Research and Development
How the United States Compares
October 25, 2022

Back in 2011, I looked at the National Science Board's *Science and Engineering Indicators* (SEI) publication for clues to the decline in U.S. manufacturing employment. As I noted in my 2011 observation, SEI contains a wealth of information on research and development (R&D) patterns in the United States and other countries, as well as information on the U.S. science and engineering workforce.[1] At that time, I did not find anything in the R&D data that would explain the decline in U.S. manufacturing, although I did note that the U.S. educational advantage over the rest of the world was rapidly diminishing.

In the following, I look at more recent SEI R&D data with the same question: do R&D trends provide any insights into the decline in U.S. manufacturing? In particular, is there any reason to think that U.S. manufacturers have become less innovative than competitors in other countries? Starting with the 2020 edition, the format of SEI was changed; instead of a single volume, SEI now consists of nine "thematic reports" and an overview. This observation summarizes and makes a few comments on the thematic report *Research and Development: U.S. Trends and International Comparisons, 2022.* I do not address the adequacy of the science and engineering workforce here.

Key Points

The big development over the past two decades has been the growth in R&D activity in China. In the United States, R&D expenditures increased in real terms and relative to GDP; but growth fell well short of that in China. Rapid growth in China's R&D capabilities was evident at the time of my 2011 observation, but the United States ranked ahead of all other countries in R&D expenditures by a wide margin. China was a far-back third. Now, China is a fast closing second.

Another development of potential significance is the diminishing share of U.S. R&D funded by the federal government. Business has always performed most R&D in the United States. However, the federal government played a much bigger role in funding – and presumably shaping - R&D in the past than it does today.

R&D in the United States

U.S. R&D expenditures amounted to 3.1 percent of GDP in 2019.[2] This was historically high. R&D relative to GDP – R&D intensity – fluctuated around 2.5 percent since the late 1950s,

[1] See Original Entries on this website. Observation is dated August 15, 2011.
[2] The ratio was even higher in 2020 – 3.4 percent - as R&D expenditures are estimated to have increased 6 percent, while nominal GDP declined 1.5 percent. GDP is from the FRED data base at the Federal Reserve Bank of St. Louis.

reaching highs of 2.8 percent in the space race and in the Great Recession year of 2009, and falling to lows of 2.1 percent in the mid-1970s.

Business carried out most R&D throughout this period – generally about 70 percent. However, the federal government played a much greater role in funding R&D in the past than recently. In the 1950s, 1960s and most of the 1970s, the federal government funded over half of R&D. Defense needs and the space race drove this spending. In 2019, in contrast, the federal government funded 20 percent of R&D. Business largely funded its own research.

About half of the federal government's spending on R&D in 2019 funded work by the federal government itself. Close to 30 percent supported R&D at institutions of higher education and less than 20 percent went to business.

Higher education carried out 12 percent of R&D in 2019, receiving funding from the federal government, business and non-profits as well as from its own sources. Non-profit organizations perform and finance about 4 percent of R&D.

Two-thirds of U.S. R&D in 2019 took the form of "experimental development," which draws on "research and practical experience" to develop new or improved products or processes.[3] Applied research, or the acquisition of new knowledge with a specific application in mind, accounted for 20 percent and basic research, which consists of "experimental or theoretical work" to advance understanding without a specific application in mind, accounted for 15 percent. Higher education performed about half of basic research, with business responsible for about 30 percent. Business carried out most experimental development and over half of applied research.

Industrial Composition

Manufacturing accounted for 58 percent of business R&D in 2019. Within manufacturing, the most important performers were the chemicals industry, particularly pharmaceuticals and medicines, and the computer and electronic products industry. Transportation equipment, specifically producers of motor vehicles and aerospace products and parts, also had sizable R&D expenditures.

Among nonmanufacturing industries, most R&D is carried out by the information industry, including software publishers, and by the professional, scientific and technical services industry, which includes computer systems design and related services and scientific R&D services.

Most companies in these industries relied on their own funds to support R&D but the federal government supplied 46 percent of the funds for aerospace. Also, two-thirds of R&D

[3] Definitions are based on lengthier definitions in the glossary for *Research and Development: U.S. Trends and International Comparisons, 2022*.

carried out by scientific R&D services was funded by other companies, which could be in any industry.

International Comparisons

Magnitude

In 2019, the United States accounted for 28 percent of world R&D expenditures. For context, the U.S. share of world GDP was 16 percent.[4]

Sixty years ago, the United States was much more dominant: the United States was responsible for 70 percent of global R&D in 1960. Half of this was federally funded defense-related R&D (Sargent and Gallo 2021, 3). Since then, other countries' share of world R&D has grown, as their economies expanded and, in many countries, research intensity (ratio of R&D to GDP) increased. China is particularly noteworthy for both the rapidity of its economic growth and the increase in the research intensity of its economy. In 2000, R&D spending was less than one percent of GDP in China; in 2019, 2.2 percent. With real GDP growth of 9 percent per year during this interval, China's share of world R&D jumped from 5 percent to 22 percent. Meanwhile the U.S. share fell from 37 to 28 percent. The European Union's share also declined – from 22 to 18 percent.

The United States and China are far ahead of other countries in their shares of world R&D. Third ranked Japan accounted for 7 percent in 2019. As noted, a country's share of global R&D reflects both the size of its economy and its research intensity. The United States has the world's second largest economy, using PPP exchange rates, and its research intensity, at 3 percent, is relatively high. China has the world's largest economy and a research intensity of 2.2 with a target of 2.5. The country with the highest research intensity is Israel, with a ratio of R&D to GDP of 4.9 percent in 2019. However, Israel is too small to rank in the top group in total R&D expenditures. South Korea, on the other hand, had the second highest research intensity at 4.6 percent and ranked 5th in R&D expenditures in 2019, even though ranking about 14th in terms of GDP.[5] Taiwan also ranked in the R&D top ten – 10th – despite having a GDP ranking around 20. The other countries making up the top ten in 2019 were Germany (4), France (6), India (7), the UK (8) and Russia (9). India has a low R&D intensity (below 1 percent) but with a very large population, its economy is also large.

Focus

As in the United States, business performs and funds most R&D in other countries. In China, Japan and South Korea, over 75 percent of R&D was carried out and funded by business in 2019; in Germany, two-thirds. In France and the UK, business carried out two-

[4] The R&D and GDP shares are in purchasing power parity dollars. GDP figures are from The World Bank International Comparison Program.

[5] Below the very largest countries, GDP rankings are sensitive to the year and source. For example, The World Bank does not provide data for Taiwan, while other sources show it around 20th.

thirds of R&D and funded somewhat over half. In the three European countries, higher education plays a somewhat larger role in carrying out R&D than in the United States or East Asia. In all these countries, government's role in financing R&D is larger than its share of performance.[6] Also, it should be noted that business in China includes state-owned enterprises; so the business versus government distinction is not clear-cut.

In the United States and East Asia, the bulk of R&D is considered experimental development. In China, over 80 percent of R&D expenditures were classified as experimental development in 2019; basic research accounted for 6 percent. In the United States, as noted previously, experimental development made up 65 percent of R&D and basic research 15 percent. Japan and South Korea were similar to the United States. France and the UK had larger shares of applied and basic research.

In terms of industrial focus, manufacturing plays a larger role in business R&D in China, Japan, South Korea and Germany than in the United States.[7] In these countries 85-90 percent of R&D is carried out by manufacturers, compared to 60 percent in the United States. In France and the UK, manufacturers' share is less than half.

In South Korea and Germany, business R&D tends to be relatively concentrated. In South Korea, the computer, electronic, and optical products industry (henceforth, computers) was responsible for over half of business R&D in 2018 (latest year available for these data.) In Germany, the motor vehicles industry accounted for close to 40 percent of business R&D. In Japan, motor vehicles was responsible for over 25 percent of business R&D and computers for another 20 percent. In the UK and France, non-manufacturing industries were more active, with the grouping professional, scientific and technical activities having the largest share of business R&D.

SEI data on the industrial composition of China's business R&D show computers as the most important performer, accounting for 16 percent of business R&D. Motor vehicles and chemicals other than pharmaceuticals were also sizable. However, we do not have a complete picture, as R&D expenditures by industry add up to only 40 percent of total business R&D. Because only industries with relatively high R&D activity are shown in the SEI report, industry expenditures do not sum to the total for any country, but the shortfall is largest for China. Whatever the data show about the present, China seeks to increase and broaden its technological capabilities. In various strategic plans, including the 14th Five Year Plan, covering the period 2020-2025, the Chinese Communist Party and the government have called for increased R&D and innovation in a wide range of manufacturing activities. Priority sectors range from new energy vehicles to biological medicines and medical devices to power equipment to aerospace to high tech ships. Next generation information technology gets particular attention in the 14th Five Year Plan.

[6] SEI also provides data for India. India is an outlier, with government performing and funding more than half of R&D.

[7] The international data on business R&D by industry uses a slightly different industry breakdown than the NAICS system. The most recent year is 2018.

In the United States, as mentioned above, the major performers of business R&D are the information industry (nonmanufacturing) and in manufacturing, pharmaceuticals and computers and electronic products.

One area where the U.S. differs from other countries is the allocation of government R&D monies. In the United States, government funded 20 percent of total R&D in 2019. Government's share in the six comparison countries was roughly similar, ranging from 15 percent in Japan to 33 percent in France with the rest in the 20s. In the United States, somewhat under half of government R&D expenditures went to defense.[8] China provides no data on how the government spends R&D monies. But in all the other countries, the defense share is much lower. In France, Germany and Japan, the defense share was less than 5 percent in 2019. In the UK, it was 11 percent and in South Korea, 16 percent. U.S. funding of R&D for "health and the environment" is also larger than the shares in the comparison countries, while they are more supportive of economic development programs and the "general advancement of knowledge."

Discussion

Over the past twenty years, China's expenditures on R&D have surged and now rival those of the United States. It is not that the United States has stood still. U.S. R&D spending has increased in real terms, and recently, relative to GDP. However, the rapid growth in China's economy, coupled with increasing research intensity, has caused China's share of global R&D to rise from 5 percent in 2000 to 22 percent in 2019. And its share is likely to rise further as the latest Five-Year Plan calls for China to become "a global leader in innovation" and for R&D relative to GDP to rise from 2.2 percent to 2.5 percent. The government will provide tax and other incentives to encourage R&D, and the message itself is likely motivating.

This raises the question of whether the United States should take a more strategic approach to R&D. Does the United States need more of an industrial policy? This question was debated in the 1980s when U.S. motor vehicles and other manufacturers were challenged by Japanese competitors. Although the government intervened to limit Japan's motor vehicle exports to the United States and to create a public-private consortium to develop advanced semiconductors, the United States did not adopt an industrial policy; and the perceived threat from Japan faded.

But in response to the challenge to U.S. economic and technological leadership posed by China, as well as demands to address climate change, the U.S. government has moved to adopt industrial policy. Legislation passed in 2021 and 2022 calls for substantial increases in investment in semiconductors, electric vehicles and high-speed internet; public infrastructure of all kinds, but particularly to support renewable energy sources and electric vehicles; and research and development. The development and manufacture of

[8] Defense's share was 44 percent in 2019. Before a definitional change, the defense share was over 50 percent.

advanced chips is a key focus of this R&D. The creation of regional "innovation hubs" is also a priority.

In the 1950s and 1960s, the U.S. federal government influenced the direction of R&D through its defense expenditures and space exploration. In the debates over industrial policy in the 1980s, some argued that this defense spending was a de facto industrial policy - and quite a successful one. Others saw defense and space R&D as diverting talent and financing away from making non-defense industries more competitive.

A major challenge in developing an industrial policy today is that there are so many conflicting demands. This challenge is reflected in recent legislation; is the priority next generation technologies? Good jobs? More equity in the workplace? In a war, there is no choice. But without widespread recognition of an imminent threat – and despite heated rhetoric, I do not think many policy makers perceive an imminent threat - priorities will shift and proliferate; and funds are likely to be dissipated across multiple pseudo wars and moonshots without accomplishing the stated goals and without encouraging the risk-taking and technological boundary-pushing that characterized R&D in World War II, the Cold War and the race to the moon.

References

Boroush, Mark and Ledia Guci. 2022. *Research and Development: U.S. Trends and International Comparisons.* National Center for Science and Engineering Statistics/National Science Board. April 28, 2022.
https://ncses.nsf.gov/pubs/nsb20225

Donnelly, Drew. 2022. "Made in China 2025 – Everything You Need to Know." 2022. Horizon. Website. Last updated, July 2, 2022.
https://nhglobalpartners.com/made-in-china-2025/

Sargent, John F. Jr. and Marcy E. Gallo. 2021. *The Global Research and Development Landscape and implications for the Department of Defense.* Congressional Research Service. CRS Research Report R45403. Updated June 28, 2021.
https://crsreports.congress.gov/product/pdf/R/R45403/8

Tsang, Alice and CH Poon. 2021. *China's 14th Five Year Plan: Research Priorities and Industrial Policies.* HKTDC Research. July 15, 2021.
https://research.hktdc.com/en/article/Nzk3NTY5NzUx