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Science and Technology in a Global Commons: The End of Techno-Nationalism?

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The global challenges now facing all nations transcend national boundaries. Summoning the global talent and resources necessary to address these problems will require global science, technology, and innovation (STI) collaboration. Whether climate change, global poverty, or the threats from cyber technologies, effectively dealing with these challenges and opportunities will increasingly require advanced industrialized nations to move beyond their historical techno-nationalist STI policies.

Currently, STI policies being proposed in the US and elsewhere assume a “zero-sum” competition where one nation’s STI successes are assumed to come at the expense of other nations. They seek ways to outcompete other nations in the production of new STI and restrict foreign access to their STI. History suggests that such policies had, at best, limited success, and the current environment for them seems even less promising. When China was a global STI leader, its techno-nationalistic policies failed to prevent the spread of its advanced technologies and the rise of other nations. England was unable to use techno-nationalist policies to monopolize the skills and technology it pioneered during the industrial revolution.

America pursued its own techno-nationalist policies in the post-World War II years, attempting to maintain the leadership it enjoyed as other countries recovered from World War II devastation. Today new centers of STI development are rapidly

emerging and expanding in China, India, Southeast Asia, and other parts of the world. In response, many US policy makers and business leaders harken back to prior failed strategies and advocate intensifying the techno-nationalistic STI policies. This paper proposes a more techno-globalistic approach through the development of a global STI commons, an approach that holds the promise of benefiting people all over the world, including those in currently dominant nations.

Keywords

[techno-nationalism, techno-globalism, intellectual property rights, common pool resources, science, technology, innovation, science and technology policy](#)

Introduction

A nation's standing in the world has historically been gauged by its military and economic prowess and its ability to dominate other nations. National science, technology, and innovation (STI) policies have typically focused on developing a country's "competitiveness" with other countries, whether trying to gain an advantage in developing its industrial capacity or, for highly industrialized nations, achieving or maintaining a dominant position in the global economy. Throughout history, nations that were dominant powers tried to maintain their position not only by their military prowess but also through carefully developing and guarding their STI capabilities, pursuing what is referred to as "techno-nationalist policies" that assume the STI development of one nation comes at the expense of other nations.

Techno-nationalist policies that lead dominant nations to protect their STI advantages by erecting barriers to the flow and exchange of knowledge, skills, and technology have not been successful over the long term. In today's world of globalized STI development, multinational enterprises (MNEs), and markets, there is even less ability for a nation to constrain global STI flows. More importantly, the nature of global problems—from disease to poverty to climate change—require greater STI integration, not less, to ensure survival as well as equitable prosperity. It is both the current structure of STI globalization and the nature of the most important global challenges that require a new approach to national policies. Following a brief historical overview (for a more detailed historical background, see Lynn and Salzman, 2022), we discuss current techno-nationalist policies in the US, the nature of multinational firms, national economies, and STI development, and conclude with suggestions on how an "STI Global Commons" might be developed that would offer an alternative mutual gain policy, and address the major

challenges facing the world and lead to a more equitable prosperity.

Background

Historically, STI-dominant nations have included the Roman, Chinese, Ottoman and British Empires, and the United States. Each led in the production of key technologies, as well as in economic and military power. While military and economic power are the most visible indicators of strength in the competition between nations, these capabilities rely on a broad base of STI. Leadership in STI is seen as essential for a nation to maintain or increase its power and to ensure its prosperity and well-being. Exchanges of STI with other countries typically have been seen as zero-sum games in which the success of one nation can be achieved only at the expense of other nations.¹

A common reading of history is that for the first fifteen centuries CE, East and South Asia led in the development and exploitation of new technologies (see Figure 1). From the thirteenth to fifteenth centuries, the Mongol Empire created a global trade system that took Chinese technology across Asia to Europe (Favereau, 2021). As technological innovation slowed in China, the Mongol trading system was blocked by the rise of the Ottoman Empire, and Europe began its renaissance, domination in technological innovation and trade shifted to the West, which maintained its position over the past three to four centuries.² In the past half-century, challenges to Western dominance from China, India, and other rapidly developing economies raised questions about STI strategies in a new era of globalization.³ We see this new era as the beginning of a “third era” of STI globalization (Lynn & Salzman, 2004).⁴

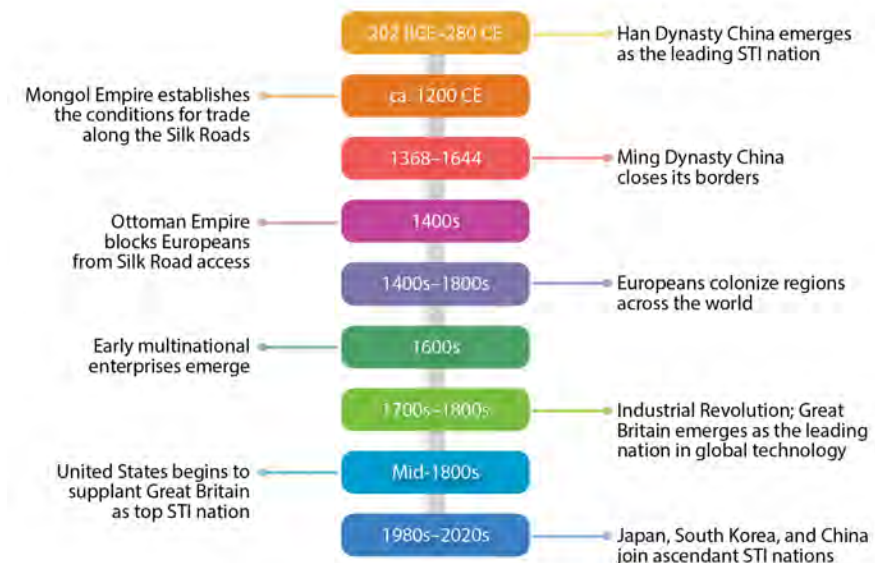


Figure 1: Milestones in global science, technology, and innovation (STI) history.

A central issue is whether the currently dominant nations will try to maintain their position by continuing zero-sum strategies that seek to monopolize access to “their technologies” or whether new, mutual-gain strategies will emerge. Characteristics of the emerging era make past strategies untenable for the currently dominant countries and for those trying to catch up. Instead, it may be possible for new STI policies to create a global STI commons,⁵ which would allow nations to collaborate on solving the world’s most pressing problems and better enable emerging economies to prosper. It is important to rethink the notion that economic prosperity is a zero-sum game in which nations lifting their populations out of poverty, advancing their industries, and developing STI workforces, are a threat to the dominant economies. In the conclusion of this article, we suggest an approach to providing mutual gains and shared prosperity.

Techno-Nationalism

The strategy underlying many prevalent policies and policy recommendations is to pursue what scholars call “techno-nationalism” (e.g., Edgerton, 2007; Ibata-Arens, 2019; Nakayama, 2012; Ostry & Nelson, 1995).⁶ Techno-nationalistic policies by

dominant countries include restricting exports of key technologies, particularly those that are seen as being of strategic military or economic importance. Techno-nationalistic countries also enact policies to promote the technology of companies that were founded in their country and that historically based most of their high-value-added activities there.⁷

Controlling intellectual property allows a firm to restrict other firms from copying its technology, but it can also be used to make it harder for them to develop competing technologies.⁸ The use of patents can make it more expensive for other firms to engage in related R&D and limit the number of firms that can engage in the necessary R&D to enter those markets. A second way to protect domestic firms is to limit imports by imposing tariffs or setting import quotas.⁹

Believing they must protect their home-country firms to support a prosperous and growing economy, techno-nationalistic policymakers ally with “their firms.” Sometimes they use intellectual property rights agreements to control the international diffusion of technology. Further, the dominant countries may try to attract the “best and brightest” personnel from emerging economies to increase their STI human resources, depriving emerging countries access to them. Many of these policies and activities are carried out by multinational enterprises (MNEs) based in dominant countries (see Figure 2).



Figure 2: Policies imposed to restrict STI flows.

“Developmental states” are nations that use these and other techno-nationalistic policies in their drive to catch up. Notable recent examples of developmental states include Japan, South Korea, and Singapore. Earlier examples include the United States and Germany.¹⁰ All these countries used “infant industries” policies: restricting imports and providing subsidies to domestic firms until they were internationally competitive. Developmental state firms focus on acquiring foreign technology to build capabilities (for further discussion on Japanese technology import policies, see Lynn, 1994). Accordingly, developing nations (including the United States during its developmental stage) have had less concern about intellectual property rights (IPR) protections than the developed economies. Sometimes developmental states subsidize exports to build market share and acquire foreign exchange reserves.¹¹ Many of these developmental state policies have been severely restricted during successive rounds of World Trade Organization (WTO) agreements, a practice Chang (2002, 2007) refers to as “kicking away the ladder,” making it difficult for emerging economies to catch up.

Other policies support STI development and dominance. During the post-World War II period, the United States increased government investments in STI and expanded support for primary, secondary, and college education (see Figure 3). Some of this was triggered by concerns about technological challenges in aerospace and military technology from the USSR.¹² Higher education enrollments in the United States rose more than threefold from the years after World War II to 1970,¹³ and the federal government spent 1.5 percent to 2 percent of GDP on R&D during the 1960s, with over 80 percent for military R&D from the late 1940s through the mid-1960s, declining to less than 1 percent of GDP today, with about half spent on military R&D.¹⁴ The overwhelming size of the US economy at a time when Europe and Japan were recovering from the devastation of the war made this strategy effective. No other country could come close to matching the US level of spending on R&D.

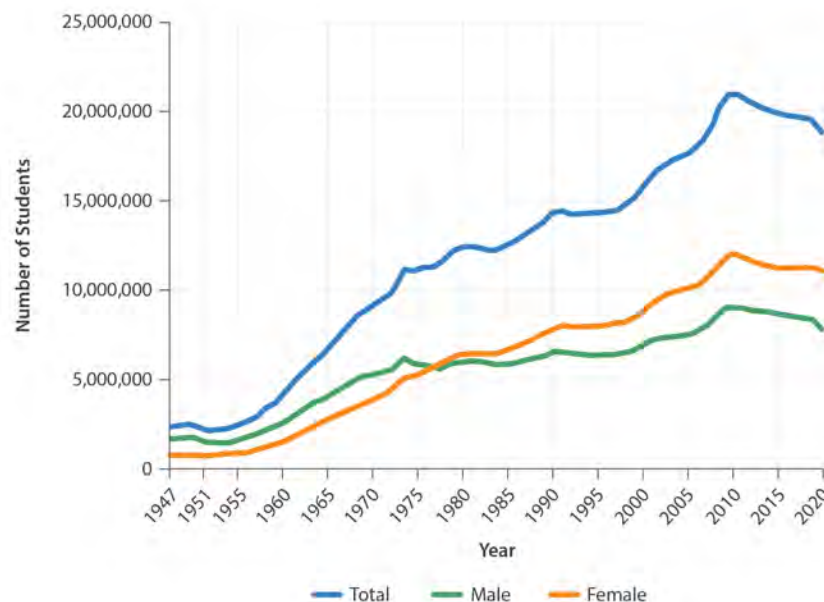


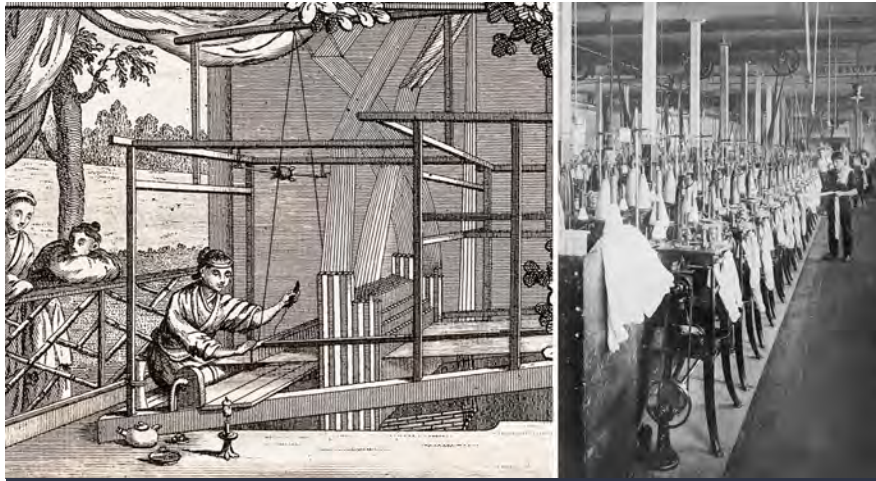
Figure 3: Higher-education enrollments, 1947–2020.

Data source: Digest of Education Statistics (2021).

In the 1970s and 1980s, the United States faced economic challenges from Japan and other countries. Japanese automakers claimed a large and growing share of the US market. US MNEs like RCA and Zenith¹⁵ disappeared when they failed to innovate in the face of competition from Sony, Panasonic, Sharp, and other

companies. Often American firms were slower to make use of technologies developed in the United States than their Japanese rivals (Schaede, 2020; Lynn, 1988). Following the developmental economy strategies previously described, they built competitive strength by keeping foreign products out of their home markets and maintained technological independence by restricting foreign direct investment (Schaede, 2020; Meil & Salzman, 2017). American firms in some industries, such as steel, were more concerned about “protecting” the home market than investing in technology that would increase efficiency or product quality (Lynn, 1982). In America, government funding was increased for STI but it did not go far in restoring US competitiveness.

Techno-nationalist policies may have seemed compelling in the previous phases of technology globalization when the movements of technology and people were much slower. Even so, techno-nationalists failed to recognize that STI advances were developed through cross-national exchanges, and withdrawal from those exchanges led to declines. More than a thousand years ago, the Chinese tried to restrict the export of their iron-making technology to maintain their military superiority and their silk-making technology in order to maintain their economic superiority.¹⁶ Both efforts failed, and Chinese insularity led to their inability to understand the threat from a rising West. In the eighteenth and early nineteenth centuries, the English tried to maintain their superiority in Industrial Revolution technologies by restricting exports of certain machinery and not allowing artisans to emigrate. Again, these efforts did little more than delay the diffusion of these technologies to America and continental Europe for a few years (Lynn & Salzman, 2022).



Left: Ancient Chinese silk weaving loom. Right: British cotton loom during the Industrial Revolution. Over a thousand years ago, the Chinese attempted to preserve their economic superiority and limited the export of their silk-making technology; however, Chinese techno-nationalism ultimately led to underestimating the ability of Western development to rival China's STI.

Left image (engraving): Wellcome Collection gallery, CC BY 4.0, via Wikimedia Commons. Right photo: Internet Archive Book Images, Public domain, via Flickr.

Factors allowing the “leakage” of technology via the movement of people and communications across boundaries are stronger today, allowing for faster and larger flows of technology. Moreover, Western MNEs are less willing and able to support the interests of Western technology hegemons.

The Nationality of Multinational Enterprises

MNEs have often been instruments of Western techno-nationalism. From the early seventeenth to late nineteenth centuries, Holland, England, France, and other countries established embryonic MNEs (Brown, 2009; Nierstrasz, 2015). Today MNEs in the pharmaceutical, aeronautical, IT, and other industries continue to shape the patterns of technology creation and diffusion around the world.

Some techno-nationalists advocate supporting “national champion” MNEs. It is increasingly unclear, however, how much an MNE's nominal home country matters.

Historically much of a country's military and economic strength was based on the major companies that formed its "military-industrial complex" and agents of international trade (Eisenhower, 1961; Mills, 1959;). In the 1950s, Charles Wilson, the chairman of the board of General Motors, famously said that he could not conceive of a situation where a decision made by the US Secretary of Defense would be averse to the interests of GM "because for years I thought what was good for our country was good for General Motors, and vice versa" (Historical Office, n.d., para. 3). Aside from their role in creating and using new technology, home-based firms provided good-paying jobs, products for the domestic market, and support to the communities in which they were based. In the United States, it seemed evident that having strong "US firms" benefitted the country economically, technologically, and militarily.



"For years I thought what was good for our country was good for General Motors, and vice versa." —Charles Wilson, CEO of General Motors (GM) in the 1950s, explaining to Senators why his appointment as Defense Secretary would not be a conflict of interest with his role at GM.

Photo courtesy General Motors Archive, Public domain, via Wikimedia Commons.

When most of the production, employment, and financing of firms were based in their home country, it may have made sense to protect them from foreign competitors. Over time, US federal and state governments adopted “Buy American” policies as an act of patriotism. These policies were not unique to the United States, as European governments supported, protected, and promoted

some of their domestic firms. The firms were seen as “national champions,” reinforcing their home country technological strengths in strategic industries.

In emerging economies, protection sometimes allowed “infant industry” companies to develop and become internationally competitive. For the advanced economies, it often delayed the decline of incumbent firms and slowed the adoption of new technologies and products in their home markets.

There is also reason to doubt the alignment of the interests of a country’s MNEs with its national interest. For example, “American companies” such as GE provided China with the engineering and technology know-how for critical technologies such as the latest jet engines or pioneering medical devices. China required such sharing as the price of entry into its market while also broadcasting its intention to help its own national companies compete with foreign MNEs. Often the technologies being traded away were acquired from, or developed with, the support of the US government.

For MNEs, their business strategies are not tied to any particular nation. As the British-born CEO of Ford explained in the 1990s: “Ford isn’t even an American company, strictly speaking. We’re global. We’re investing all over the world. Forty percent of our employees already live and work outside the United States, and that’s rising. Our managers are multinational. We teach them to think and act globally” (quoted in Reich, 1997, p. 275). David Farr, the CEO of the 125-year-old, Missouri-founded Emerson Electric company, said he was moving his production out of the country: “If half of your sales go outside of the United States, you’re going to have half of your engineering outside of the United States, too.” Farr repeatedly said later that because he was unhappy with US policies: “I’m not going to hire anybody in the United States. I’m moving.” (Lynn & Salzman, 2015, pp. 22–23). These sentiments, and the corporate strategies they reflect, have profound consequences for a nation’s STI policies. If major companies, whose nationalities were unquestioned for over a century, are now conducting business without concern for political borders or responsibility to any particular nation, or sometimes even their own long-term interests (if short-term profits may be gained), what are the implications for a nation’s STI policies?



“If half of your sales go outside of the United States, you’re going to have half of your engineering outside of the United States, too. . . . I’m not going to hire anybody in the United States. I’m moving.” —Emerson Electric CEO David Farr explaining his opposition to President Obama's tax policies and the company's disinvestment in longstanding manufacturing sites such as Ferguson, MO.

Photo courtesy Philip Epifanov, CC0 1.0, via Wikimedia Commons.

A significant change in the relationship between MNEs and their “home countries” occurred in the 1980s and 1990s as MNEs outsourced core operations. Under this “new economy model,” strategies to increase short-term returns to shareholders were given priority over those that might result in longer-term growth and development. Cuts were made in R&D investments, worker skill development, production equipment, community relations, and other traditional business strategies that allied business interests with the home nation (Lazonick et al., 2014). As financialization strategies permeated the economy, there were growing openings for STI acquisitions by China and other countries with strong state-directed enterprises, as well as by foreign MNEs. By taking controlling positions in firms in other countries, developmental states acquire their IPR to build indigenous firms. This sidesteps global IPR restrictions and trade agreements. While the

problem might be addressed through techno-nationalistic policies, the globalization of MNEs and their attenuated ties with their home nation limit the ability of the government to intervene.¹⁷



Developmental states may try to build up their own STI industry by acquiring or heavily investing in foreign firms. For example, after a Chinese investment firm obtained a controlling stake in amphibious aviation manufacturer Icon Aircraft, it allegedly undertook technology transfer to China in violation of US export controls.

Photo courtesy Charly W. Karl, C BY-ND 2.0, via Flickr.

The structural and operational changes of MNEs were partially an evolutionary change in production strategies. Outsourcing began as large manufacturing firms started buying rather than making commodity parts. Firms gradually expanded outsourcing to the external acquisition of innovation and high-value-added functions. This change occurred throughout many industries, and, in a remarkable shift, Wall Street came to consider firms to be poorly managed if they relied on strong internal R&D rather than the external sourcing of technology (Lynn & Salzman, 2007).

These changes provided critical elements in the foundation for the globalization of STI work we are now witnessing. US MNEs profited in the short term with lower costs and an increased pool of human resources. Further, the international workforces of US-based MNEs facilitated globalization by providing firms with cross-

cultural experience and knowledge. Indeed, the more integrated organizational form and less international workforces of European and Japanese firms caused them to be somewhat slower than their US counterparts in globalization, especially of high-level activities (e.g., see Lynn & Salzman, 2007; Lynn et al., 2012). It is not just that the largest markets for technology and innovation are now outside the advanced economies, but also that technology flows across boundaries.

Innovations developed in the home country of an MNE may be quickly transferred to locations elsewhere in the world. In today's environment, innovation leadership by an MNE does not necessarily confer greater advantage to the MNE's nominal home country than to the other countries in which it operates.

The weakening of national ties to MNEs through these changes weakens their usefulness as a tool for implementing techno-nationalistic policies, except in the case of state-owned or tightly controlled MNEs like those in China.

The Current Phase of Globalized Innovation and Technology Diffusion

Now we appear to be entering a new phase of technology globalization, one in which past techno-nationalistic policies are increasingly problematic.¹⁸ The rise of non-Western nations has diminished the ability of the West to monopolize the development of STI. STI global "centers of excellence" have been growing in Japan, South Korea, and other East Asian nations. While these have been largely incorporated into the Western IPR regimes, this is less true of those in the Chinese and Indian economies (accounting for more than a third of the world's population), along with some other emerging economies.¹⁹ Foreign MNEs are also establishing a growing number of foreign MNE R&D facilities in China, India, and other emerging economies where loyalties to the MNE home countries is weak at best (see Figure 4).

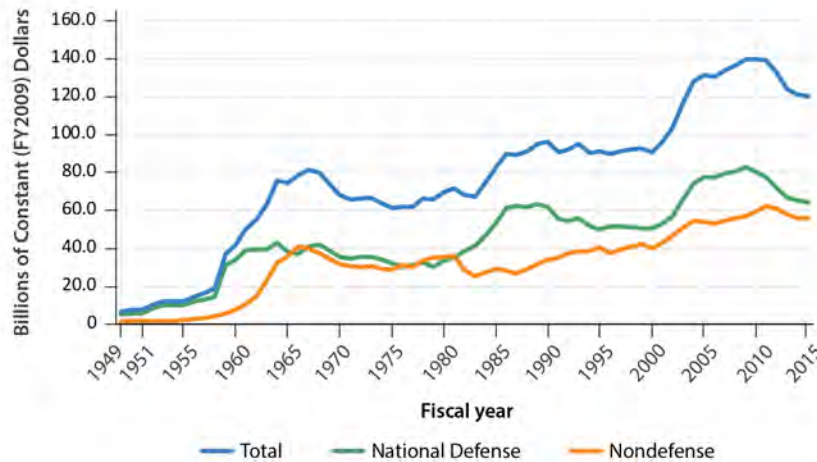


Figure 4: Annual research and development (R&D) outlay in the United States, 1949–2015.

Data source: Office of Management and Budget. (n.d).

Thus techno-nationalistic policies to dominate and restrict the global diffusion of STI are increasingly inconsistent with MNE business strategies. The exception may be China, where large firms are either state-owned or at least tightly state-controlled. China is also trying to exert control over foreign firms doing business in that country. History suggests this strategy could be countered if other nations, in concert with leading MNEs, were to resist it. But thus far, there are few signs that governments and MNEs are able to do this.

The Challenge to Trade Policies and Regimes

While Western MNEs have been one major instrument of Western techno-nationalism, another is the system of rules and policies governing international trade, particularly trade in IPR. Today, this system is increasingly challenged by non-Western countries and by some Westerners who argue that the system is unfair to emerging economies, and that favoring MNEs is unfair to most people in developed economies (Stiglitz, 2017; Rodrik, 2011). For some, the 1995 WTO Trade Related Aspects of Intellectual Property Rights (TRIPS) agreement to regulate and standardize trade in patents, copyrights, and other aspects of intellectual property was a last straw.

The contours of the TRIPS agreement were strongly influenced by US, European, and Japanese biotech and IT MNEs, and highly favored these businesses to the detriment of other interests (Stiglitz, 2017). The agreement stopped India from making affordable generic versions of life-saving drugs and prevented countries from adopting policies similar to those that helped Japan, South Korea, and Taiwan to catch up with the West. The emerging economies signed the agreement because they needed to be part of the broader WTO agreements, but complaints about the unfairness of this agreement and, more generally, about “Washington Consensus” policies²⁰ remain a sore point.

In brief, the criticisms of TRIPS are: (1) it assumes “one-size-fits-all” (e.g., the agreement does not recognize the special needs of emerging economies to use “developmental state” policies); (2) it assumes that more IPR is better, ignoring the ways IPR can block innovation; and (3) it assumes the Western IPR system, which has been described as a “broken system” (Archibugi & Filippetti, 2010), should be the model for the world despite abuses of this system by MNEs, especially in the IT and pharmaceutical industries (Stiglitz, 2017; Rodrik, 2011).

Countering the new techno-nationalism would first require a change in existing approaches and policies that reflect the Western techno-nationalism of prior decades as expressed in global organizations such as the WTO and in policies pursued by the United States and international financial institutions. These policies provided access to markets in emerging nations, limiting the ability of those nations to protect their firms and markets. They provided strong enforcement mechanisms of IPR regimes established to protect the STI controlled by dominant MNEs. Dominant nations are also losing out in the current environment. Their STI resources are declining due to a lack of domestic investment by MNEs and the offshoring of STI activities. Meanwhile, large emerging economies are making strong techno-nationalistic strategic maneuvers that challenge the West.

Conclusion: A Proposal for an STI Global Commons

We believe that enlightened self-interest argues for the West to work with emerging economies to develop a framework for a shared global technology development and diffusion system. In discussing the problems with the TRIPS agreement, Dinwoodie and Kur (2018) argue that a central problem is that TRIPS

focuses solely on trade. Trade, after all, was the area of the WTO's concern and expertise. Dinwoodie and Kur suggest that an international regime for the protection and international diffusion of intellectual property should take into account other interests and draw on other bodies of expertise (see Figure 5). There are interests related to development where the expertise of the United Nations (UN) Conference on Trade and Development could provide input. And the World Health Organization (WHO) might provide input on the best way to motivate the development of new pharmaceuticals and distribute them to rich and poor alike around the world, dealing with the problems like TRIPS posed for India. The WHO might also help coordinate the development and distribution of technology to combat global pandemics. The UN Convention on Biological Diversity could give guidance on the environmental implications of policies. When the WTO agreement was drafted, some thought a bigger role should have been played by the World Intellectual Property Organization, which handled global issues related to patenting. UNESCO could provide guidance on how to handle the intellectual property of Indigenous peoples, such as traditional remedies (some of which are now being patented by multinational pharmaceutical companies). The science community can also play a role in creating structures to foster international collaboration, especially beginning in areas of clear common interest and expanding these as trust builds (Karplus et al., 2021; Hill et al., 2021).



Figure 5: Sources of expertise needed to reform the international IPR regime.

The incorporation of input from these organizations would be a significant, albeit partial, move toward addressing the criticisms of the current system by Stiglitz (2017), Rodrik (2011), and others. It would also amplify the voice of emerging economies and non-MNE interests in the West. Being less techno-nationalistic, it might also create an alternative to techno-nationalistic responses in China.

How might the coordination of these international bodies, national governments, professional groups, and other interested participants in the creation and distribution of technology be managed? Perhaps the designers of the new system might look at the work of Elinor Ostrom, who won the 2009 Nobel Prize in economics for her studies of long-enduring commons. The commons Ostrom studied developed governance mechanisms that successfully sustained, replenished, and allocated common pool resources to disparate groups in a way that was viewed as fair, allowing these commons to persist for generations. Her case studies ranged from commonly owned pastures in the Swiss Alps to groundwater basins in neighboring political jurisdictions in the Los Angeles area. Her ideas were used in developing governance, institutions, and finances in Alaska, where more than 95 percent of all land is owned by governments or collectively by Indigenous nations.²¹



Elinor Ostrom receiving a Nobel Prize for her work on common pool resource governance. Ostrom was the first woman to win a Nobel Prize in economics. Photo courtesy Pascal Le Segretain, Getty Images.

Ostrom and her colleagues (1990) developed a substantial body of evidence and principles for structuring a successful commons while also noting that "...‘getting the institutions right’ is a difficult, time-consuming, conflict-invoking process" (p. 14). Although the common resources institutions described by Ostrom were typically for the management of natural resources, or more generally for how a common pool of resources can be used without exploiting or depleting them, we

propose a similar model can be used for the global *development* of resources that are non-depletable and whose use may allow some participants, emerging nations in this case, to use them to greater advantage than other participants.

Nelson and others²² have pointed to the attractiveness of the commons model in the context of STI (though Nelson does address the international trade of technology). The goal would be to develop institutions for the global development and exchange of STI knowledge creating a common resource for firms and nations to use nonexclusively. It rests on the principle that collaborative advantage can be gained by participants to provide greater benefits than the zero-sum techno-nationalist approaches that assume STI can be best developed within the borders of one nation to the exclusion of other nations. As previously discussed, both the lessons of history as well as a full accounting of the origins of STI advances show they are the result of global exchanges and suggest that an informal and/or “grey commons”²³ has always existed. In the first two stages of technology globalization, this commons eventually led to a failure of techno-nationalist policies.²⁴ Trade policies are typically developed as the social institutions governing markets through exclusionary tactics, generally to the advantage of particular firms and nations and not providing mutual gain outcomes.

A first step toward creating an STI commons might be developing new collaborative institutions for the development of STI R&D. There are examples of bilateral (and some multilateral) STI agreements for particular and limited technology or science endeavors. And there have been, and currently are, international projects and funding programs. These collaborative institutions, staffed globally, would operate on principles of open access to all participating nations. These would be truly global institutions that adhere to a common set of principles and operations, perhaps similar to the UN (and learning from the experiences of the UN to advance institutional governance and operations).

Although nations with more advanced STI will be disproportionately contributing their IPR to the commons, we note that America, Japan, most of Europe, and other nations already have universities and research labs that are fairly open to other nations’ researchers. They have publication traditions that widely share knowledge and provide, formally and informally, access to proprietary knowledge and technology. A global STI commons will, in part, formalize existing practices and potentially provide more effective means of governance because it formalizes participation and access. Moreover, as STI knowledge becomes part of common pool resources, the advantage to any one firm will be in its ability to commercialize products based on the common pool STI rather than by monopolizing IPR. This

should foster the more rapid application of IPR. Of course, the most important gain is the collective and collaborative effort of addressing existential global problems from climate change to disease.

Notes

1. A “zero-sum game” is one in which a gain by one player is always equaled by a loss for another player.
2. See Lynn and Salzman (2022) for a review and explication of the links between the technology, trading institutions, and power structures of these eras.
3. For a description of the “Chinese Challenge,” see Congressional Research Service (2020).
4. The first era was dominated by China and the second by the West. In the third era, globalization of leading STI is more broadly diffuse, and domination is contested by a number of global powers with uncertain outcomes, as we have discussed previously (Lynn & Salzman, 2022).
5. See Nelson (2004) for a discussion of the science commons.
6. Various nations have been described as “techno-nationalistic,” including the United States and other Western countries, as well as Japan, South Korea, Taiwan, China, and India. Some scholars (e.g., Amsden, 1999; Johnson, 1982; and Samuels, 1994) use the term “developmental state” to describe techno-nationalistic policies used to catch up with the advanced economies.
7. See Table 1 for a more comprehensive list of “techno-nationalistic policies” that have been used at various times. In earlier stages of globalization and the exchange of technology, the relationship between high- and lower-income nations has been one in which the lower-income nations provide raw materials, low-cost labor, and markets for low-cost products. Late-lifecycle products being replaced in high-income markets by newer, more expensive products may also be produced and sold in lower-income nations (Vernon, 1966).
8. MNEs may use devices such as “patent thickets.” A patent thicket includes not just the focal technology but also a range of related technologies that might be used by potential competitors to develop lower-cost products similar to those which the thicket is designed to protect. The result is not just to protect IPR but to discourage related areas of research.

9. During the US trade wars with Japan in the 1980s, for example, quotas were set on Japanese automobile and steel exports to the United States. These quotas were supposedly “voluntary” on the part of exporters, but the Japanese auto “voluntary restraint agreement,” for example, was imposed as a result of pressures from the US government with the implicit threat that more damaging punitive tariffs or import quotas might follow if there were no voluntary export restrictions (VER). See, for example, Ryutaro Komiya’s (1990) statement, “Given the basic U.S. policy towards Japan in the mid-1950s, it is ironical that the United States has asked Japan to impose ‘voluntary export restrictions’ (VERs) on certain exports to the United States. The request resulted from the U.S. executive branch’s compromise with Congress” (p. 9).
10. For a good description of US development state policies in the nineteenth century, see Ben-Atar Doron (2004).
11. A state subsidizing their exports, allowing them to be sold in other nations at a lower cost, is often referred to as “dumping” by nations where those imports compete against domestic products. In 2010 and 2011, for example, the WTO ruled that Airbus had received improper government subsidies through loans at below market interest rates. This artificially lowered export prices for Airbus airplanes. WTO also found that Boeing had received local and government aid in violation of WTO rules.
12. For a review, see Salzman and Douglas, 2023; Salzman, 2023; Teitelbaum, 2014.
13. From 1950 to 1970, enrollments in higher education rose from 2.3 million to 8.6 million (Digest of Education Statistics, 2021).
14. Summary of Outlays for the Conduct of Research and Development: 1949–2017, Table 9.7 (Office of Management and Budget, n.d.).
15. RCA was the dominant firm in radio and television technology from the 1920s until the 1970s; it was also a pioneer in developing radio and television broadcasting networks and a number of other product innovations until it was acquired and dismantled by GE in 1985, and then various divisions were sold off and eventually most of the company and its successor operations were dissolved. Zenith was a radio and electronics pioneer founded in 1918 and a common household name for half a century; credited with inventing the wireless TV remote, the first portable radio, and a major manufacturer of TVs, including the early development of HDTVs, among many other innovations. Contributing to its decline in the 1980s was, it claimed in a lawsuit, “dumping” of TVs in the US market by Japanese firms; Zenith lost the lawsuit and ultimately was purchased by the South Korean firm LG in 1995.

16. Iron-making artisans were not allowed to leave China, but some were kidnapped and took the technology to a neighboring country. People trying to take out silkworms and sericulture were subject to the death penalty, but some took the risk.
17. Recently, a Shanghai investment firm took a controlling stake in a California-based—and founded—aircraft firm using innovative technology to build an air and amphibious craft and, according to one report, began “hollowing out” the firm and “moving its technology” to China. Although board members resigned in protest, the only action that could be taken was to assert the technology had military applications and therefore fell under export control laws (O’Keefe, 2022).
18. In our earlier work, we describe how various MNEs manage and coordinate globally distributed technology development teams (Lynn & Salzman, 2015).
19. In the 1990s, Chinese spending on R&D (US dollar PPP) was about one-tenth that of the United States; now it is nearing the US level and increasing at a faster rate.
20. The Washington Consensus was a set of policies developed in the 1990s that broadly describe trade and finance policy principles adopted by the World Bank, the International Monetary Fund, and more generally by Global North institutions in shaping policies of Global South countries to assist them in reforming their economies. They have been criticized as imposing market fundamentalism or neoliberal policies that provided economic benefits to MNEs and Global North economies and did not support economic development in the Global South. For further discussion of the Washington Consensus, see Williamson (2004), who argues that criticisms misconstrue these policies, and Rodrik (2006), who finds: “... policies spawned by the Washington Consensus have not produced the desired results” (p. 1).
21. Alaska’s Governor, and later US Secretary of the Interior, Walter Hickel, was strongly influenced by Elinor and Vincent Ostrom’s work on the commons, as were other Alaska legislators when drafting the state constitutions and institutional governance (Hickel, 2002; Wohlforth, 2010). Alaska uses the common pool resources governance model for land and fisheries management and also established a state Permanent Fund that uses revenues from natural resources to pay for public services, pays each resident an annual cash dividend, and enables the state to avoid income taxes. A common resource management approach was also used in the Magnuson-Stevens Fishery Conservation and Management Act for fisheries management. Many of the lessons learned from these experiments can provide guidance in developing a global STI commons, though, as noted by Ostrom (1990), “...‘getting the

institutions right' is a difficult, time-consuming, conflict-invoking process" (p. 14).

22. See the chapters in Hess and Ostrom (2007), for example.
23. Similar to the informal or grey economies that exist in all nations to some extent, and to a greater extent when institutions and governance are not well developed, not fairly governed, and/or not enforced (enforcement, in turn, depends on the perceived legitimacy of the institutions and governance regimes).
24. We discuss some of these factors in Lynn and Salzman (2022), finding that closing borders and trying to restrict the outflow of STI doesn't forestall the rise of competitors. Second, closed nations don't benefit from global exchanges that lead to the development of leading innovation. Although dominant nations can control STI and knowledge to some extent, continued innovation requires the global flows and exchanges of knowledge and people in multiple capacities, not just the direct and specific invention activities. In the case of the Mongols, it was their "governance" of the silk road that provided the means for exchange and trade throughout a wide geographical area. In terms of attracting the "best and brightest" people, it requires incentives for people to emigrate in addition to whatever negative factors in their home country. It has been noted that this is always the case made about the failures of Soviet science (e.g., Wolfe, 2018), and despite well-trained scientists and technical personnel, their innovation lagged. Of course, there were multiple factors, but openness seems to be important. It remains to be seen if China's effort this time does better than in the past of remaining dominant and closed; though they are approaching this problem very differently by supporting a wide outflow of students and professionals and then attracting them back after they have acquired global knowledge and technical skills.

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