RAND's Rose-Colored Glasses: How RAND's Report on U.S. Competitiveness in Science and Technology Gets it Wrong

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RAND's report contains serious structural and analytic flaws that misread the fundamental position of U.S. science and technology, and economic, competitiveness.

Over the last several years a number of reports have raised concern about the growing challenge to U.S. science and technology (S&T) leadership – and long-term economic competitiveness – from both rapidly developing Asian nations and European countries with a renewed competitive focus. Reports such as *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future, The Knowledge Economy: Is the United States Losing Its Competitive Edge?,* and *The Looming Workforce Crisis*[1] collectively argued that the United States faces intensifying foreign competition in science and technology, and that the country is falling behind in key building blocks of the S&T base, specifically its research and development infrastructure, science and engineering (S&E) workforce, and math and science education.[2]

Now bursting onto the scene is a new report, *U.S. Competitiveness in Science and Technology,* from the RAND Corporation which seeks to evaluate the relevance of S&T to assessments of national competitiveness, to ascertain the effects of globalization on S&T in the United States, and to assess the current state of U.S. S&T competitiveness by reviewing key input, output, and outcome indicators.[3] The authors argue that the United States continues to lead the world in most key science and technology measures and that therefore the "clarion call" of concern about threats to the state of U.S. S&T competitiveness is alarmist and overblown.[4] The report has received attention in the policy debate regarding the state of U.S. S&T competitiveness, and has left many questioning the legitimacy of calls for concern about the strength of the U.S. S&T enterprise.

However, RAND's report contains serious structural and analytic flaws that misread the fundamental position of U.S. science and technology, and economic, competitiveness. While this brief is not a definitive response – ITIF will release a comprehensive report this November detailing the state of U.S. competitiveness vis-a-vis leading European and Asian countries – it provides an overview of what we believe to be the report's key limitations. These include:

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- Framing the wrong fundamental question regarding the S&T competitiveness debate;
- Providing an incomplete historiography of U.S. S&T policy development, particularly policies developed in response to previous challenges to U.S. S&T competitiveness;
- Using inappropriate or incomplete benchmark metrics to assess U.S. S&T and economic competitiveness;
- Under-emphasizing within the report a number of indicators that clearly demonstrate trends of weakening U.S. S&T competitiveness;
- Failing to include certain key measures needed to deliver a true assessment of U.S. S&T competitiveness; and
- Using available time-series data sets – ending by 2003 at the latest in most cases – that are not reflective of the competitive challenge that has emerged since 2000 and do not adequately reflect the competitive landscape of mid-2008.

To be clear, we do not disagree with the authors' contention that the United States *currently leads* the world in science and technology.[5] But this is not the fundamental question of the competitiveness debate. Rather, the relevant question is whether the United States is adopting sufficiently effective policies to *maintain* that lead in the face of: 1) both rapidly growing and increasingly sophisticated Asian competitors and European countries that have awakened to the competitiveness challenge by implementing concerted national S&T and innovation strategies; and 2) trends that clearly show the U.S. lead on many key competitiveness indicators eroding – and in several cases vanishing.

To argue that concerns about the state of U.S. S&T competitiveness are overblown because the United States *currently leads* the world in science and technology and has come out ahead in previous challenges is like the CEO of General Motors proclaiming that his firm, its employees and shareholders, should have little cause for concern because General Motors *currently leads* the world in automobile market share, always has, and has emerged from previous competitive scraps still ahead. A true picture of the situation would need to reveal key trends that its competitors have substantially eroded GM's global and North American market share, that its top competitor Toyota is now within one percentage point of overtaking GM's market share leadership in its home market, and that, with regard to the environmentally-conscientious vehicles that its customers will increasingly demand, its top competitor has sold 1.5 million hybrid vehicles to date, while it has sold less than 15,000.[6] Calls for concern about the state of GM's long-term competitiveness would be warranted, in spite of its global leadership on key measuring sticks such as corporate size and market share. Likewise, the fact that the United States currently leads the world on most science and technology indicators is no assurance that it will continue to do so or that its leadership position is not under imminent threat.

Previous S&T and industrial competitiveness challenges to the United States were in fact real – and met head-on with proactive reforms to U.S. S&T policies and strategy.

IS THE CLARION CALL WARRANTED?

The authors make four key arguments to allay concern that U.S. S&T leadership is imminently threatened:

1) Previous warnings that U.S. S&T competitiveness was under threat proved to be false alarms, as evidenced by continued U.S. leadership in the field over the past three decades, so current warnings must likewise be groundless; 2) the concern about S&T competitiveness is misguided, because downstream innovation is more important than upstream innovation and because countries do not really compete anyway, only their companies do; 3) the globalization of innovation is an asset, not a threat, to U.S. innovation and S&T leadership; and 4) whether or not national competitiveness in S&T is a legitimate topic, the United States is in fact currently the world leader in science and technology, so there is little cause for alarm. We consider the first four arguments in turn, along with a fifth, not explicitly stated in the report but implicit in its reasoning, that trends demonstrating an eroding U.S. advantage (where that advantage persists) are generally not of impending concern.

Previous Warnings That U.S. S&T Leadership Was Threatened Turned Out to Be False Alarms; Current Warnings Are Likely to Be as Well

The authors suggest that one cause for skepticism regarding current concern for U.S. S&T competitiveness is that similar warnings in the past turned out to be false alarms, and current warnings are likely to be false alarms as well. The authors first reference a *Washington Watch* article claiming that "similar fears of a STEM workforce crisis in the 1980s were ultimately unfounded."[7] Continuing this line of argument, the authors cite Cato Institute policy analyst Neal McCluskey:

> Using the threat of international economic competition to bolster federal control is nothing new. It happened in 1983, after the federally commissioned report *A Nation at Risk* admonished that, "our once unchallenged preeminence in commerce, industry, science, and technological innovation is being overtaken by competitors throughout the world" as well as the early 1990s, when George Bush the elder called for national academic standards in order to better compete with Japan.[8]

Thus, since the United States ultimately retained its lead in science and technology through the competitiveness challenges of the 1980s, then-calls for concern were unfounded, as current ones are likely to be. What this rosy assessment ignores entirely is that policymakers in the early- to mid-1980s took warnings seriously and responded by instituting a comprehensive set of policy measures and other changes to meet challenges to U.S. competitiveness in science, technology, and industry.

The United States passed the Bayh-Dole Act and enacted the Stevenson-Wydler Technology Innovation Act of 1980, launched the Advanced Technology Program (ATP) and Manufacturing Extension Program (MEP), created SEMATECH to support the nascent U.S. semiconductor industry, established the Malcolm Baldrige National Quality Award, and put in place the R&D tax credit.[9] Legal changes enacted in the 1984 National Cooperative Research Act led to an explosion of cross-industry consortium-based research by removing a defect of anti-trust law that suggested collaborative, joint research efforts amongst corporations were potentially collusive.[10]

To take one example, the Bayh-Dole Act transformed the relationship between federal research, academic institutions and their researchers, and the commercial marketplace. It transferred ownership of an invention or discovery from the government agency that had helped to pay for it to the academic institution that had carried out the actual research, and it provided academic researchers with incentives to exploit their ideas. Regarding the Bayh-Dole Act alone, *The Economist* wrote that it was:

> Possibly the most inspired piece of legislation to be enacted in America over the past half-century… It unlocked all the inventions and discoveries that had been made in American laboratories throughout the United States with the help of taxpayers' money. More than anything, this single policy helped to reverse America's precipitous slide into industrial irrelevance.[11]

That feared STEM workforce crisis of the early 1980s? It never materialized largely because the U.S. increased immigration of foreign S&E professionals at the time.[12]

What this rosy assessment ignores entirely is that policymakers in the early-mid 1980s took warnings seriously and responded by instituting a comprehensive set of policy measures and other changes to meet challenges to U.S. competitiveness in science, technology, and industry.

Thus, the authors have presented an incomplete historiography of U.S. S&T policy development. On the contrary, previous S&T and industrial competitiveness challenges to the United States were in fact real – and met head-on with proactive reforms to U.S. S&T policies and strategy. To argue today that there is no rationale for responding to the challenges to U.S. S&T competitiveness is a fundamentally risky strategy that no effective corporation would ever undertake.

The Concern About National S&T Competitiveness is Misguided Anyway

The authors present two arguments for why leadership in science and technology may not really matter to the competitiveness debate anyway. The first contends that the downstream innovation which commercializes inventions into desirable offerings through attractive design, marketing, and business models is more important than the upstream innovation with which fundamental scientific research and technological development are concerned. The second holds that national competitiveness is a misguided concept in the first place because countries do not really compete, only their companies do.

Strength in downstream innovation is more important than strength at upstream technological invention. To make this case, the authors cite work by Columbia University Professor Amar Bhidé, who argues that there exists a general misunderstanding of how innovation contributes to economic growth. First, Bhidé posits, too much attention is paid to upstream development of new inventions and technologies by scientists and engineers and too little to the downstream process of commercialization that turns these inventions into products.[13] The second misconception, he asserts, is the belief that national leadership in upstream S&T activities is the same thing as general leadership in generating economic value from innovation. Since (in Bhidé's view) most of the value of innovations accrue to their users and not their creators, and stays in the country where the innovation is consumed, if China and India generate more *invention*, then so much the better for American consumers (especially as U.S. firms are likely to do a better job at translating those *inventions* into commercially-profitable *innovations*).[14]

But Bhidé presents a false choice, for there is no reason why the United States should not seek global leadership in both the upstream development of new technologies and inventions by scientists and engineers and the downstream activities that realize effective commercialization of innovations. UC Irvine Professor Kenneth Kraemer has performed extensive research into how countries and their companies capture value within global innovation networks. His research into the value chain for notebook PCs reveals that the United States realizes substantial value-added from the Intel processor and Microsoft operating system. For example, the U.S. share of value capture from a $1,400 HP notebook computer accounts for 87 percent of the total value (when the sale of the computer occurs in the United States), with Intel's processor and Microsoft's Windows operating system accounting for 15 percent of the notebook's value-added, distribution and retail for 25 percent of the value-added, and HP's margin at 12 percent.[15] Kraemer finds that much of the value of innovation actually accrues to the parties that control the standards and define the market, meaning that U.S. technology embodied in microprocessor chips and Windows operating systems is just as important as HP's or Apple's ability to sell shiny notebooks or iPods with effective marketing campaigns and novel business models.[16] Moreover, the best engineers and entrepreneurs in America could not have produced iPods, computers, or GPS devices had it not been for fundamental research conducted in quantum mechanics. Countries benefit from demonstrating strength at both the upstream and downstream aspects of invention and innovation, respectively. In fact, not only are the twain not mutually exclusive, they actually operate complementarily.

Lastly on this point, the authors' invocation of Bhidé's venturesome consumption (demand-oriented) thesis is strange given their flat assertion elsewhere in the report that, "Technological and scientific innovation is the engine of U.S. economic growth, and human talent is the main input that generates this growth," suggesting that the authors themselves ascribe a very high degree of importance to upstream innovation.[17]

Countries do not really compete, only their companies do. Secondly, in questioning whether the notion of competition in S&T is even relevant, the authors resurrect an old argument from economist Paul Krugman. Krugman has posited that the idea that nations "compete" is incorrect; countries are not like corporations and "are [not] to any important degree in economic competition with each other."[18] This is quite a contention; let's examine its rationale.

Krugman reasons that, while companies within a nation do sell products that compete with each other, the companies and consumers in these nations are also simultaneously each other's main export markets and suppliers of useful imports. Since international trade is not a zero-sum game (in Krugman's view), even if European or Asian countries gain a larger share of global high value-added production, this benefits the United States (in a win-win relationship) by providing it with larger export markets and access to superior goods at a lower price. Moreover, because approximately ninety percent of the U.S. economy consists of "non-traded" goods and services created for domestic use and only ten percent of the U.S. economy is comprised of exports for trade, Krugman argues that the growth rate of U.S. living standards essentially equals the growth rate of domestic productivity, not U.S. productivity relative to competitors.[19] Thus, it is the non-traded (domestic) sectors of an economy that really drive its productivity and growth, and therefore countries are not really competing against one another for economic pre-eminence.

But Krugman's argument misses on one critical account: he underestimates the importance that a high value-added traded sector provides to an economy. While the domestic sector of an economy does account for the majority of its activity and opportunities for productivity growth, this does not mean that the traded sector of an economy is not an extremely important driver of its productivity growth due to its own activities as well as to spillover effects. Krugman is right that the primary way economies boost per-capita income growth over the medium and longer term is to increase productivity. Nations can achieve this in two ways. One is for existing firms to become more productive, such as by using new technologies or improving workers' skills; the second is for firms in low productivity sectors to be replaced by firms in high productivity sectors. Across-the-board productivity growth (the growth effect) and shifts in the mix of establishments toward more productive ones (the mix effect) both contribute to an increase in a nation's productivity and average incomes.

So Krugman is correct that non-traded sectors do drive much of an economy's productivity (the growth effect). In fact, many countries under-value the non-traded sectors of their economy, particularly with regard to service sectors, focusing economic policy almost entirely on the export sector to the exclusion of domestic sectors. For example, despite extremely productive and innovative multinational firms, overall Japanese productivity is just 70 percent of the U.S. productivity rate, and South Korea's productivity is just 50 percent of U.S. levels.[20] Indian retail banking is but nine percent as productive as U.S. levels and its retail goods sector is only six percent as productive. In fact, if India could raise productivity in those two sectors to just 30 percent of U.S. levels, it would raise its standard of living by over 10 percent. However, this does not mean that the traded sector of an economy is not extremely important to its overall performance, for several reasons. First, there are considerable geographic spillover effects from a healthy, high-value added export sector because it leads to growth in the domestically traded sector (the growth effect.) Second, the growth of high-value added sectors – a pre-dominant share of which are traded technology or information technology jobs – changes the mix (the mix effect).

Krugman is simply reflecting the conventional neo-classical economic wisdom, which holds that what a country makes does not matter. As a senior economic advisor in the first Bush administration quipped, "Potato chips, computer chips, what's the difference? A hundred dollars of one or a hundred dollars of the other is still a hundred dollars."[21] But there is a difference, and it is profound. First, some industries, such as semiconductor microprocessors (computer chips) experience very rapid growth and reductions in cost, spark the development of subsequent industries, and increase the productivity of other sectors of the economy. In essence, spillover effects from computer chips make potato chip manufacturers more efficient. Second, jobs in computer chips require a higher skill level and thus pay more than jobs in potato chips. Third, if you lose the computer chip industries due to foreign competition, that value similarly disappears; the assumption the neo-classical models make that residual assets will get redeployed to high-value added sectors is not necessarily the case.

The argument that firms compete but countries do not, and that as a result there is little need to put in place policies to help boost national competitiveness, is held by both conservative neo-classical and liberal economists alike. According to this view, if Boeing, for example, goes out of business, as long as America maintains flexible labor and capital markets, these resources will flow into other industries, including into expanding or new firms and sectors. In such a market environment, policies are needed only to facilitate the transition of resources from losing to winning companies, including making sure that losing companies are not protected from this tough but necessary discipline, and helping workers get reemployed quickly. As a result, proponents of this view believe that as long as we have a good education system and don't restrain creative destruction, then all should be well.

This conventional view may have accurately described a country's economy before the emergence of the globalization era over the last two decades. During the old economy era, if firms could not compete and went out of business the only issue was making sure that their assets, including employees, were quickly redeployed to other companies that could compete successfully. But in the new global economy, in which knowledge is increasingly the major factor of production, this framework no longer sufficiently explains industrial and economic change.

In the 21st century global economy, nations can no longer be indifferent to the industrial and value-added mix of their economy.

In contrast to the neo-classical view, knowledge is not a free-flowing commodity held solely by individuals. It is embedded in organizations and if organizations die so too does a significant amount of knowledge. Moreover, there are significant spillover effects from firm activities and significant first-mover advantages, including learning effects that enable firms' early leads to translate into dominant positions. There are also significant network effects that mean that advancement in one industry (e.g., broadband telecommunications) can lead to advancement in a host of others (e.g., Internet video). As a result, for many parts of the U.S. economy exposed to international competition, if you lose it, you can't easily reuse it. In these cases, foreign high-value imports may end up substituting for the defunct U.S. product.

Research by economist Elvio Accinelli has shown that there is strategic complementarity between the percentage of high-skill workers and high-value added, innovative firms in an economy. Accinelli finds that economies can be in perfect neo-classical equilibrium at either high levels of innovation, or in a "poverty trap" of low skills and underinvestment in innovation. Since the poverty trap can be avoided if the number of innovative firms in an economy exceeds a threshold level leading to an increased number of skilled workers, there is a role for public policy to move economies to a high-level equilibrium on innovation.[22]

This alternative framework – what some have termed a neo-Schumpeterian framework – better describes a growing share of a country's economy, particularly those sectors focused on technology- and knowledge-based production, than does the neo-classical adjustment model. This means that losing international competitions in knowledge-based industries means losing much more than just the firms. It means losing much of the value from these dispersed pieces of value now represented by unemployed workers and underutilized suppliers. If a firm using highly-trained scientific and technical talent cuts production, it's often not easy to put the workers and the training they embody into use in other sectors. The old model focuses on tangible capital – a worker, a piece of machinery, financial capital – but when much of a country's capital resides in intangible capital, it does not get reallocated easily. If a country loses the intangible knowledge about how to build an airplane, it cannot get reconstituted without massive government subsidies or trade protection to create competitive breathing room while that knowledge base is rebuilt.

Moreover, in the previous era, when the United States was the dominant technology-based economy, both the old and new industries were domestic (e.g. U.S. semiconductor firms replaced U.S. vacuum tube firms; U.S. biopharmaceutical firms took market share from the dominant U.S. pharmaceutical firms). But in a flat world, domestic transfers of market leadership are increasingly less likely to be the case. More global players mean that more potential first movers will come from an increasingly large pool of technology-based economies, and that shifts in the locus of global competitive advantage across technology life cycles will occur with increasing frequency.[23]

Thus, in the 21st century global economy, nations can no longer be indifferent to the industrial and value-added mix of their economy. Indeed, with the sole exception of the United States, virtually all nations have consciously adopted national policies to "intervene in the market" – in this case to make it easier for corporations to invest in higher value-added activities that create higher-wage jobs in their nation. These nations are not content to sit idly by to observe how the market will allocate production, for they know that it could just as easily allocate to them low-wage t-shirt factories and call centers, instead of semiconductor factories and software companies.

In the United States, there is one group of elected officials who understand that political jurisdictions compete for economic pre-eminence. Since the mid 20th century, most governors, regardless of their politics, have put in place policies to tilt the playing field so that corporations create higher-value added jobs in their states.[24] These governors recognize that markets generally create prosperity, but they also have the real-world understanding that markets don't always generate that prosperity for *their citizens*. The next 1,000 high value-added jobs could just as easily be created in another state or another nation. Thus, governors understand the necessity of going beyond letting firms alone determine the location of high-value added economic activities; that's why they "intervene" in their economies with activist economic development policies such as workforce development programs, industry-university research centers, and R&D tax incentives.

Other countries certainly believe they are competing against the United States for science and technology, and economic, pre-eminence.

In essence, the U.S. economy has now become a large state – in the sense that a large share of the economy is now traded – and it competes against other nations, the way states have long had to compete. Leaving it up to the results of market competition alone will lead to the United States increasingly losing out in global competitions for high value-added technology and knowledge-intensive production.

Other countries recognize they are in a competition, and the authors even take stock of the competitiveness measures being implemented by China and the European Union:

> Other nations/regions certainly have ambitions to strengthen their competitiveness as knowledge-based economies. China and the European Union are two examples. In January 2006, China initiated a 15-year "Medium- to Long-term Plan for the Development of Science and Technology." China aims to become an "innovation-oriented society" by 2020 and a world leader in science and technology by 2050, develop indigenous innovation capabilities, leap-frog into leading positions in new science-based industries, increase R&D expenditures to 2.5 percent of GDP by 2020, increase the contribution to economic growth from technological advances to 60 percent, limit dependence on imported technology to 30 percent, and become one of the top five countries in the world in the number of patents granted.[25] … In March 2000, the EU heads of states and governments agreed to make the EU "the most competitive and dynamic economy in the world" by 2010.[26]

Notwithstanding Krugman's argument, other countries, at the very least, certainly believe *they are competing against the United States (and other countries)*. Moreover, the authors do not seem to interpret these recently-introduced strategies, commitments, and policies emerging from European and Asian countries as long-term threats to U.S. S&T leadership, as their report maintains that the status quo is generally producing acceptable results and there is not a need for the United States to likewise articulate a coordinated national agenda for sustained U.S. leadership in innovation, science and technology.

The Changing Nature of Innovation, Especially Its Globalization, Does Not Pose a Threat to America's S&T Performance

In evaluating whether the globalization of innovation poses a threat to America's S&T performance, the authors favor the viewpoint of Jonathan Eaton and Samuel Kortum, who hold that offshored research and development is good for the United States, over the analysis of Richard Freeman, who argues that outsourcing R&D may weaken U.S. S&T competitiveness.

Eaton and Kortum, economists at Yale University and the University of Chicago respectively, have studied the consequences of the globalization of S&T and the rise of other nations on the level of innovation activity in the United States (which the authors broadly equate with strong performance in S&T). They argue that, so long as trade barriers are not too high, globalization and the rise of significant amounts of R&D and innovation performed outside the United States may in fact increase foreign and domestic demand for U.S. R&D, thus raising wages, generating employment, and increasing the pool of technology in the United States.[27] The theory behind Eaton and Kortum's argument is that since the United States is assumed to have a *comparative advantage* in the performance of research and development over foreign countries, faster diffusion (enabled by open international trade) will shift research activity toward the country that performs it better.[28] Thus, globalization – transmitted through the channels of international trade with open and undistorted markets for the performance of research and development activities – will for the most part inure to the benefit of the United States. Or, to put it another way, losing R&D activity is good for the United States, since it means we will gain R&D.

The theory of comparative advantage, originally developed in the late 1800s by economist David Ricardo, postulates that even if one country is a superior producer of two different goods over another country, if that country specializes its production in the good for which it has the highest *relative advantage* and the other country focuses on the second good, both countries will benefit from trade. For example, England may produce cloth forty percent more efficiently and wine twenty percent more efficiently than Portugal, but if England specializes in cloth production and Portugal on wine, aggregate output will be higher and both countries will benefit. Hence, Eaton and Kortum theorize, if the United States is the most efficient producer of R&D goods and services, it will specialize in R&D production, while other countries, China for example, might focus on producing lesser-value commodity goods.

In Eaton and Kortum's model (as with any neoclassical trade model), comparative advantage is a naturally occurring phenomenon. It is essentially tautological, existing by definition, and there is really nothing a country can or should do about it. But comparative advantage can be lost, and countries applying activist economic development policies can wrest comparative advantage for key industries. Thus, there is no reason to presume an enduring or given U.S. comparative advantage in research and development.

One of the leading opponents of the view that globalization will perfunctorily inure to the benefit of U.S. R&D and innovation is Harvard's Richard Freeman. However, the authors downplay Freeman's warnings of a long period of adjustment for U.S. workers if changes in the global job market for S&T workers erode U.S. dominance in S&T and diminish its comparative advantage in high-tech production.[29] As the authors summarize Freeman's thesis:

> Freeman argues that several indicators suggest that globalization threatens U.S. technological and economic leadership. First, major high-tech firms are locating new research and development facilities in China and India. Second, some form of skilled work are being offshored, such as information technology jobs to India. Third, indices of technological prowess show a huge improvement in the technological capability of China, in particular. Finally, data on production and exports of high-tech products show that the improved capability of China in high tech has begun to appear in production and sales in the global market.[30]

In contrast to Eaton and Kortum's rather optimistic vision, Freeman's account seems much closer to describing what is actually happening in international markets today. Indeed, the OECD observed that as early as December 2005, China overtook the United States as the world's largest exporter of *high-technology* goods, including computers (routers and servers), mobile phones and digital cameras.[31] As OECD analyst Sacha Wunsch-Vincent noted, this "highlights China's steady rise up the value chain - from televisions, stereos and other low-margin electronic goods to expensive hi-tech equipment."[32] Moreover, since 2001 the United States has run a trade deficit in *advanced technology products*, a U.S. Census Bureau category that includes new or leading-edge technologies such as biotechnology, life science, optoelectronics, information and communications, electronics, aerospace, and nuclear technology. The United States annually imports $53B more in advanced technology products than it exports.[33]

Freeman's account also squares well with statistics showing that companies are increasingly shifting their R&D overseas. Indeed, between 1998 and 2003, investment in R&D by U.S. majority-owned affiliates increased twice as fast overseas as did all corporate investments in R&D in the United States (52 percent to 26 percent).[34] Moreover, over that time period, the share of U.S. corporate R&D sites located within the United States has declined from 59 percent to 52 percent, while the share of U.S. corporations' R&D sites located in China and India have increased from 8 to 18 percent.[35] U.S. R&D does seem to be increasingly sourced abroad, in contrast to Eaton and Kortum's predictions based on the theory of comparative advantage.

Finally, Eaton and Kortum's analysis warns of distortions to international trade from trade barriers, but does not anticipate the proactive approaches governments take to intervene in the R&D marketplace. Countries can engage in two types of activities to support the competitiveness of their economies and businesses: the first set of activities is legitimate, while the second set is not. Legitimate policies include funding for basic and applied R&D, R&D tax credits, programs to build information technology or other technical skills, and liberalization of domestic markets. The second, illegitimate approach, relies on erecting unfair and protectionist policies that systematically disadvantage foreign competition, including by raising the relative price of foreign goods or services through applying tariffs, taxes, subsidies, or excessive antitrust enforcement or by blocking or limiting access of foreign companies to markets through standards, government procurement or data privacy policies.[36]

The authors' use of time-series data sets – generally spanning from 1993-2003 – are not adequately reflective of the competitive challenge that has emerged since 2000 and do not satisfactorily depict the competitive landscape as it exists in mid-2008.

Either way, countries are deploying these strategies to gain advantage in key industries, an advantage which if lost cannot be easily replaced. For example, countries intervene in the marketplace to create favorable tax regimes to encourage companies to situate research and development activities in their country. In Canada, for example, qualifying companies can obtain an R&D tax deduction of up to 60 percent, about ten times greater than in the United States. Intel's experience in Israel – another country with a highly favorable R&D tax regime – is instructive, and confounds the received wisdom that U.S. companies may outsource their manufacturing but will keep higher-value added activities such as design or R&D in the home country. As Gregory Tassey writes:

> When technological advances take place in the foreign industry, manufacturing is frequently located in that country to be near the source of the R&D. The issue of co-location of R&D and manufacturing is especially important because it means the value added from both R&D and manufacturing will accrue to the innovating economy, at least when the technology is in its formative stages. This phenomenon occurs because much of the knowledge produced in the early phases of a technology's life cycle is tacit in nature and such knowledge transfers most efficiently through personal contact. Intel's major R&D program in Israel is an example. Collaborative research developed a new architecture for the company's 64–bit microprocessor, which was followed by Intel's investment in a $4 billion manufacturing plant near the R&D facility. Thus, an economy that initially controls both R&D and manufacturing can lose the value added first from manufacturing and then R&D in the current technology life cycle - and then first R&D followed by manufacturing in the subsequent technology life cycle. This is the economics of decline.[37]

While the globalization of innovation and R&D does bring real and important benefits to U.S. companies and consumers, it is not necessarily unassailably positive and does bring considerable threats to U.S. technological and economic leadership.

EVEN IF THE NOTION OF COMPETITIVENESS IN S&T IS LEGITIMATE, THE UNITED STATES CURRENTLY LEADS THE WORLD, SO THERE IS LITTLE CAUSE FOR ALARM

The balance of RAND's competitiveness report consists of the presentation of a number of different metrics pertaining to the core "building blocks" of science and technology – R&D activity, patent awards, scientific publications, U.S. math and science education, and the S&E workforce – which collectively the authors argue present a rosy picture of the United States' global competitive position in science and technology. However, these metrics suffer from a number of problems, including use of time-series data that fail to reflect current realities, use of inappropriate denominators, the failure to include key metrics, and considerably over-optimistic reporting of the actual results. We review general methodological weaknesses in the report and then assess the authors' evaluation of the state of U.S. competitiveness in each of the key building blocks of the U.S. science and technology infrastructure.

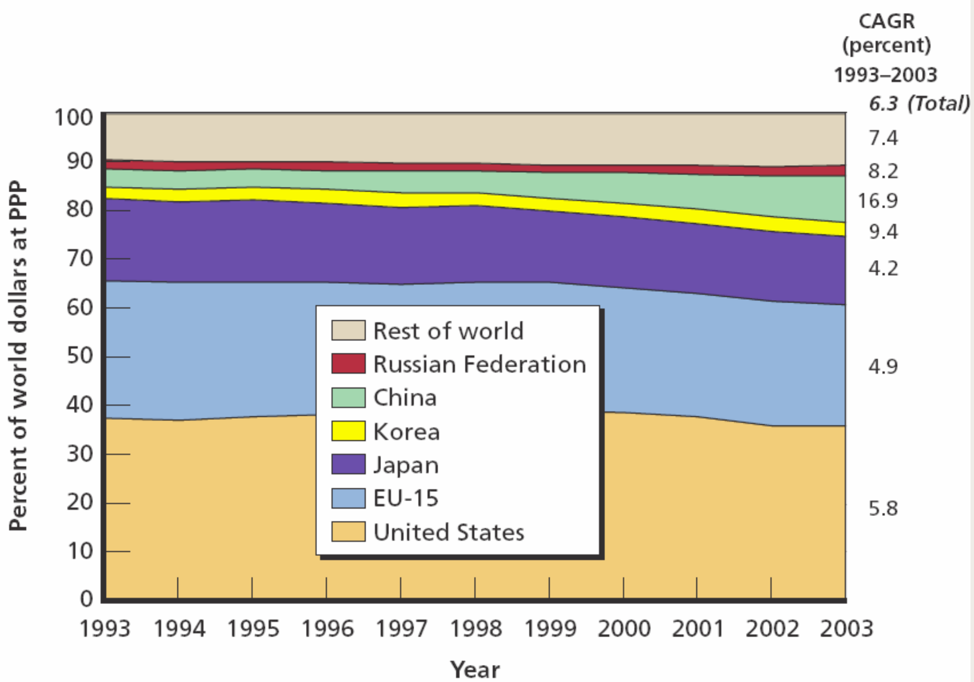
Methodological Weaknesses

The authors' use of time-series data sets – generally spanning from 1993-2003 – is not adequately reflective of the competitive challenge that has emerged since 2000 and do not satisfactorily depict the competitive landscape as it exists in mid-2008. While the United States performed very strongly up until 2000-2001, the new competitive challenge has really emerged post-2000. For example, the ability to easily perform and the reality of intensive R&D offshoring didn't arise until well after 2000. Factors responsible for the intensifying competitive environment over the course of this decade include: 1) innovations in information technology that have made offshoring of R&D and other services economically feasible; 2) changes in the political and economic strategies of many countries, especially China, India, South Korea, Brazil and other rapidly emerging economies; and 3) Europe's competitive awakening. As we saw previously, the authors noted how China, the EU, and individual European countries such as the UK, Germany, Ireland, Finland, Denmark, Sweden, and others have just in this decade (and since 2005 in many cases) begun to unveil national strategies to drive their competitiveness in innovation, science, and technology. Japan, Taiwan, and Singapore can be added to that list as well. In effect, the authors are using the wrong benchmark year; a more realistic picture of U.S. competitiveness would baseline the year 2000 and assess subsequent trends.

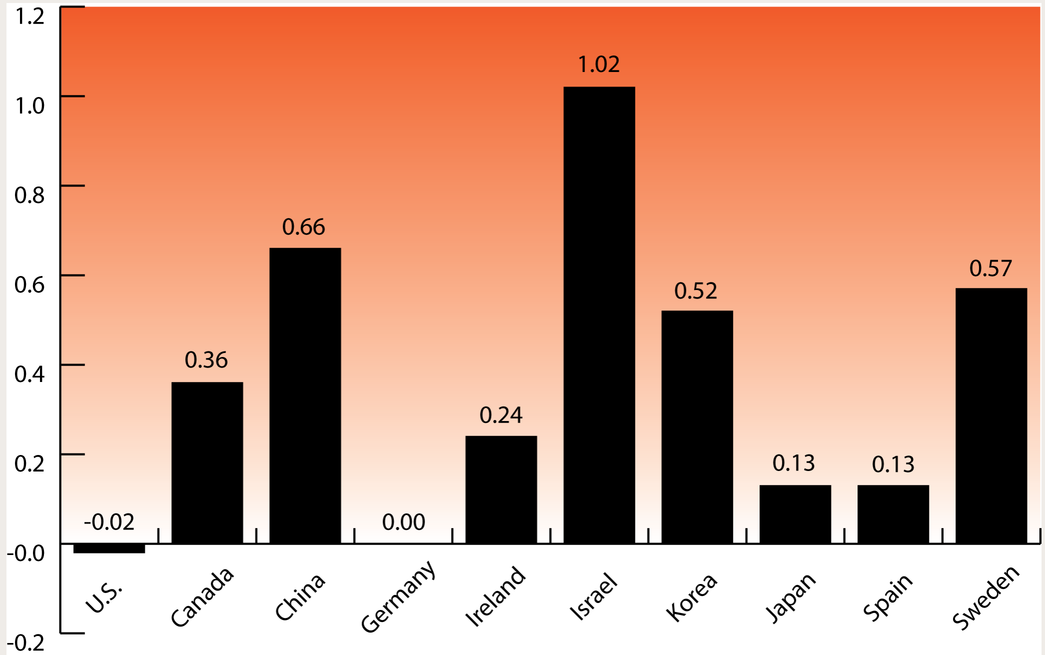
In addition, the authors assess countries' overall economic performance on the basis of the size of the economy (GDP at PPP). But this is a flawed variable to use in assessing international economic competitiveness because it rewards size (especially countries with high birth and immigration rates) as outsize components of economic growth. A much stronger measure of international economic competitiveness is GDP per capita, which both controls for a country's population size and picks up its unemployment rate. Growth rates in GDP per capita is further a superior metric because it demonstrates how gains in economic productivity inure to the benefit of all a country's citizens.

A key indicator not included in their report, but one necessary to present a complete picture of U.S. economic competitiveness, is that the United States is running an unprecedented trade deficit, with a current account deficit of approximately $700B in 2007.[38] The

Figure 2.2
R&D Funding in Current Dollars at PPP (1993–2003) as Percentage of World Total



SOURCE: OECD (2006b, 2006c).



ITIF Figure 1: Percent Change in R&D/GDP Ratio, 1991-2003

United States even has a $53B annual trade deficit in advanced technology products. It is astounding that somehow there is seen to be no relationship at a national level between strength in the technology sectors of an economy and selling more than a country buys.

U.S. Investment in Research and Development

Perhaps the argument the authors advocate most strongly to allay concerns about U.S. S&T competitiveness is that *"other nations/regions are not significantly outpacing the U.S. in research and development (R&D) expenditures."*[39] A country's total R&D expenditures include federal, corporate, and university investments in R&D. But the key international comparative metric is not what countries' raw financial expenditures in R&D are, but what countries' R&D expenditure are as a share of their GDP, a measure known as a country's *R&D intensity*. By not controlling for changes in the size of an economy, it is impossible to compare countries' relative investments in R&D. As we will see, while the U.S. continues to lead the world in raw dollar amount of R&D expenditure, its R&D intensity compared to peer countries is rapidly deteriorating.

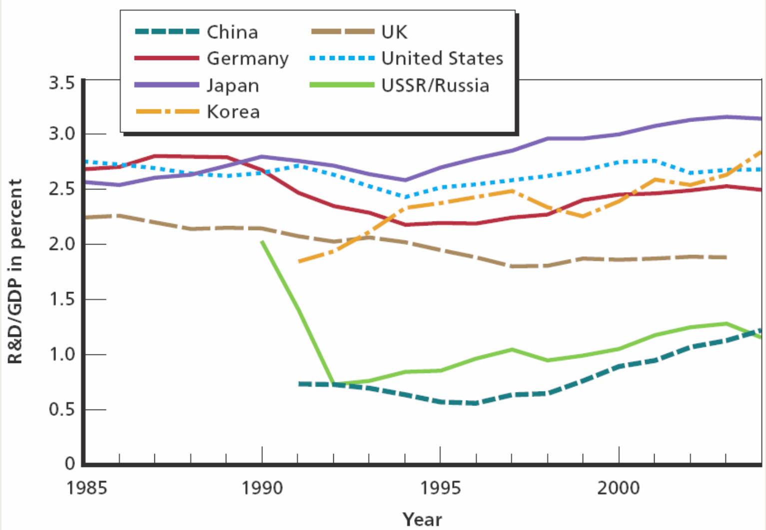
RAND authors' Figure 2.2 (page 10) first considers countries' share of world R&D investment, where at first glance U.S. performance appears dominant.[40] But on closer inspection, the chart actually visually illustrates a disturbing *weakening* in the U.S. share of global R&D. Whereas U.S. total R&D investment represented an *increasing share* of world R&D investment from 1993 to approximately 1998, the U.S. share of world R&D investment has been receding since then (and a chart plotting out to 2008 would continue to show a downward curve). An initially *upward* trend has been replaced with a *downward* trend.

The major reason for this slippage has been a slowdown in federal R&D investment since the mid-1990s. As the authors duly note, "Total federal R&D spending grew at 2.5 percent per year from 1994-2004, much lower than its long-term average of 3.5 percent from year from 1953-2004."[41]

Indeed, the United States is one of only a few nations where total investment in R&D as a share of GDP fell from 1992-2005, largely because of a decline in public R&D support.[42] ITIF Figure 1 depicts this, plotting the percent change in R&D/GDP ratio for the years 1991-2003 for the United States against a group of competing industrial countries.[43]

Authors' Figure 2.3 considers seven countries' levels of R&D intensity, comparing U.S. R&D intensity

Figure 2.3
R&D Intensity: Gross Domestic Expenditure on R&D as Percentage of Gross Domestic Product, 1985–2005



SOURCE: Reproduced from Eaton and Kortum (2007); OECD (2006b, 2006c). Used with permission.

from 1985-2005 against six other countries: China, Germany, Japan, Korea, UK, and USSR/Russia. [44]

In 2006, U.S. corporations spent three times more on litigation than they invested in the R&D investments needed to secure their competitive future.

Again, a cursory glance seems to tell a positive story. While the United States has consistently trailed Japan in R&D intensity since 1989, it did generally achieve higher R&D intensity than Germany, China, the UK, Russia, and South Korea. However, the chart reveals several disturbing trends: 1) By 2004, South Korea catches and surpasses the United States in R&D intensity, and 2) the levels of R&D intensity for each of the countries in the analysis are consistently rising, with the exception of the United States and the United Kingdom. Moreover, the figure omits an assessment of the rest of the world, the EU-15, or individual countries such as Singapore, Taiwan, and the Nordics that have the highest levels of R&D intensity in the world.

Indeed, when U.S. R&D intensity is compared to OECD peers, we find that, at 2.6 percent of GDP devoted to R&D investment, the U.S. ranks only seventh amongst OECD countries in R&D intensity, behind a list of countries including Japan, South Korea, Finland, and Sweden.[45] In more recent rankings (2006) from the OECD, the United States places only 22nd in the fraction of GDP devoted to nondefense research.[46]

Though the authors acknowledge the decreasing activity of the federal government in funding R&D, they assure us not to worry because: 1) federal R&D accounted for only 30 percent of total U.S. R&D expenditures in 2004 ($86 billion out of a total $288 billion), so private industry R&D investment is actually the larger component of the United States' aggregate R&D investment; and 2) the private sector has been picking up the government's slack in R&D funding.[47] The authors point out that industrial R&D expenditure in the United States evinced a growth rate of 5.3 percent from 1994-2004, in line with the long-term growth average from 1953-2004 of 5.4 percent.[48]

But there is not compelling evidence that corporate R&D is picking up the slack left by reduced government R&D investment. Looking at the more recent time period of 1999-2003, corporate-funded R&D as a share of GDP fell in the United States by 7 percent, while in Europe it grew by 3 percent and in Japan by 9 percent.[49] Moreover, the majority of those corporate R&D investments are directed towards the commercialization (development) of products, not to basic and applied research. Indeed, between 1991 and

2003, the share of corporate R&D devoted to basic and applied research fell by three and four percentage points, respectively.[50] In 2006, U.S. corporations spent three times more on litigation than they invested in the R&D investments needed to secure their competitive future.[51] Since federal and corporate R&D investments are actually complements, the growth rate of corporate R&D might have been stronger if the federal R&D funding level was higher.

Even those statistics come well before the current capital market environment in the United States. Corporate earnings in the United States were a paltry 2.6 percent in 2007, and analysts believe 2008 U.S corporate earnings will struggle to make a meager 3 percent.[52] This intense pressure on corporate earnings will further squeeze U.S. companies' ability to fill the R&D funding gap left by decreased government investment in R&D.

So neither the fact that the federal government has recently reduced its R&D investments nor our reliance on corporations to pick up the slack should bring us comfort; and we have already seen that an increasing share of U.S. R&D is being performed offshore. In a recent ITIF report, Fred Bloch and Matthew Keller documented the importance of federal funding to R&D innovation in the United States. They noted that in 2006, only eleven of the eighty-eight entities that produced award-winning innovations were not beneficiaries of federal funding.[53] Indeed, Google, Oracle, and Akami, three iconic companies of the information economy, each owe their origins to knowledge that was initially developed with federal funds.[54] More than half the papers cited in computing patent applications between 1993 and 1994 acknowledged government funding, and seventy percent of U.S. biotech patent citations were to papers originating solely at public science institutions.[55]

Thus, the overall decrease in federal R&D funding is of serious concern. Finally, the RAND authors themselves note that the strongest area of recent federal R&D funding, the life sciences, may actually be crowding out other fields of S&T R&D:

> The relatively low level of funding for the physical sciences raises the possibility that they are being underfunded. A study of the condition of and outlook for condensed-matter and material physics (CMMP) (National Research Council, 2007) finds that while the United States remains a leader in CMMP worldwide, its premier position is in jeopardy, as other parts of the world are investing heavily in CMMP and industrial involvement in CMMP has declined.[56]

Patent Activity

The authors use "triadic patent" awards, a proxy measure of countries' innovative activity, as a second reason to argue that U.S. S&T performance is doing just fine. (Patents become "triadic patents" when their inventor seeks patent protection for the same patent in the US, EU, and Japan simultaneously.)[57] The authors review the number of triadic patents awarded to American, European, and Japanese corporations or individuals in 1985, 1993, and 2003 and find that the U.S. share has increased considerably from 1993 to 2003. By 2003, the United States accounted for 38 percent of industrialized nations' (OECD countries) triadic patents, while the EU-15 and Japan claimed 31 and 26 percent respectively.[58]

But there are a number of reasons why U.S. patent activity was inordinately elevated between 1993-2003, a period when companies would attempt to patent ideas like bread without the crust on it. U.S. patent law changed significantly during this period, permitting business method patents (such as Amazon.com's one click checkout method) that encouraged an explosion of applications for process and business method/model patents which were fundamentally unrelated to true scientific-discovery or technology-based patents. Applying for defensive patents – so that competitors could not appropriate economic gain from specific technologies – also became a more widely used business practice at this time. So tenuous were many of these patents that patent litigation in the United States increased by 120 percent between 1990 and 2005, imposing a significant tax on the U.S. innovation system.[59] As the authors themselves concede:

> Besides greater innovation activity, the large increase in triadic patents [from 1993-2003] could reflect increased use of patents as part of legal and business strategies to protect against piracy or to improve competitive position by blocking market entry or impeding rival's innovation.[60]

Moreover, using the triadic patent measure, which sets the hurdle for recognition of patent activity as seeking and winning patent awards from the U.S. Patent and Trademark Office (PTO), the Japan Patent Office (JPO), and European Patent Office (EPO), suggests that China, Russia, and Korea combined together accounted for less than four percent of global patent activity in 2003. In fact, nearly 60 percent of the patents filed with the U.S. Patent and Trademark Office in the field of information technology now originate in Asia.[61]

Between the years 1993-1997 and 1997-2001 the United States experienced a three percent loss in world share of total S&T publications, citations, and top 1 percent highly-cited publications.

For these reasons patent activity, especially triadic patent activity, is simply not a reliable comparative tool for measuring either S&T or economic competitiveness amongst countries.[62]

U.S. Share of Scientific Publications

Sagging U.S. competitiveness in science and technology is clearly reflected in scientific publication trends. The EU-15, Japan, and many other nations have steadily gained on the United States since 1993. Indeed, between the years 1993-1997 and 1997-2001 the United States experienced a three percent loss in world share of total S&T publications, citations, and top 1 percent highly-cited publications.[63] The EU-15 and Japan averaged annual growth rates of 3-4 percent per year in scientific publications growth and over 5 percent annual growth in top 1 percent most-cited publications over that time period. Meanwhile, U.S. growth was flat and well-below the world averages of 2.2 percent and 2.3 percent, respectively, in scientific publications and top 1 percent most-cited publications.[64] Japan's performance, a 5.8 percent growth rate in the share of the world's top 1 percent most-cited publications, becomes particularly impressive considering its declining adult working age population.

While the authors document this weakening U.S. performance in scientific publications, they ascribe to it little cause for long-term concern.

U.S. Education and Academic Performance in Science & Technology, K-12

U.S. annual expenditures per elementary and secondary school student relative to GDP per capita are the second highest in the world. Despite this investment, the performance of U.S. students in international assessments of math and science competencies continues to lag that of foreign students. The performance of U.S. 15-year-olds (generally 10th graders) ranked 24th in mathematics literacy and 19th in science literacy out of 29 OECD countries in the 2006 Program for International Student Assessment (PISA). Remarkably, the authors observe of a separate Trends in International Mathematics and Science (TIMMS) study that, "limiting the comparison to OECD countries still indicates that U.S. students performed relatively well." 'Relatively well' is seen as 6th out of 11th place for fourth graders (age 9) and 8th out of 13th for eighth graders (age 13) in mathematics.[65] (To be fair, performance in science literacy was somewhat stronger, with fourth graders placing 3rd of 11 and eighth graders 5th out of 13 countries.) Even the authors are forced to concede that, "The relatively poor test performance of U.S. students has been a persistent aspect of the U.S. education system," going all the way back to:

> The first systematic cross-national assessment of mathematical competencies conducted in 1964 that included 13- and 17-year-olds from twelve industrial nations [which] indicated that American adolescents were among the most poorly educated mathematics students in the industrialized world. Of the twelve participating nations, the American 13-year-olds ranked 10th and 11th, across two comparisons. The assessment of the 17-year-olds was based on students who were enrolled in a math-intensive college preparatory high school curriculum, that is, each country's best prepared students: The American 17-year-olds ranked last.[66]

Not only is the math and science performance of U.S. students subpar in international comparisons, so are overall high-school graduation rates. The United States has fallen to 17th among nations in overall high school graduation rates (and 14th in college graduation rates).[67] Within the United States, high school graduation rates have remained basically unchanged since World War II.[68] One other disturbing aspect of the performance of U.S. students in international comparisons of math and science competencies is that it tends to weaken as American students 'mature.' That is, U.S. students compare relatively well in international comparisons in math and science at the lower grades, but older students demonstrate less achievement than most of their peers in other industrialized nations.[69]

So despite its large investment, U.S. high school students especially continue to under-perform their OECD counterparts in math and science, putting students behind as they enter more advanced collegiate courses in science and technology. The authors admit that, "U.S. students are not as well prepared for careers in science and engineering," and acknowledge the strain that an underdeveloped pipeline will place on the long-term development of qualified domestic talent in science and engineering:

> R&D often requires a master's or PhD degree in S&E…There is a long lead time associated with increasing the degree production at U.S. universities, as scientists and engineers require substantial investments in human capital. Obtaining such degrees requires taking a number of math and science courses in high school and as an undergraduate… In the long-run, expanding the number of students in S&E graduate study depends on attracting more K-12 students to math and science.[70]

Given the enormous labor cost disparity between the United States and developing countries, graduating students with average skills and capabilities into the workforce will not offset that disadvantage.

U.S. Education and Academic Performance in Science & Technology, Post-Secondary

Whether the reason is that U.S. students are not as qualified in S&E as foreign students or they are simply not as interested (both an issue of relevance for policy makers), the fact is that graduates of science and technology programs in the U.S. – at the undergraduate, masters, and PhD levels – are increasingly foreign born. At the undergraduate level, companies find that 50-80 percent of advanced degree candidates in science and engineering disciplines at leading U.S. universities are foreign born.[71] In 2000, the number of foreign students studying physical sciences and engineering in U.S. graduate schools surpassed for the first time the number of U.S. students.[72] Sixty percent of engineering PhDs awarded in U.S. universities go to foreigners, and across all S&E fields almost as many foreign nationals receive PhD's as do U.S. citizens.

As for the *overall* number of science and engineering graduates, both China and the EU-15 outpaced the United States in 2002. That year, the EU-15 and China graduated about 500,000 and 530,000 respectively, whereas the United States graduated only 430,000.[73] Moreover, the ten-year compound growth rate of U.S. graduates in S&E fields from 1992-2002 was a meager 1.0 percent – below even that of Japan, which eked out a 1.2 percent *growth rate* over this period, despite the fact that Japan's working age population is decreasing in absolute numbers.[74] As the authors recognize, "Regardless of the differences in the numbers reported, various sources consistently find that the EU and China graduate more scientists than the United States does." As we will see in the next section, the decreasing percentage of American students in advanced S&E degree programs is translating directly to increased reliance on foreign nationals in the S&E workforce in the United States – at a time when the United States has made it much more difficult for foreign students and professionals to enter and remain in the country.

Long-term trends in the number of graduates in science and engineering fields in the United States are no more encouraging. Some worrying statistics:

- In China, virtually all high school students study calculus – the gateway to advanced degrees in S&E – while only 13% of U.S. high school students do.[75]
- Over the past two decades, the number of engineers, mathematicians, physical scientists, and geoscientists graduating with a bachelors degree declined by 18 percent. The proportion of university students achieving bachelor's degrees in those fields declined by 40 percent.
- In 2002, Asian countries as a whole awarded 636,000 first engineering degrees, European countries awarded 370,000, and North American countries awarded 122,000.
- The United States ranks 17^{th} among developed nations in the proportion of college students receiving degrees in science or engineering, a fall from third

place three decades ago. It ranks 26th in the proportion receiving undergraduate degrees in mathematics.[76]

- The number of engineering doctorates awarded by U.S. universities to U.S. citizens dropped by 23 percent from 1996 to 2006.[77]

How this litany of statistics of the woeful performance of U.S. students and institutions in math and science education does not warrant a clarion call of concern from the authors is truly puzzling. Perhaps the authors side with the perspective of Roger Pielke of the University of Colorado, who believes that:

> Such issues as poor student performance have an even longer history, with no negative outcomes. Arguments that certain other countries produce a greater proportion of scientists and engineering students or that those students fare better on tests of achievement...have been made for almost 50 years, yet over that time frame the economy has done quite well.[78]

Making national policy on the basis that "we've been doing quite well" is akin to a doctor telling a patient with a history of risk factors and early signs of symptoms of a particular disease that, "you've been doing quite well so far, and there's really no need to worry or be proactive about managing risk factors and symptoms that might catch up to you one day." That would never be accepted as a sound basis for medical advice; it is not one for public policy.

The Science and Engineering Workforce

The report next examines the state of S&E employment in the United States, asking if S&T employment is growing more rapidly in other nations or regions. Here, the authors observe that the U.S. leads the world in S&T employment and that the growth rate of US S&T employment is roughly in line with the OECD average.

But again, this metric is meaningless unless S&T employment is assessed on a per worker basis. For example, the authors assert as positive the metric that, from 1995-2002, the U.S. S&T employment growth rate, at 3.7 percent, exceeded Japan's, at 2.3 percent. But Japan achieved that 2.3 percent growth rate *despite* its declining adult working age population. When assessed on a per capita basis, the U.S. performance does not look as strong. The raw percentages the authors present do not fully tell the truth, for it is much harder for Japan to expand their S&E workforce when their adult, working-age population is not only not growing, but actually shrinking. Not controlling for such environmental conditions gives an exaggerated impression of the performance of countries simply growing in population (due in part to high fertility rates or more foreign immigration).

Finally, the authors clearly document that the U.S. S&E workforce is becoming increasingly reliant on foreign talent. In 1995, non-U.S. citizens accounted for six percent of the S&E workforce; by 2006 that percentage had doubled to twelve percent. Moreover, 20 percent of the younger (ages 21-35) cohort of scientists and engineers in the U.S. are foreign born.[79] In effect, the United States has been importing foreign S&E talent to offset the shortcomings of our own citizenry.

The authors debate the merits of U.S. reliance on non-U.S. citizens in the S&E workforce, evaluating potential concerns such as whether their presence crowds out domestic talent, keeps wages artificially low in S&E fields, creates a national security risk, or leads to faster diffusion of technology overseas. Ultimately, the authors express the view that, "Given the benefits associated with the foreign S&E workforce, the United States is likely to be worse off if foreign access to U.S. graduate education and S&E jobs is limited."[80]

On this point we agree, which makes it all the more surprising that in their analysis of the overall state of U.S. S&T competitiveness, the authors ascribe little deleterious effect to the current and deepening H-1B visa restrictions on foreign S&E talent entering the United States. In the most recent window for H-1B visa applications (beginning April 1, 2008 and lasting one week), almost 50 percent of highly talented foreign professionals were denied entry to the United States, as 163,000 applicants vied for a mere 85,000 visas.[81] At least 65,000 applicants were turned away in 2007 as well.[82] Clearly, foreign access to U.S. S&E jobs is being severely limited at levels far below employer demand, a factor likely contributing to the decision of many companies to source R&D operations abroad to be closer to local pools of S&E talent.

While the authors do commendable work in assessing the stay rates of foreign PhD graduates in the United States (finding that roughly seventy percent of these graduates *would want to stay* in the United States if they could over both the short- and long-term after receiving their PhDs), the authors fail to note that changes to U.S. immigration law have made it increasingly difficult for those who receive an H-1B visa (which allows visa holders to stay in the United States for up to six years) to ultimately translate it into permanent residency via a green card.[83] Indeed, backlogs of up to seven years[84] for the more than one million individuals waiting to receive permanent residency are causing many talented foreign-born S&E professionals to either return to their home countries or accept employment offers in countries with more liberal immigration policies.[85]

The United States has become increasingly dependent on a foreign-born S&T workforce at precisely the same time it has severely restricted the immigration of talented foreign labor into the workforce.

While the authors do call for alleviating H1-B visa restrictions in their recommendations section, the United States' growing dependence on a foreign-born S&T workforce merits urgent attention when the prevailing policy is staunching the lifeline of organizations in the United States dependent on the S&T skills of foreigners. As a November 2006 ITIF report "Global Flows of Talent: Benchmarking the United States" concluded, at a time when other countries like Canada, Australia, and even the United Kingdom are liberalizing their high-skill immigration policies to more effectively compete in the global competition to attract highly skilled-workers, the historic U.S. dominance in innovation and high-skill immigration is being challenged.[86] This is a far more serious issue than the authors give it due.

IN SUMMARY

- Maintaining a leadership position in S&T is fundamental for long term U.S. economic competitiveness.
- Governments have an appropriate role to play in proactively establishing a national S&T and innovation agenda, this includes: funding basic and applied scientific R&D, implementing R&D tax incentives, supporting strong schools that produce competitive S&E talent, developing workforce skills in S&E, and fostering industry-academic-government research partnerships.
- The United States' competitors – including every EU-15 and most rapidly growing Asian countries – have explicit national science and technology agendas; the United States does not.
- Previous calls for concern regarding U.S. S&T competitiveness were not false alarms, but rather wake up calls which prompted the U.S. to strategically adjust its competitive policies, helping the U.S. maintain its globally-leading position.
- Trends clearly show U.S. leads in key S&T and economic competitiveness metrics to be eroding (where not vanishing).
- Thus, calls for concern heard from multiple quarters are valid, and the overall impetus to put into place more robust national competiveness and innovation strategies are not just warranted, but required.

CONCLUSION

The central contention of RAND's *U.S. Competitiveness in Science and Technology* report is reiterated in the first sentence of their Discussion and Recommendations section, "The United States continues to lead the world in science and technology."[87] But this framing misses the point. The real question is, "Is the United States acting sufficiently to maintain its lead in science and technology in the face of trends that show a clear deterioration of its lead in key metrics and of competitors that are becoming increasingly sophisticated with policies to enhance their S&T enterprise and economic competitiveness." On page 125, the authors belie the spirit of their defense, questioning even the legitimacy of the premise that the federal government should take an active role in safeguarding U.S. leadership in science and technology:

> Some may believe that the U.S. government must commit to keeping the growth of its S&E enterprise on par with that of other advanced and rapidly developing countries. But the United States is not a monolithic decision maker, and much of the invest-

ment in R&D is nonfederal and is not under the control of the federal government.[88]

As neither the United States nor its federal government are monolithic decision makers, does that absolve the federal government of a fundamental role in ensuring that the United States should lead the world in education, transportation, healthcare, or environmental quality? Worse is the implicit view in this argument that – *at best* – the federal government should commit to remain *on par* with the S&E enterprise in other advanced and rapidly developing countries; making a commitment to maintain *the leading position* is not here envisioned.

We believe that the evidence the authors *themselves* cite in their report alone – not even including trends that clearly demonstrate deterioration of U.S. S&T leadership – justifies urgent concern for the state of U.S. S&T competitiveness. Combined with the additional evidence presented here, there exists a strong and compelling case to give serious consideration to implementing proactive measures to fortify the science and technology base in the United States.

ENDNOTES

1. National Academy of Sciences, National Academy of Engineering, Institute of Medicine, Committee on Science, Engineering and Public Policy, *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future* (Washington D.C.: National Academies Press, 2006) <www.nap.edu/catalog.php?record_id=11463> and *The Knowledge Economy: Is the United States Losing Its Competitive Edge? Benchmarks of Our Innovation Future* (Washington, D.C.: Task Force on the Future of American Innovation, February 2005) <futureofinnovation.org/PDF/Benchmarks.pdf> and *The Looming Workforce Crisis: Preparing American Workers for 21st Century Competition* (Washington, D.C.: National Association of Manufacturers, 2005) <www.nam.org/s_nam/bin.asp?CID=202592&DID=235064&DOC=FILE.pdf>.

2. The authors use the terms *science and technology* (S&T) and *science and engineering* (S&E) interchangeably. They note (p. xiii) that when referring to science prowess indicators, one commonly refers to science and technology indicators, but when referring to people or the workforce, it is common to refer to scientists and engineers (rather than scientists and technologists). Their convention has been so adopted here.

3. Titus Galama and James Hosek, *U.S. Competitiveness in Science and Technology* (Santa Monica, California: RAND Corporation, 2008).

4. The phrase “clarion call”, as the RAND report notes (p. 9), was originally used in a report by the President’s Council of Advisors on Science and Technology (June 2004), and also appears in other source material on the topic.

5. Galama and Hosek, 2008, p. xv.

6. Rick Newman, “How Toyota Could Become the U.S. Sales Champ,” *US News and World Report* 9 Jun. 2008 and Ian Rowley, “Honda Goes Whole Hog for Hybrids,” *BusinessWeek* 28 Jul. 2008: 62 and “Battery Pack Recall Leaves GM Stuck in Neutral” at <www.leftlanenews.com/battery-pack-recall-has-gm-hybrid-sales-stuck-in-neutral> (accessed February 18, 2008) and Sam Abuelsamid, “Chicago 2008: Just how many hybrids has General Motors sold?” *AutoblogNews* 8 Feb. 2008 <www.autobloggreen.com/2008/02/06/chicago-2008-just-how-many-hybrids-has-general-motors-sold/>.

7. STEM is as acronym that stands for “science, technology, engineering, and mathematics”. Gillian Anders, “The Cost of Doing Business: Should the United States Create Incentives for STEM Labor?” W*ashington Watch* March 2006, <www.aibs.org/washington-watch/washington_watch_2006_03.html> (accessed on February 28, 2008).

8. Neal McCluskey, “A Real Competitiveness Initiative” (Washington, DC: Cato Institute, 2006) <www.cato.org/pub_display.php?pub_id=6010>.

9. James Turner, “The Next Internet Revolution: Laying the Groundwork in the United States,” *Innovations* Spring (2006): 126-129.

10. Ibid, 128.

11. “Innovation’s Golden Goose,” *The Economist* 12 Dec. 2002 <www.economist.com/search/displaystory.cfm?story_id=E1_TQSGGVP> (accessed on July 14, 2008).

12. A decrease in federal R&D at the time worked to alleviate demand for STEM workers in the early 1980s.

13. Amar Bhidé, “Venturesome Consumption, Innovation and Globalization,” paper for the Venice Summer Institute 2006, *Perspectives on the Performance of the Continent’s Economies* 21-22 Jul 2006 <www.cesifo-group.de/link/vsi06_ep_bhide-new.pdf>.

14. “Venturesome Consumption,” *The Economist,* 27 Jul. 2006.

15. Kenneth Kraemer, Jason Dedrick, Greg Linden, *Capturing Value in a Global Innovation Network: A Comparison of Radical and Incremental Innovation* (Irvine, California: Personal Computing Industry Center, September 2007): 23 and Kenneth Kraemer, Jason Dedrick, Greg Linden, *Capturing Value in a Global Innovation Network: Comparing the iPod and Notebook PCs* (Irvine, California: Personal Computing Industry Center, September 2007): 10.

16. Kraemer, 2007, 23.

17. Galama and Hosek, 2008, 129.

18. Galama and Hosek, 2008, 11 and Paul Krugman, “Competitiveness: A Dangerous Obsession,” *Foreign Affairs* March/April 1994 (Cited by Galama and Hosek, 2008, 11.)

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44. Galama and Hosek, 2008, 23. Figure 2.3 reproduced from Eaton and Kortum (2007); OECD (2006, 2006c.) Used with original author's permission.

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57. The intent of using triadic patents as a basis for international comparison to eliminate "home advantage bias," that is, domestic applicants tend to file more patents in their home country than foreign applicants and thus are overrepresented. While the authors use triadic patents to facilitate making international comparisons, the standard sets a high hurdle that a given "patent" must be patented in the EU, US, and Japan.

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59. Jeffrey Johnson, Ali Dhanani, Kenneth Liu, Shince Thankappan (eds.), "PATSTATS: U.S. Patent Litigation Statistics," (Houston, Texas: University of Houston Law Center) <www.patstats.org/editors_page.rev6.html>.

60. Galama and Hosek, 2008, 30.

61. Augustine, 2006, 18.

62. For this reason, ITIF will not use patent activity as an indicator of country competitiveness in its European-American competitiveness report to be released by November 2008.

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65. Galama and Hosek, 2008, 76.

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