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Technology Globalization and Techno-nationalism: A Brief Introduction

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Technology has advanced through global exchanges, with different nations technologically ascendant at different periods. Nations' perceptions of and policies about achieving and maintaining technological leadership have been based on zero-sum assumptions that ultimately have proved futile and may lead to their decline in the face of emergent technology powers. In the first fifteen or so centuries BCE, China led the world in the development and use of the world's most consequential technologies, including printing, gunpowder, the compass, and the production of superior iron and steel. These technologies spread as far as Western Europe, especially as the network of trade routes known as "the Silk Roads" were brought under the control of the Mongol empire in the thirteenth and fourteenth centuries. The Mongols radically reduced travel and trade barriers over the four thousand miles from the Sea of Japan to the Mediterranean, spanning widely diverse countries and cultures. In effect, they developed the first global technology trade system. The roads were blocked by the Ottoman Empire in the fifteenth century, and China's technological dynamism stagnated. From the eighteenth through the twentieth centuries, the West became the primary center for the development and use of military and industrial technologies that enabled a substantial Western domination of the world. The Western domination may now be coming to an end as China and other Asia countries have achieved new levels of technological strength and, as emerging economies, are increasingly challenging

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the Western domination of the rules of intellectual property rights and technology trade. This article describes the China- and Western-centric eras of technology diffusion, noting prevailing zero-sum assumptions about sharing technology and the perceived need for nations to maintain technological “superiority” over other nations. The article concludes with suggestions for the development of a global commons of technology development and sharing.

Keywords
globalization, Silk Roads, Industrial Revolution, intellectual property protection, techno-nationalism, history of international trade

Introduction

Globalization[1] and technology development involve exchanges and collaborations among nations as some emerge to dominate science and technology innovations. In the face of newly emergent nations, once preeminent nations often enact policies to protect their position by restricting these exchanges and flows of technology and knowledge. However, these policies fail to protect their preeminent position and often hamper that nation’s continued science and technology innovation. Examining two eras, we discuss the historical shifts between nations that were dominant technology powers (see Figure 1).

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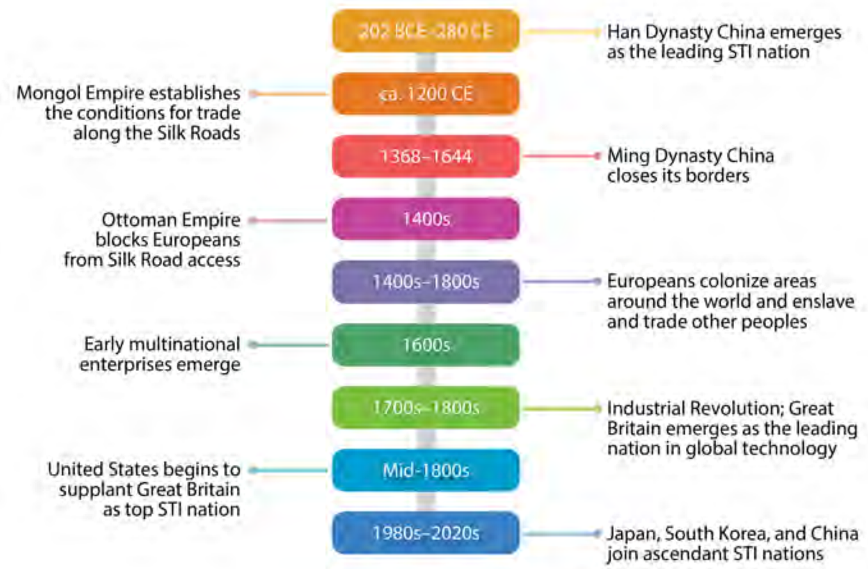

Figure 1: Phases of science, technology, and innovation (STI) globalization.

First, beginning during the Han Dynasty (202 BCE–280 CE), China emerged as the leading nation in global technology and, under Mongol rule (beginning in the thirteenth century CE), established the conditions for trade along the Silk Roads. Then, after China closed its borders during the Ming Dynasty (1368–1644), Western Europe and North America increasingly became dominant (Archibugi & Iammarino, 2002). The experiences of these earlier periods have much to tell us about how new technologies globalize and what some of the forces are that slow technology diffusion and hamper the sustained benefit of innovation to national economies. More recently, we find an emergent phase of technology globalization that involves more widely distributed sources of innovation and thus raises anew questions about policies nations should pursue to ensure their prosperity.

Over recent decades, a growing number of economists have focused on the crucial role of endogenous technology development in a nation's economic growth. Unlike neoclassical theory that attributed national economic growth to savings rates and education, with technology being an *exogenous* factor (essentially available to all countries), *endogenous* growth theory emphasizes policies that promote the development of technology within a country (e.g., tax subsidies for advanced technology investments, antitrust laws, research subsidies and government procurements), the R&D activities of a home country's multinational enterprises

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(MNEs), strong intellectual property rights (IPR) protection, and support for research-oriented universities (e.g., Romer, 1994).

The theory of endogenous technology resembles, in some ways, earlier techno-nationalistic theories of the German political economist Friedrich List, who similarly argued that the prosperity of a nation depends on its ability to develop productive forces, including those based on technological and scientific innovation. List's work underpinned many of the techno-nationalistic policies implanted in Germany and Japan in the late nineteenth century (List, 1841; Samuels, 1994). But the techno-nationalistic policies advocated by List and his followers in Germany and Japan were also based on a zero-sum view of global science, technology, and innovation (STI)—that is, they held the underlying belief that an increase in the technological strength of one nation comes at the expense of other nations (List, 1841; Samuels, 1994). Additionally, a nation had to have greater strength in STI than other countries to ensure its own military and economic welfare.

Viewing STI as zero-sum—as benefitting only the nation that develops and dominates its use to the exclusion of other nations—leads to techno-nationalist policies. If STI is conceptualized as limited, developed without external collaboration or contributions, and exclusive to the nation that develops it, then it would follow that a nation should enact policies that try to contain STI within national borders and limit the exchange or collaboration with other nations. However, theories of endogenous STI growth do not necessarily assume that the growth comes at the expense of other nations. Indeed, one might suppose the creation of new STI in any country might benefit people in other countries, leading to better medical care, better products, less poverty, or a cleaner environment, and thus provide mutual benefits through collaborative development of STI as well as its use.

Today, many policymakers in advanced industrial nations see their countries as leaders whose fortunes depend upon maintaining a lead over other nations and, as will be discussed in this article, pursue policies based on the perspective that economic prosperity comes through monopolizing and protecting a lead in technology development to better "compete" with other nations. Echoing the perspectives advanced by previous followers of List, in recent decades, industry executives, policymakers, and the media have sounded alarms about an ascendant China winning the "technology race" through its large investments in a range of technologies from solar panels and batteries to computers, chips, and cars, along with the acquisition of innovation through a range of policies and strategies (e.g.,

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Augustine & Lane, 2021; Navarro & Autry, 2011; US Senate Committee on Small Business and Entrepreneurship, 2019; Kashmeri, 2019).[2] This perspective of an ascendant Asia that threatens Western prosperity is not new.

Half a century ago, the ascendant Asian challenger was Japan (Vogel, 1979; Johnson, 1982).[3] The challenge to Western firms came from technologies Japan (and later South Korea) acquired from the West and then commercialized and/or improved in products such as handheld calculators, digital cameras, copy machines, printers, small high quality fuel-efficient cars, and now hybrid cars, along with other products. This is a global dimension of a process often referred to as "creative destruction" of existing technologies and businesses as an ongoing evolution of industrial societies. As notably discussed by the political economist Joseph Schumpeter, it is a process "that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one" (1943/2010, p. 83).

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Creative destruction during the rise of Japanese technology. The Datsun Fairlady (circa 1961) begins to take market share from MG, Austin-Healy, and other British sports cars; Casio and other Japanese electronic calculators replace mechanical calculators; digital cameras contribute to the decline and fall of Kodak. Datsun Fairladies: Photo courtesy Ниссан Мануфэкчуринг РУС, CC BY 4.0, via Wikimedia Commons. Casio Calculator: Photo courtesy Multicherry, CC BY-SA 4.0, via Wikimedia Commons. Sony Camera: Photo courtesy Jürgen Matern, CC BY-SA 4.0, via Wikimedia Commons.

While US automakers and their American employees clearly suffered from Japanese auto imports, the Japanese automotive challenge spurred advances in technology, quality, and efficiency, and ultimately in production and employment in the US. And while China’s subsidies of its solar panel industry may have (perhaps unfairly) forestalled the development of a US solar panel industry, the lower cost led to widespread diffusion of solar panels that, arguably, provided a net benefit to all nations by increasing the adoption of solar power and expanding employment in the installation sector (Hughes & Meckling, 2017). Alternatively, it is harder to see the benefits to the US of the controversial acquisition of some computer technology by the Chinese technology company Huawei (alleged to be based on at least some IPR stolen from competitors). The possible use of this technology by the Chinese government in surveillance may pose security threats to other nations that far

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outweigh the benefits provided by the low cost of Huawei's technology, as well as the effect of Huawei's possibly improper use of the R&D of other companies to lower its own R&D costs and produce lower-cost rival products (Yap et al., 2019).

Policies by which countries, governments, and companies have sought to use technology to pursue corporate and national interests have often been based on an implicit assumption that technological innovation is a zero-sum game in which one country's technological successes are seen as disadvantaging other countries in terms of relative military, political, and/or economic strength. This zero-sum assessment of technology development had a certain plausibility in previous phases of the globalization of technology development and diffusion (Lynn & Salzman, 2004, 2006), but even then, it overlooked the interdependencies of nations in the exchange and development of technology and other innovations (Mann, 2011; Crosby, 1972/2003).

This view of the nature of technology development and a nation's role in the global economy is more consequential with the heightened need for technological advances to address global problems, such as viruses, poverty, and climate change. The increase in global integration and interdependencies also offers greater potential for mutual gains in both the development and application of technology (Lynn & Salzman, 2004, 2006, 2018), as is, for example, seen in the global collaboration to develop a COVID vaccine. In the past, the level of a nation's industrial development and access to electricity or telecommunications, for example, limited its ability to access and use advanced technology. New technologies that allow manufacturing to be done globally—such as Apple's product design in California, parts manufacturing in a half dozen countries, and then assembly in China, with the final product shipped globally (Dedricket et al., 2010)—integrate a larger share of nations and populations in commerce and in product development. Advanced STI can both be used by nations at a greater range of levels of industrial development and as a greater number of people across the globe have the education and ability to contribute to STI development. Rather than dominant nations trying to outcompete and exclude other nations by pursuing techno-nationalist policies, what may be needed is some form of a global STI commons. A global STI commons can provide mutual gains through strategies to develop collaborative advantage that draw on this more widely available pool of talent and capabilities (Lynn & Salzman, 2004; Nelson, 2004; Ostrom, 1994).

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Asian Ascendancy in the Development of Technology

Until the eighteenth century, Asia was preeminent in the production of new technology. As Nathan Rosenberg (1982) notes: “Francis Bacon observed almost 400 years ago that three great mechanical inventions—printing, gunpowder, and the compass—had ‘changed the whole face and state of things throughout the world; the first in literature, the second in warfare, the third in navigation” (p. 286). Rosenberg (1982) goes on to observe that none of these inventions originated in Europe but rather represented technology transfer from China.

Printing, gunpowder, and the compass were among the many transformative inventions to come out of ancient China.
Photos courtesy Getty Images.

Two thousand years ago, Chinese metalworkers had developed iron smelting and refining technologies that allowed better control over temperature and additions of carbon to produce higher grade iron and even steel. When Roman Legions encountered Parthian armies using weapons made from Chinese iron and steel, they found their own weapons were grossly inferior. The Romans believed the superiority of Chinese iron was due to the ores found in China, not thinking the refining technology could be responsible (Ball, 2016).

The Chinese also pioneered the production and utilization of silk. Wild silks had been harvested in Greece, but cloth made from these silks was coarser than Chinese silk and lacked the same sheen and tensile strength. The difference was the technology used to produce and harvest silk. The manufacture of Chinese silk was complex, entailing the selective breeding of silkworms, careful control of temperatures and humidity to control the life cycle of the worms, and painstakingly removing the single strand of raw silk that made up each cocoon.

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The ancient Chinese perfected silk production by cultivating and breeding silkworms, improving upon an available natural resource.
Photo courtesy Getty Images.

Each of these strands could be several hundred yards long compared to the strand lengths of just a few inches for plant-based fibers such as cotton or flax. As a result, silk fiber has a tensile strength far greater than that of plant-based materials. The Chinese also developed spinning and weaving technologies to make cloth from the strands as well as mechanical drive belts based on the superior tensile strength of silk (Needham, 1969).[4] When the Romans first encountered Chinese silk, they speculated that it was made from some kind of growth on trees unique to China, again mistaking natural resources for innovations in technique and technology.

Mistaking natural resource endowments for advances in technique born of skill and innovation has been a long-running historical mistake. As Ball (2016) notes, the Chinese thought the glass used in some of the jewelry they imported from Europe was a natural substance, while the Romans thought Chinese technology in iron and silk was due to the inherent properties of unique natural resources rather than through the techniques in developing and using the materials.

Beginning more than two thousand years ago, trading networks began to appear over a variety of land and sea routes, eventually (but indirectly) connecting Yuan dynasty China with the Roman Empire. Now referred to as “the Silk Roads” (the term was the invention of a German geographer in the late nineteenth century), the roads encompassed trade in spices and a variety of other commodities and

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products, not just silk (Ball, 2016).[5]

Camels carrying brick tea from China begin their Silk Road journey to Russia.
Photo courtesy Wellcome Images, CC BY-4.0, via Wikimedia Commons.

The diffusion of technology along the roads was slow and uncertain. The Chinese were concerned about the military applications of their iron and steel technology and tried to keep it secret. Their enemy in Central Asia, the Xiongnu, captured Chinese metalworkers, forcing them to share the technology. From the Xiongnu, the technology eventually spread further west (McLaughlin, 2016). The Chinese also sought to monopolize the benefits of their technologies to produce and use silk. An imperial decree set the death penalty for efforts to export silkworms or eggs. Still, variants of silk leaked to India and Japan in the third and fourth centuries BCE and to the Byzantine Empire in the sixth century (McLaughlin, 2016).[6]

Governments along the Silk Road also slowed the diffusion of Chinese technology as they sought to maintain their control over the movement of goods through their territory and profit from those traveling through their lands. By charging various fees and taxes to those crossing their territories, they enriched themselves but, along with marauding bandits, increased the risk and reduced the gains to be made by trading along the Silk Roads.

Moreover, Persians, Parthians, and others also deliberately misinformed the Chinese about the routes to the West, and Romans about the routes to the East, to

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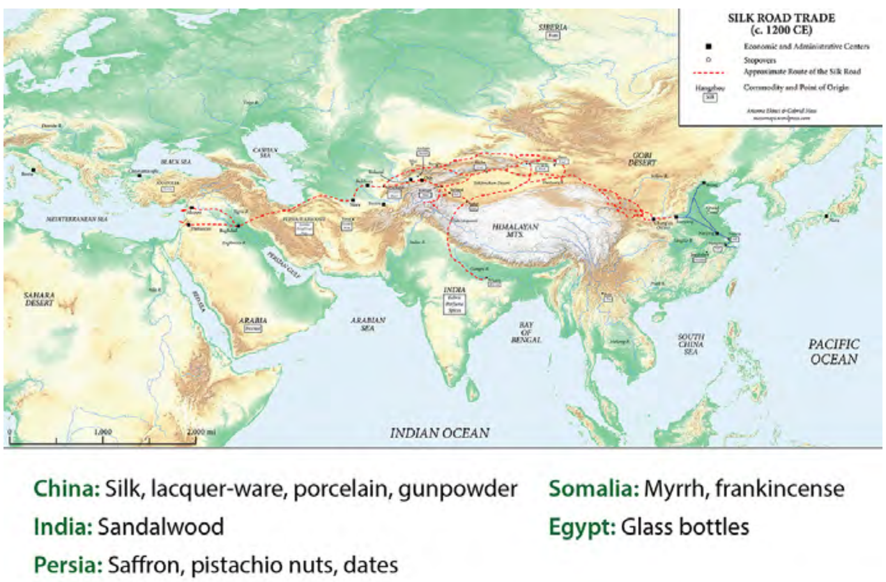
be able to maintain their indispensability as guides over the trade (Ball, 2016; Benjamin, 2018). This changed with the rise of the Mongol Empire in the thirteenth and fourteenth centuries.

At its height, the Mongol Empire extended from the Sea of Japan to Eastern Europe. The Mongols subjugated all the states along the Silk Roads, eliminating the power of local elites and opening up trade along a four-thousand-mile path (Favereau, 2021). Many of the Chinese technologies gradually spread through Eurasia, most famously carried by Marco Polo among many other traders. Given the transportation and communications technology of the time, this diffusion of technology still took centuries, but the interdependencies and institutions for global exchange established the means for trade and advancement in technology, governance, and empire building (Favereau, 2021; Frankopan, 2015; Weatherford, 2004).



The Silk Roads became effective roads for the flow of science, technology, and innovation under Mongolian rule, when it also united the largest contiguous empire in world history.
Map compiled by Gabriel Moss and A. Ekinci, CC BY-SA 4.0, via Wikimedia Commons.

The Rise of the West: The Industrial Revolution and Rise of MNEs

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From the eighteenth through the twentieth centuries, Western Europe and North America (later joined by Japan and other East Asian economies) rose to global technological dominance. The technological primacy of the West was established through often intertwined developments: the Industrial Revolution and subsequent technological advances, colonialization/capture of global resources (including enslavement) and potential competing centers of power, and the emergence of powerful multinational enterprises. As a result, Western elites gained substantial control over the development and use of emerging technologies (Chang, 2007; Hickel, 2018; Mokyr, 1990, 2016).

The rise of American industry was recognized at the Crystal Palace exhibition in London in 1851.
Photo courtesy Philip Henry Delamotte (1821–1889), Public domain, via Wikimedia Commons.

After the blockage of the old Silk Road land trade routes by the Ottoman Empire in the mid-fifteenth century, European adventurers sought new trade routes. As explorers rounded Africa and crossed the Atlantic in an effort to reach India and China, European shipbuilding and navigation technology advanced. The Europeans colonized the New World and sent emigrants there in a race for control and sources of raw materials and labor. They also built strongholds in Africa and Asia to support their trading fleets. Enslavement of local populations occurred throughout the areas of colonial expansion to provide labor and, from Africa, the trade in humans, which led to dramatic transformation of the political economies and demography of

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much of the New World to this day (e.g., Mann, 2011).

From the early seventeenth to the late nineteenth centuries, Holland, England, France, Sweden, Russia, and other countries established embryonic MNEs, including the Dutch, English, and French East India Companies, the Hudson's Bay Company, and the Russian-American Company (Bown, 2009; Nierstrasz, 2015). These companies enjoyed highly profitable royal trade monopolies and supported the colonial rule over and expansion of colonies by their home nations. India was governed for much of the period by military and political arms of the British East India Company, as was Indonesia by the Dutch East India Company, much of Canada and the US Pacific Northwest by the Hudson's Bay Company, and Alaska by the Russian-American Company (see Figure 2).

Figure 2: Early multinational enterprises.

British flag: Courtesy Yaddah, data from FOTW, public domain, via Wikimedia Commons. Dutch flag: Courtesy Giro720, public domain, via Wikimedia Commons. Hudson's Bay Company flag: public domain, via Wikimedia Commons. Russian-American Company flag: Courtesy Ltkizhi, CC BY-SA 3.0, via Wikimedia Commons.

In the eighteenth and nineteenth centuries, England gradually emerged as the global industrial and technological leader with the development of steam engines, textile production technologies, railroads, and other technologies. Some new technological advances were brought by immigrant craftsmen from continental Europe, attracted by newly enacted patent laws that gave them monopoly rights to the technology they brought for a set period of time.[7] As the British assumed technological leadership, they attempted to keep the new technologies, particularly

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those related to the textile industry, within England, or at least within the British Empire (Jeremy, 1977). These efforts intensified in the 1780s after the loss of the American colonies and then the prolonged wars with France. Skilled artisans and manufacturers were not legally allowed to leave England to practice their trade. It was also illegal to encourage technicians to emigrate. Further, it was illegal to export any textile, metal working, clock-making, leather working, papermaking, or glass manufacturing equipment.

By the early nineteenth century, the looming challenger to English technology preeminence was the United States.[8] Like China some centuries earlier, England tried to maintain its leadership by restricting the outward flow of technology (Morris, 2012; Chang, 2007; Jeremy, 1977). In support of these restrictive trade policies, customs officials in Britain tried to prevent emigrants from leaving the country, reporting that glass workers, goldsmiths, and cotton workers were attempting to go to the United States. English artisans risked losing their citizenship and property if they emigrated. Recruiting agents could be sentenced to a year in prison and fined 500 pounds for each emigrant recruited. Some artisans were caught by Customs officers as they attempted to leave England. Others were reported by English consulates in the US and elsewhere. A US government survey during the War of 1812 found some 1,300 British workers in the US working in the textile trade. Workers from Birmingham arms manufacturers were reportedly taking their tools with them to America. Craftsmen also moved to Germany, Austria, France, Russia, and other countries, bringing their technology and craft knowledge with them (Jeremy, 1977). Table 1 provides examples of policies designed to keep technology within the borders of the country in which it was developed.

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Examples of techno-nationalistic policies[i]

Policies	Examples
Human Resource	
Restrict emigration of STEM workers[ii]	- Chinese iron workers, Venetian glass artisans, English textile workers
Promote immigration of STEM workers from dominant nations	- German engineers to Russia (18th century) - Western engineers to Japan (19th century) - German scientists to US and Russia (post–World War II) - Bringing expatriate Chinese and Indian STEM workers back to China and India
Race to train more STEM workers than "rivals"	- US, Russia, China, India
Protect "Infant Industries"[iii]	
Tariffs, import restrictions, subsidies	- US, Japan, South Korea, others
Intellectual Property Rights	
Strategic use to prevent competition - Development of competing products	- Western MNEs in biotech and elsewhere
Forced sharing of IP for market access	- China
Espionage	- US textile production from England - China (Haier)

i) Techno-nationalistic policies assume a zero-sum situation in which nations are assumed to be in competition with each other in the development and use of technology. One nation's gains are seen as coming at the expense of other nations.

ii) We use the current term "STEM" (science, technology, engineering, and math) to encompass workers expert in the technology and innovation of previous eras, including artisans making glass, iron, and textiles.

iii) Alexander Hamilton, the first US Secretary of the Treasury and founder of the US financial system is commonly associated with this term. The idea was that US industries needed to be protected from import competition in order to catch up with England and other advanced economies. Germany followed similar policies as did many other "developmental states," including Japan after World War II and South Korea more recently.

Table 1: Examples of techno-nationalistic policies

The measures restricting emigration had limited effectiveness. It was difficult to define and identify the targeted skilled workers. Some emigrants were caught because they tried to take their tools with them, but others went without tools, hid tools in the ship's cargo, or took small boats with their tools to board ships that were already at sea. Definitions of covered technologies were not clear. The loss of citizenship was an effective deterrent to those hoping to go to continental Europe, but less so for those going to the US, where they could become naturalized citizens (Jeremy, 1977).

Early on, artisans played a central role in the diffusion of technology. But by the 1820s, new machines had been developed that had less need for skilled practitioners. It also became easier to copy machines based on models, drawings, and specifications. All restrictions on artisan emigration were ended in 1824. Efforts to limit the outflow of technology now focused on machinery, but here again,

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complications arose. Government officials and manufacturers found it difficult to agree on what exports should be allowed. Machinery that would be used at the initial stages of production, preparing products for high value-added processing in the UK, could be exported, as could obsolete equipment and equipment not relevant to the industries of concern in England. A technology that, in retrospect, would seem to have been important was machine tools, but machine tool exports were not restricted, whether because of a lack of foresight or perhaps because of political pressures from machine tool manufacturers (Jeremy, 1977).

Exporters also found ways of circumventing export restrictions. Some machines were simply smuggled out of the country; others were broken up into components not recognizable by customs inspectors. Finally, in 1843, “[a]fter nearly one hundred fifty years, all types of British machinery were at last freely exportable” (Jeremy, 1977, p. 33). By this time, several American industries, including textiles, had become formidable competitors for the British, who were deeply impressed by what they saw at the Crystal Palace Exhibition in London in 1851 (Ben-Atar, 2004). Much of the American success, of course, was based on English technology and innovations by English immigrants who brought their trades and technology with them (Tucker, 1981). Industrial espionage also played a role, such as Francis Cabot Lowell’s covert copying of British factories during a visit and building improved versions of the textile mills to then compete with the British, giving birth to the American Industrial Revolution (Ben-Atar, 2004).[9]

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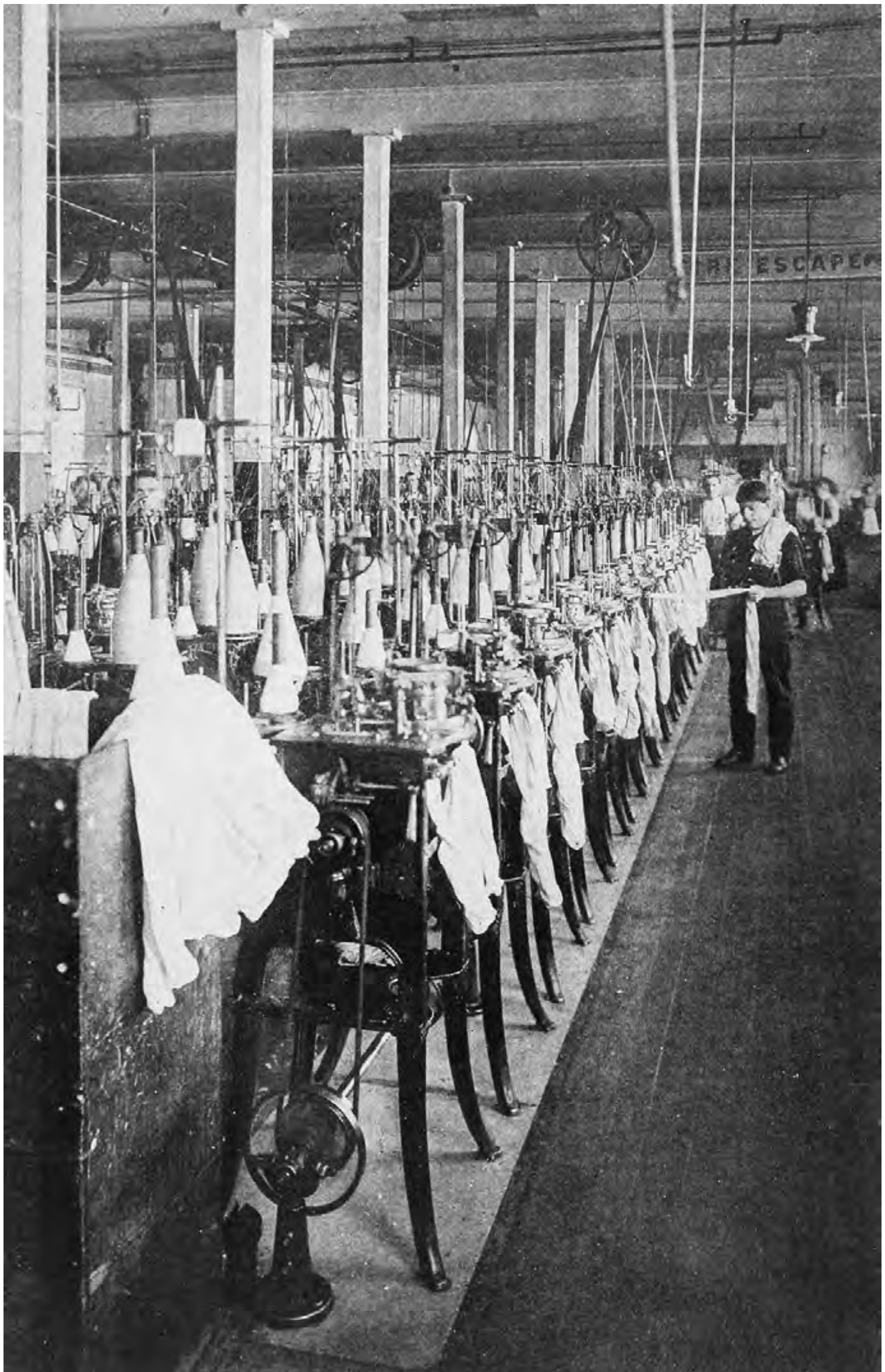

Francis Cabot Lowell's industrial espionage in England resulted in the adaptation of the power loom and textile factories, which would become integral to the American Industrial Revolution and the founding and development of cities like Lowell, Massachusetts. Photo courtesy Internet Archive Book Images, Public Domain, via Wikimedia Commons.

Conclusions

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The first phase of technology globalization was clearly dominated by China. As would occur throughout the centuries that followed, nations that led in STI tried to maintain their positions through various restrictions on trade and global exchange that provided short-term gains while failing to recognize emergent technology advances from other regions (see Figure 3). Clearly, the Chinese benefited from monopoly profits in the silk trade. Still, the Chinese failed to recognize the potential benefits of continuing to absorb foreign technology.[10]

Figure 3: Policies imposed to restrict STI flows.

The Chinese efforts to improve national security by restricting the flow of iron and steelmaking technology failed. Efforts to restrict the outflow of silk-related technology also failed over time. Later, in the eighteenth and nineteenth centuries, the Chinese sense of superiority seems to have hindered their willingness to import Western technology, which weakened their ability to resist Western incursions.

After the blockage of the Silk Roads by the Ottoman Empire, new centers of technology and science development emerged and led to the eventual beginning of

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the Industrial Revolution in the eighteenth century. Western Europeans seeking new trade routes to East and South Asia began using and improving some Asian navigation and military technologies (e.g., the compass and gunpowder), eventually colonizing much of the world. In time, the Industrial Revolution accelerated the ability of the West to control vast expanses of the globe and also accelerated technological development. The British, and later the Americans, became the technological leaders in this era. Both sought to control the outflow of “their” technologies by a variety of means: restricting the emigration of technical people (in the case of the British), developing IPR laws, and eventually securing international IPR agreements, but technologies still flowed relatively quickly within the West.

In the latter part of the twentieth century, new STI development emerged in Japan, and later South Korea, that challenged US dominance. Similar to Britain a century before, and to China several hundred years prior to that, the US first tried to protect its existing technology and companies in the face of this inflow of new STI. It was Japan’s eagerness to adapt and exploit Western technology in the late nineteenth century, followed by South Korea, that led to their ability to challenge US dominance and techno-nationalism; Japan’s approach to absorbing and building on foreign STI also provides an interesting contrast to China’s closure to the outside (Morris-Suzuki, 1994).

In the first stages of globalization, there was a slow development of STI. This occurred through the international movements of people, ideas, and technologies, particularly when these movements were allowed to occur more or less freely. These processes and exchanges constitute an “STI commons,” a shared pool of resources that maintained vibrant economies and ongoing innovation.

Efforts by nations to constrain the outflows of STI also constrain continued exchanges and flows that enrich STI development. As we have seen with the case of China and England in the earlier stages of globalization, efforts to control STI outflows tend to be futile. Indeed, these outflows can lead to further STI developments in other countries that can enrich the original innovators as well as those receiving the technology. An STI commons requires systems of governance that support those flows and provide a certain degree of stability and engagement, as was provided by the Mongols when the Silk Roads flourished under their rule (Favereau, 2021). As discussed by Nobel laureate Elinor Ostrom (1994), the fair and effective governance of a commons is crucial to its long-term sustainability. In an STI commons, the common pool resources are the science, technology, and

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innovations that are created and drawn on by its participants or members.

When nations attempt to maintain a position of dominance through zero-sum strategies, the STI commons withers. After centuries of technological leadership, China's attempted restriction of technology outflows and isolation led to the ascendency of other nations in developing STI. With the rise of Europe, and the UK in particular, again hubris, war, and techno-nationalism led, in turn, to the rise of technology advancement in other nations, principally the United States. As American STI dominance is now being challenged by China and other nations, it remains to be seen whether these nations develop an STI common pool system that engages nations in research and development that provides mutual gains.

The ebb and flow of technology development and dominance is part of the broader political and policy shifts that occurred throughout the nineteenth and twentieth centuries in the West. Technology alone does not determine the political order or the fate of nations, but certainly, the attempts to control technology diffusion in order to maintain international dominance have failed. Recognizing that technology policies cannot exist independently of geopolitics, we find that history suggests the need for an integrated global science commons, a system in which not only are advancements diffused globally but also constrains attempts to dominate technology in a zero-sum strategy.[11]

Notes

1. This article builds on previous (and continuing) work by the authors. See, for example, Lynn and Salzman (2018). The research was supported through grants by the National Science Foundation (HSD #SES-0527584; SDEST #0431755).
2. Kashmeri (2019) links China's ascendency to the current Chinese Belt and Roads Initiative, inspired by the Silk Roads. He says if China continues its recent rate of economic growth for another two generations, it will become "the most powerful and influential country in the world" (p. 1). Though not arguing for techno-nationalist policies, Gomory and Baumol (2001) examine the detrimental effect of "free trade" ideology and policies on the US.
3. Ezra Vogel's book *Japan as Number One: Lessons for America* (1979) and Chalmers Johnson's *MITI and the Japanese Miracle* (1982) both became influential best sellers widely read by businesspeople and government officials as well as academics.

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4. Joseph Needham (1969) is the grand authority on the history of Chinese science and technology. This is one of his more accessible works.
5. While Chinese silk and iron were highly valued by the Romans, the Romans had little to offer China aside from gold and silver. There was some demand for Roman glassware, jewelry, and fabrics interwoven with gold, but the high demand for Chinese silk enriched the Chinese, while leading to the depletion of the Roman silver and gold reserves.
6. McLaughlin (2016) cites what he calls a “semi-legendary” story from the seventh century about how Chinese sericulture technology crossed what was then the Western border of China to the kingdom of Khotan. The emperor of China refused requests from the King of Khotan to share the technology. The King of Khotan then requested permission to marry a Chinese princess. This request was granted. The King then let the princess know that the people of Khotan did not have the technology to make the beautiful clothing she was accustomed to. The princess supposedly acquired mulberry seeds and silkworm eggs and hid them in her headdress. The Chinese border guards searched her clothing and possessions, but not her headdress.
7. During the late nineteenth century, IPR became an important factor in the development and diffusion of technology. Venice established the first real patent system in 1474. Inventors were given a ten-year monopoly for “new and useful” devices that had not previously been used in Venice. As various European nations competed to attract skilled Italian glass workers and other craftsmen (and the technology they could bring with them), they found intellectual property rights systems were a strong attracting factor.
8. Ironically, a historian of the rise of the US during the period, Charles Morris (2012), sees strong parallels between the jostling of leadership between the nineteenth-century leader, England, and the upstart contender, the US, and current competition for leadership between the US and the new upstart contender, China.
9. As Ben-Atar (2004) explains, this theft of intellectual property, as it is now termed, was crucial in the technology development history of the US: “…the statutory requirements of worldwide originality and novelty for American patents did not hinder widespread American appropriation of innovations protected under other nations’ patent and intellectual property laws. In fact, once a technology was in the New World, its introducers quickly claimed it as their own and used the courts to discourage infringements” (p. 204).
10. Although the notable innovations of silk, gunpowder, and the compass came from China, other areas were also contributing to China’s development, such as glass from Rome, woolens from Central Asia and the Mediterranean, and

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the larger and faster horses from central Asia that provided the Han court with an advantage in battle.

11. In other work (Lynn & Salzman, 2022), we discuss the structure of globalization and the possibilities for developing an STI commons that provides mutual gain collaboration. Centers of technological development are more widely dispersed across the globe than ever before, and zero-sum notions of technological development are being challenged as the world faces the need to deal with climate change, growing inequality, and the spread of viruses and diseases—it seems increasingly that a global science commons is needed.

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