are not the only firms that have created such networks. Related studies suggest that Japanese firms (Branstetter, 2006) and British firms (van Reenen et al., 2006) have created global networks of R&D-performing affiliates that route useful knowledge back to the parent firm. Unfortunately, a full exploration of recent developments within non-U.S. multinationals is limited by the lack of data. Few nations maintain a database on multinational activity as extensive and comprehensive as the BEA data upon which we rely, so a quantitatively precise assessment of the relative role of U.S. multinationals within the broader phenomenon of R&D globalization is well beyond the scope of this paper and may be all but impossible given current data constraints. What seems likely, however, is that U.S. firms play an especially important role, for many reasons, of which we will here highlight two. We have noted, in many places in this essay, the apparent importance of an ethnic diaspora in helping connect U.S. firms to foreign sources of talent. As resident firms within an immigrant nation that hosts many multinationals, U.S. MNCs may have a decided advantage over those based elsewhere, an idea that gets some evidentiary support in Arora et al. (2013), Branstetter et al. (2018), and Foley and Kerr (2016). Secondly, this paper has stressed the particular salience of IT and software in R&D globalization, and these are sectors in which U.S. firms have been traditional leaders, especially in the latter domain.

## 10. Policy Challenges to the Global Innovation System

Over the past 20 years, the growing importance of software and IT has driven US MNCs to significantly increase the scale and scope of their R&D activities outside the United States. New R&D hubs like China and India are not only yielding high returns for US MNCs but also, as hosts of these R&D activities, benefiting directly from the innovation supported by US MNCs and indirectly from spillovers through technology transfers to local firms. The globalization of R&D activity, and the global innovation system it supports, has the potential to increase global productivity growth—a mutually beneficial opportunity for the entire world.

Yet, in spite of the promise this opportunity brings, a number of policy challenges threaten the continued health of the global innovation system. As already noted, the trade policies of the Trump administration increasingly pose a risk to the global innovation system. It may take years before data are available to measure the impact of these policies on global R&D activity, but the risk that they will decrease cross-border collaboration is real.

We have also emphasized how critical skilled immigration is for the global R&D system. Immigrant engineers have long served as a human bridge between their American employers and the research communities in their former countries (Foley and Kerr 2013). While the current

U.S. Administration has undertaken recent policy shifts to reduce immigration, these follow a substantial decline in annual H-1B visa quotas implemented more than a decade ago that have have measurable effects on the global allocation of high-skilled tasks within U.S. multinationals, as shown by Glennon (2019).[23] The EU nations and Japan have long maintained relatively more restrictive immigration policies, which hold back their own economic growth. A greater global commitment to (skilled) immigration and temporary movement would facilitate the development of a more global R&D system.

Another ongoing concern is the protection of intellectual property. Prior research documents that stronger intellectual property rights in reforming countries attract more investment and more technologically intensive MNC activity (Branstetter, Fisman, and Foley 2006; Branstetter and Saggi 2011; Bilir 2014). The shortcomings of enforcement systems in China and India are particularly salient, because both countries have so much to contribute to human innovation through greater participation in a global R&D system. R&D managers we interviewed suggest that global MNCs would invest more in R&D-intensive activity in China if intellectual property were better protected there and technology transfers were not forced. Likewise, the unwillingness of the Indian government to enact pharmaceutical patent reform truly consistent with the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) has gravely discouraged MNCs from investing in R&D in the Indian pharmaceutical industry. This is a major lost opportunity, given this sector's rising potential (Arora, Branstetter, and Chatterjee 2008). Strengthening intellectual property rights in places where they are currently weakly protected would foster a more robust global innovation system.

This essay has repeatedly emphasized the rising importance of software and IT in the broader innovation activities of U.S. multinationals, and it has offered up evidence in support of the idea that the growing software/IT-intensity of innovation has powerfully reinforced the globalization of R&D. In this broader context, it is clear that a global innovation system will depend on the free flow of data between the R&D facilities of MNCs. Efforts that restrict these data flows (for example, forced data localization) could pose a significant impediment to the operation of such a system. A greater global commitment to the free international flow of data, with appropriate safeguards to ensure privacy and other important social goals, could help ensure the healthy development of a global R&D system. Of course, these considerations make clear that national efforts to close the internet of particular nations to the broader global system constitute a serious impediment to international trade in ideas. China's distinctive digital protectionism will become a more important challenge to the global trading system as the importance of international data flows continues to rise.

The last challenge is the emerging Western response to an increasingly authoritarian and ambitious China. China is an important destination for US MNC R&D and an important supplier of scientists and engineers to the US education system and US firms. The current U.S.

[23] For example, President Trump signed a "Buy American and Hire American" executive order, directing government officials to "rigorously enforce" immigration laws. As a result, more H-1B and L-1 visa applications have been rejected, with rejection rates for H-1B visas tripling. Starting in April 2018, the Trump administration suspended premium processing of H-1B petitions subject to the visa cap. In November 2018, the administration introduced a new Labor Condition Application form requiring more information from companies applying for H-1B visas, which some believe might reduce interest in H-1B visas. The Trump administration is also proposing changes to the H-1B visa application process. These changes, at a minimum, increase uncertainty around the visa process.

administration has sought to limit technology transfers and exchange of researchers (e.g., by limiting visas to Chinese engineers) in a series of policies that look increasingly like an attempt to decouple the US and Chinese economies. This essay does not assess the relative merits of a US policy of economic engagement with China versus a US policy seeking to isolate it economically. But a major bipartisan shift is under way with regard to how best to engage (or not) with China in the hopes of incentivizing changes in its political and economic behavior. It is difficult to foresee how the economic relationship between China and the United States will evolve, but the current direction will likely harm the global R&D system. The potential costs and benefits of having China inside the global innovation system should be carefully weighed in any reassessment of these policies. Branstetter (2018) outlines a series of policies that could provide a useful response to the challenges China presents, while maintaining a significant degree of economic integration.

## References


Arora, A., L. Branstetter, and C. Chatterjee. 2008. Strong Medicine: Patent Reform and the Emergence of a Research-Driven Pharmaceutical Industry in India. Paper prepared for NBER Conference on Location of Biopharmaceutical Activity, March 6–8.

Arora, Ashish, Lee G. Branstetter, and Matej Drev. 2013. Going Soft: How the Rise of Software-Based Innovation Led to the Decline of Japan's IT Industry and the Resurgence of Silicon Valley. *Review of Economics and Statistics* 95, no. 3: 757–75.

Arora, Ashish, and Alfonso Gambardella, eds. 2005a. *From Underdogs to Tigers: The Rise and Growth of the Software Industry in Brazil, China, India, Ireland, and Israel.* Oxford University Press.

Arora, Ashish, and Alfonso Gambardella. 2005b. The Globalization of the Software Industry: Perspectives and Opportunities for Developed and Developing Countries. *Innovation Policy and the Economy* 5: 1–32.

Bilir, Kamran. 2014. Patent Laws, Product Life-Cycle Lengths, and Multinational Activity. *American Economic Review* 104, no. 7: 1979–2013.

Bloom, Nicholas, Charles Jones, John Van Reenen, and Michael Webb. 2017. *Are Ideas Getting Harder to Find?* NBER Working Paper 23782. Cambridge, MA: National Bureau of Economic Research.

Bound, John, Breno Braga, Joseph M. Golden, and Gaurav Khanna. 2015. Recruitment of Foreigners in the Market for Computer Scientists in the United States. *Journal of Labor Economics* 33, no. S1: S187–223.

Branstetter, Lee, 2018. *China's Forced Technology Transfer Problem—and What to Do About It.* PIIE Policy Brief 18-13. Washington: Peterson Institute for International Economics.

Branstetter, Lee, and Kamal Saggi. 2011. Intellectual Property Rights, Foreign Direct Investment and Industrial Development. *Economic Journal* 121, no. 555 (September): 1161–91.

Branstetter, Lee, and Daniel Sichel. 2017. *The Case for an American Productivity Revival*. PIIE Policy Brief 17–26. Washington: Peterson Institute for International Economics.

Branstetter, Lee G., Raymond Fisman, and C. Fritz Foley. 2006. Do Stronger Intellectual Property Rights Increase International Technology Transfer? Empirical Evidence from US Firm-Level Panel Data. *Quarterly Journal of Economics* 121, no. 1 (February): 321–49.

Branstetter, Lee, Matej Drev, and Namho Kwon. 2018. Get With the Program: Software-Driven Innovation in Traditional Manufacturing. *Management Science* 65, no 2: 541–58.

Branstetter, Lee, Britta Glennon, and J. Bradford Jensen. 2018. *Knowledge Transfer Abroad: The Role of US Inventors within Global R&D Networks.* NBER Working Paper 24453. Cambridge, MA: National Bureau of Economic Research.

Branstetter, Lee G., Britta Glennon, and J. Bradford Jensen. 2019. The IT Revolution and the Globalization of R&D. *Innovation Policy and the Economy* 19: 1–37.

Branstetter, Lee, Guangwei Li, and Francisco Veloso. 2015. The Rise of International Co-Invention. In *The Changing Frontier: Rethinking Science and Innovation Policy*, ed. Adam B. Jaffe and Benjamin F. Jones, 135–68. Chicago, IL: University of Chicago Press.

Branstetter, Lee, Guangwei Li, and Francisco Veloso. 2016. *Bridge to Excellence The Impacts of International Coinvention on Multinational R&D in China*. Unpublished Working Paper.

Bresnahan, Timothy F., and M. Trajtenberg. 1995. General Purpose Technologies "Engines of Growth"? *Journal of Econometrics* 65, no. 1: 83–108.

Brynjolfsson, Erik and Andrew McAfee, (2014), The Second Machine Age: Work, Progress, and Prosperity in an Age of Brilliant Technologies, W. W. Norton, Cambridge.

Byrne, David M., John G. Fernald, and Marshall Reinsdorf. 2016. Does the United States Have a Productivity Slowdown or a Measurement Problem? *Brookings Papers on Economic Activity* (Spring): 109–82.

Byrne, David M., Stephen D. Oliner, and Daniel E. Sichel. 2018. How Fast Are Semiconductor Prices Falling? *Review of Income and Wealth* 64, no. 3: 679–702.

Fernald, John G., and Charles Jones. 2014. The Future of US Economic Growth. *American Economic Review: Papers & Proceedings* 104, no. 5: 44–49.

Foley, C. Fritz, and William R. Kerr. 2013. Ethnic Innovation and U.S. Multinational Firm Activity. *Management Science* 59, no. 7: 1529–44.

Freeman, Richard B., and Wei Huang. 2015. China's "Great Leap Forward" in Science and Engineering. In *Global Mobility of Research Scientists: The Economics of Who Goes Where and Why*, ed. Aldo Guena, 155–75. Academic Press.

Furman, J. L., Porter, M. E. and Stern, S. (2002) 'The determinants of national innovative capacity', *Research Policy*, 31(2002), pp. 899–933.

Glennon, Britta. 2019. *How Do Restrictions on High-Skilled Immigration Affect Offshoring ? Evidence from the H-1B Program*. Unpublished Working Paper.

Gordon, Robert J. 2016. *The Rise and Fall of American Growth: The U.S. Standard of Living since the Civil War.* Princeton, NJ: Princeton University Press.

Hall, Bronwyn H., Adam B. Jaffe, and Manuel Trajtenberg. 2001. *The NBER Patent Citations Data File: Lessons, Insights and Methodological Tools*. NBER Working Paper 8498. Cambridge, MA: National Bureau of Economic Research.

Helpman, Elhanan, and Manuel Trajtenberg. 1998. A Time to Sow and a Time to Reap: Growth Based on General Purpose Technologies. In *General Purpose Technologies and Economic Growth*, ed. Elhanan Helpman, 55–83. Cambridge, MA: MIT Press.

Hufbauer, Gary Clyde, Theodore H. Moran, and Lindsay Oldenski, assisted by Martin Vieiro. 2013. *Outward Foreign Direct Investment and US Exports, Jobs, and R&D: Implications for US Policy*. Policy Analyses in International Economics 101. Washington: Peterson Institute for International Economics.

Jones, Benjamin F. 2009. The Burden of Knowledge and the "Death of the Renaissance Man": Is Innovation Getting Harder? *Review of Economic Studies* 76: 283–317.

Jones, Benjamin F. November 2014. "The Human Capital Stock: A Generalized Approach" *American Economic Review*, 104 (11).

Jones, Benjamin. July 2014. "The Knowledge Trap: Human Capital and Development Reconsidered"

Kerr, Sari Pekkala, and William R Kerr. 2018. Global Collaborative Patents. *Economic Journal* 128, no. 612: 1–38.

Krugman, Paul. 1992. *The Age of Diminished Expectations: U.S. Economic Policy in the 1990s.* Cambridge, MA: MIT Press.

Macher, Jeffrey T., and David C. Mowery, eds. 2008. *Innovation in Global Industries: U.S. Firms Competing in a New World (Collected Studies*). Washington: National Academies Press.

National Science Board. 2016. *Science and Engineering Indicators 2016* (NSB-2016-1). Arlington, VA: National Science Foundation.

Syverson, Chad. 2017. Challenges to Mismeasurement Explanations for the US Productivity Slowdown. *Journal of Economic Perspectives* 31, no. 2: 165–86.