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U.S. sensitive technology export controls toward China: lessons from the Soviet Union

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Rising U.S.-PRC competition in the military, economic, and advanced technology domains has brought a spotlight to the U.S. role in curtailing, or aiding, China's global ascendance. Calls for trade restrictions on technological products have attracted bipartisan support and spurred attempts at international cooperation. Whether or not broad economic decoupling between the U.S. and China is beneficial for the U.S., or even feasible at this point, the U.S. is producing legislation to control the flow of advanced technological products, particularly microprocessors and integrated circuits, to China. Of paramount concern is the preservation of U.S. lead time—a technological gap in a critical area, wherein the U.S. can sustain an advantage for a matter of years—especially in military and computing technology. A multilateral, targeted export control list on a finite number of products and intellectual property could most effectively defend American lead time in advanced technology.

Ambiguously aimed economic tools such as blanket bans and sanctions will not necessarily restrain Chinese advancement in sensitive technology. As messaging tools, poorly targeted trade controls are dubiously effective at best and potentially counterproductive if co-opted by the PRC propaganda apparatus. Restricting the flow of people and goods not directly related to specific, sensitive technologies serves no clear and immediate benefit to upholding lead time for U.S. agencies and industry. Cooperation with allies and partners, as well as among U.S. agencies and private-sector actors, is crucial. In the modern environment of rapid technological advancement, numerous domestic stakeholders and international actors must collaborate in order prevent leaks; targeted, limited export control lists are thus more feasibly enforced and maintained. Considering the global ubiquity of U.S. products, export control lists must be multilateral and up to date to be enforceable.

40 years ago, the United States was in a similar economic and technological competition with another Eurasian Communist power. Despite massive leaps in the computing and space industries during the Cold War, the Soviet Union did not reach parity with the U.S. in terms of advanced technology. U.S. analysts, both contemporary and historical, point to internal Soviet failures as the primary factor limiting Soviet technological advancement. Even those studies which explicitly sought to determine the role of export controls in limiting Soviet civilian and military technological development did not find substantial evidence that U.S. policies produced significant impacts. Soviet analysts recognized a need to overcome the heavy dependence on foreign technology in order to buffer against economic warfare and eventually surpass Western counterparts, yet this acknowledgement did not translate to domestic reform. The Soviet planned economy system—which was generally at odds with resilient, adaptive, redundant, and heterogenous industry—prevented the successful exploitation of Western technology for the purpose of innovation.

In analyzing the impact of broad U.S. advanced technology export controls, the level of innovation in the target economy is dependent more on its domestic organization than on trade restrictions. If the system is not designed to exploit Western technology for the purpose of advancing innovation, then a restriction of Western technology will not change the rate of innovation. Although Chinese firms and PRC agencies are generally more adept at incorporating advanced technology from the U.S. compared to the Soviet Union, similar organizational issues to those that plagued the U.S.S.R. hinder endogenous innovation and widespread absorption of imported technology in the PRC. Structural differences in national research and development landscapes might do more to maintain U.S. technological and innovation dominance over the PRC than any export restrictions. Innovation in advanced technology has historically relied on human capital and a robust, open relationship of collaboration and competition among the public, private, and academic sectors. Limited, internationally coordinated export control lists can restrict access to particular technologies, but organizational structures that attract, maintain, and effectively manage talent are likely more significant in national technological dominance.

U.S. sensitive technology export controls toward China: lessons from the Soviet Union

In 1983, at a time when the U.S. imposed strict export controls toward the Soviet Union, the U.S. opened access to advanced technology products for the People's Republic of China (PRC). A Foreign Affairs article a few years prior warned that "a policy of using export controls for the explicit purpose of building up China at the expense of the Soviet Union would be dangerous."[1] Forty years later, the U.S. has introduced the most stringent export control policy toward the PRC to date. Yet the degree to which export restrictions are effective in achieving policy aims is unclear. While the U.S. has pressured the European Union to join the arms embargo on the PRC, the EU has been reluctant to give up such export opportunities. Differences in geopolitics and foreign policy towards the PRC result in varying responses to intensified export controls, reducing the effectiveness of U.S. policies. As export restriction lists are hastily expanded, a greater proportion of controlled items pose no direct or immediate threat to national security. Although highly specialized export control lists can delay access to specific sensitive technologies, the efficacy of more broad and indirect controls is in question. Dual-use technology (applicable for both civil and military purposes, such as satellite imagery) and basic science can hypothetically be utilized to advance a nation's cutting-edge industrial and defense capabilities. In practice, however, applying generalized scientific know-how to develop digital and physical weaponry is not a straight-forward process. Based on lessons learned from American advanced technology export restrictions on the Soviet Union and a complex-systems analysis to determine the relative strength of the PRC import-to-innovation cycle, we find that broad export controls might not necessarily help U.S. competitiveness against the PRC, particularly in areas of advanced or military technology.

Defense and counter-intelligence professionals have argued that the U.S. is indirectly bolstering PRC military capabilities by allowing the export of sensitive technologies and information. Similar arguments to these were put forward during the Cold War. The 1976 "Bucy Report" from the Department of Defense task force on technology exports argued that intellectual property, a new term at the time, constituted the primary concern of export control policy in the emerging digital era.[2] The report advocated for a specific list of critical technologies in military research and development (R&D) to be controlled for the sake of preserving U.S. military lead time.[3] Although the Soviet Union and PRC could eventually reach parity with the U.S. in advanced technology products (ATP) and military technology, the goal was not to completely prevent technological progress but rather to preserve a relative advantage in key areas for the U.S. government and industry. Focused export controls on a finite list of advanced and militarily sensitive technologies are considered here as national security necessities—we instead address the efficacy and applicability of sweeping, unfocused export restrictions.

U.S. technology restrictions to and exchange with the Soviet Union

The U.S. imposed trade restrictions on the Soviet Union toward the beginning of the Cold War, but as tensions eased during détente, so did the export controls. This relative easing allowed bilateral cooperation between U.S. and Soviet industries, including in the science and technology sectors. Restrictions were tightened again with the 1980 Export Administration Act, which endeavored "to prevent the transfer of technology to adversaries which will contribute significantly to their military potential."[4] In order to achieve this aim, the U.S. also needed to ensure that the Soviet Union could not circumvent the U.S. supply chain by purchasing from U.S. trading partners. The U.S. exported less ATP

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[1] Bingham, Jonathan and Johnson, Victor, "A Rational Approach to Export Controls", Foreign Affairs , LVII (Spring), 1979.
[2] U.S. Senate. Transfer of Technology to the Soviet Bloc. *Hearing before the Permanent Subcommittee on Investigations of the Committee on Governmental Affairs.* University of Michigan Library, 1980.
[3] Office of the Director of Defense Research and Engineering. An Analysis of Export Control of U.S. Technology—A DOD Perspective. Defense Science Board Task Force on Export of U.S. Technology, U.S. Department of Defense, 1976.
[4] U.S. Senate. Transfer of Technology to the Soviet Bloc. *Hearing before the Permanent Subcommittee on Investigations of the Committee on Governmental Affairs.* University of Michigan Library, 1980.

to the Soviet Union than West Germany, France, or Japan in the late 1970s and early 1980s.[5] The Mutual Defense Assistance Control Act of 1951, also referred to as the "Battle Act," formalized U.S. participation in the Coordinating Committee for Multilateral Export Controls (COCOM).[6] In the early 1980s, U.S. COCOM participation was coordinated through the Economic Defense Advisory Committee, composed of State, Defense, Commerce, Treasury, Intelligence, and Energy agency representatives. This committee decided which items are submitted to COCOM as part of the U.S. Commodity Control List (CCL), and the Secretary of Commerce established and maintained the CCL under the Export Administration Act.[7]

Practical coordination issues within COCOM and methods of circumvention undermined its effectiveness, however. U.S. desire for strict controls created issues among allies and other COCOM participants,[8] as did extraterritorial application of the export control act by the U.S.[9] Collaboration with foreign partners on export control was also hindered by a lack of U.S. strategic clarity on the differentiation between export control for national security versus for foreign policy ends.[10] Even when coordination succeeded, COCOM did not create an airtight seal, as the Soviets still circumvented COCOM restrictions via covert means. "A 1985 assessment from the CIA, based on classified Soviet documents describing their technology transfer program, detailed 'a massive, well-organized campaign by the Soviet Union to acquire Western technology illegally and legally for its weapons and military equipment projects.'"[11] Soviet intelligence agencies "employed several thousand technology 'collection officers'" in an attempt to glean Western technology through espionage.[12] Furthermore, nations outside of COCOM occasionally served as an intermediary market for the U.S.S.R. The Department of Defense argued that "the U.S. should release to neutral countries only the technologies we would be willing to transfer directly to Communist countries."[13] If this recommendation had been enforced, all non-members of COCOM would have faced essentially the same export controls as the Soviet Union, severely restricting U.S. private exports.

Domestic pressure to preserve U.S. economic interests also reduced the breadth of export restrictions in practice. In the late Cold War, it was the "policy of the United States to use its economic resources and trade potential to further the sound growth and stability of its economy as well as to further its national security and foreign policy objectives."[14] Both U.S. federal agencies and corporations prioritized maintaining U.S. economic interests, and this broadly led to a preservation of U.S.-Soviet economic ties. Declassified Department of State telegrams show the preference for free trade over restrictions in practice: the "Department does not want to interfere with commercial or technical discussions between U.S. firms and East European clients even [in cases that] may involve a proposal to

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[5] Gustafson, Thane. Selling the Russians the Rope? Soviet Technology Policy and U.S. Export Controls. Defense Advanced Research Projects Agency, 1981.
[6] Flowe, B. H. Jr. An Overview of Export Controls on the Transfer of Technology to the U.S.S.R. in Light of Soviet Intervention in Afghanistan. North Carolina Journal of International Law, Volume 5 Number 3, University of North Carolina School of Law, 1980.
[7] Plousadis, James. Soviet Diversion of United States Technology: The Circumvention of COCOM and the United States Reexport Controls, and Proposed Solutions. *Fordham International Law Journal*, Volume 7, Issue 3, Article 5, 1983.
[8] Daniels, Mario. Safeguarding Détente: U.S. High Performance Computer Exports to the Soviet Union. *Diplomatic History*, Volume 46, Issue 4, Pages 755-781, 2022.
[9] Plousadis, James. Soviet Diversion of United States Technology: The Circumvention of COCOM and the United States Reexport Controls, and Proposed Solutions. *Fordham International Law Journal*, Volume 7, Issue 3, Article 5, 1983.
[10] Macdonald, Stuart. Controlling the Flow of High-Technology Information from the United States to the Soviet Union: A Labour of Sisyphus? Minerva, Vol 24, No 1, pg 39-73, 1986.
[11] Lindsay, J. R., Cheung, T. M. From Exploitation to Innovation: Acquisition, Absorption, and Application. *China and Cybersecurity: Espionage, Strategy, and Politics in the Digital Domain*, pg 51-86, 2015.
[12] Plousadis, James. Soviet Diversion of United States Technology: The Circumvention of COCOM and the United States Reexport Controls, and Proposed Solutions. *Fordham International Law Journal*, Volume 7, Issue 3, Article 5, 1983.
[13] Office of the Director of Defense Research and Engineering. An Analysis of Export Control of U.S. Technology—A DOD Perspective. Defense Science Board Task Force on Export of U.S. Technology, U.S. Department of Defense, 1976.
[14] Flowe, B. H. Jr. An Overview of Export Controls on the Transfer of Technology to the U.S.S.R. in Light of Soviet Intervention in Afghanistan. North Carolina Journal of International Law, Volume 5 Number 3, University of North Carolina School of Law, 1980.

manufacture embargoed goods."[15] The Department of State only intervened when sensitive scientific or manufacturing knowledge and specific advanced technologies were involved. Despite the focus on ATP trade, the majority of commerce between the two powers was not technological; 85 percent was agricultural goods that did not require export licenses.[16] In cases involving advanced technology or sensitive information, representatives of U.S. corporations traveling to the Soviet Union or hosting Soviet counterparts would notify the Department of State, but "in many cases, [the] only action needed [by State was] to remind [the] firm of obligations under U.S. export controls relating to proprietary technical data."[17] By the early 1990s, U.S. allies as well as domestic businesses called for the liberalization of U.S. export controls toward the Soviet Union.[18]

In addition to industry and corporate ties, U.S. researchers and academics maintained relations with Soviet colleagues. The National Science Foundation (NSF) explicitly listed "U.S. participation in science and engineering programs with Socialist countries" as a goal, particularly with China, in support of "normalized relations."[19] The NSF emphasized that bilateral programs with Soviet countries were intended to benefit U.S. scientists and that results and papers generated in conjunction with Soviet contributors would be subject to the same rigorous standards of peer review as domestic products.[20] However, researchers and industry professionals involved in bilateral programs casted doubt on the degree to which corporate and academic interests in the U.S. would benefit from exchange programs. Soviet representatives candidly rated their own technology as "poor" in comparison to their American collaborators.[21] One American report from 1980 claimed that, "in the process of increasing trade, the United States as a country has been giving the Soviet Union the benefit of its comparative advantages, especially in the area of high technology, and has received little in return from the Soviet Union."[22] The NSF stated in 1983 that these bilateral cooperation programs would nonetheless remain in place:

> "In response to the Soviet invasion of Afghanistan, the United States drastically cut back its cooperative activities with the U.S.S.R. The Administration's policy is to keep the exchanges in place so as not to foreclose options in connection with future policy initiatives. It considers that funding for cooperation with the U.S.S.R. should not drop below the minimal level for insuring that the cooperative framework remains intact. The Administration believes that only cooperative activities that are of direct and substantive interest to the United States should be conducted."[23]

Thus, the U.S. federal agencies attempted to ride a thin line in which sensitive technologies were blocked from import into the U.S.S.R. via specific, widely enforced export restriction lists, while at the same time maintaining enough industry and academic ties to mitigate financial and innovation losses to American industry and research.

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[15] Secretary of State, Washington D.C. [Telegram to American Embassies in Bucharest, Budapest, Moscow, Prague, Sofia, Warsaw, and Berlin]. Document 1973STATE090534. Electronic Telegrams, 1974 (Central Foreign Policy Files), National Archives, 1973.
[16] GAO. Export Controls: U.S. Policies and Procedures Regarding the Soviet Union. Fact Sheet for the Chairman, Committee on Finance, U.S. Senate. United States General Accounting Office, 1990.
[17] Secretary of State, Washington D.C. [Telegram to American Embassies in Bucharest, Budapest, Moscow, Prague, Sofia, Warsaw, and Berlin]. Document 1973STATE090534. Electronic Telegrams, 1974 (Central Foreign Policy Files), National Archives, 1973.
[18] GAO. Export Controls: U.S. Policies and Procedures Regarding the Soviet Union. Fact Sheet for the Chairman, Committee on Finance, U.S. Senate. United States General Accounting Office, 1990.
[19] NSF. Strategic Plan: Plan for Fiscal Year 1983. Directorate for Scientific, Technological, and International Affairs, National Science Foundation: Division of International Programs. May 1981.
[20] NSF. Strategic Plan: Plan for Fiscal Year 1983. 1981.
[21] Kelly, S. T. Marketing Contact Report, Samuel Taylor Kelly Papers. Hoover Institutional Library and Archives. November, 1983.
[22] Flowe, B. H. Jr. An Overview of Export Controls on the Transfer of Technology to the U.S.S.R. in Light of Soviet Intervention in Afghanistan. North Carolina Journal of International Law, Volume 5 Number 3, University of North Carolina School of Law, 1980.
[23] NSF. Strategic Plan: Plan for Fiscal Year 1983. Directorate for Scientific, Technological, and International Affairs, National Science Foundation: Division of International Programs. May 1981.

The Soviet technology gap

Although relaxed export control policies from 1969 remained in place for a decade, the gap between Soviet technological achievement and American preeminence did not close. The persistence of this gap was likely attributable more to internal issues in the U.S.S.R.—particularly foreign technology dependency, poor technology absorption, and stagnant research and development infrastructure—than externally imposed export controls. Reaching parity in computing was difficult for the Soviets for the same reason it was difficult for Americans. In order to operate a "modern" computing facility in 1985, an organization required the expertise of hardware, software, and communications engineers, data analysts, technical managers, and all of the complex roles that fed into creating a successful environment: supply chain administrators, financiers, instructors in both basic education and niche training, and client managers, among other inputs.[24] Having access to the physical resources for production was not only insufficient, it was virtually trivial in comparison to the task of gathering and managing human capital. The ability to independently absorb cutting-edge advancements in ATP and use that aggregated information to spur successive innovation was limited to those systems that properly acquired and managed intellectual resources.

In the 1980s, both American and Soviet professionals acknowledged a well-recognized gap between U.S. and U.S.S.R. achievement in the high-performance computing industry.[25] Individual Soviet researchers and manufacturing organizations attempted to improve their prospects in advanced computing via bilateral exchange and open-market acquisition of foreign products. Simultaneously at the state level, the U.S.S.R. employed espionage methods to gather U.S. science and technology final products. As aforementioned, covert and illegal acquisition was a massive endeavor by the late Cold War—estimates put the share of Soviet science and technology espionage materials gleaned from the U.S. at 60 percent.[26] Because much of the ATP obtained from foreign nations, whether through overt or covert means, was a final product, the inputs for the development, operation, and upkeep of these ATP were not successfully transferred in many cases. In a 1966 speech to a U.S. Department of Commerce symposium on technology and world trade, a representative from the Atlantic Institute in Paris touted the importance of "technological fallout," the spill-over effects of endogenous innovation.[27] He noted that advancements in one sector would spread via supply chains, cross-application of fundamental sciences, and personnel training if technologies are developed and produced within a country, and that this spill-over would not be achieved if the industry exclusively imported final products. Often, the U.S.S.R. also lacked the corresponding industry and capital to produce imported goods domestically. Thus, the Soviet system created a self-imposed dependency on foreign technology imports.

This lag in ATP development reflected generally poor technology absorption, in that technology was not imported via methods that would have brought meaningful benefit to Soviet industry. Without the intellectual property, human capital, managerial practices, and robust base in research and development, Soviet scientists and engineers lacked the support that would have allowed for greater technological progress. The acquisition of individual technological products might allow reverse engineering for manufacture in theory, but reproduction does not necessarily lead to innovation. Thane Gustafson argued in 1981 that internal debate within the Soviet Union regarding perceived and probable causes of "weak innovation" and "technological lag" suggested "a growing realization in the Soviet Union that the traditional strategy of concentrating scarce resources on a handful of high-priority projects cannot produce rapid gains in productivity and quality for the economy as a whole, or even

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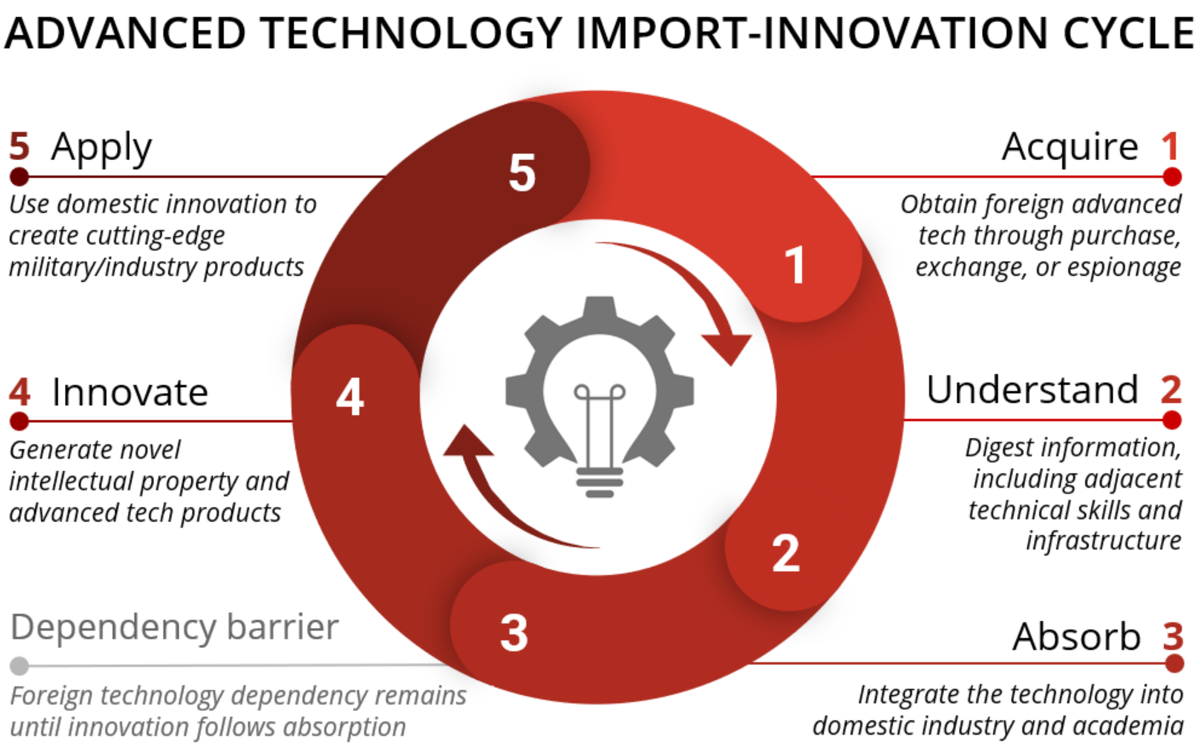
[24] Buzbee, B. L., Sharp, D. H. Perspectives on Supercomputing. Science, Volume 227, Number 4687, Feb 1985.
[25] Daniels, Mario. Safeguarding Détente: U.S. High Performance Computer Exports to the Soviet Union. *Diplomatic History*, Volume 46, Issue 4, Pages 755-781, 2022.
[26] Andrew, C., Mitrokhin, V. The Mitrokhin Archive II: The KGB and the World. Penguin Press, Page 306, 2006.
[27] National Bureau of Standards. Technology and World Trade: Proceedings of a Symposium. U.S. Department of Commerce. November 1966.

continue to meet the requirements of military industry."[28] The U.S.S.R. government, industry, and academic systems broadly lacked the level of domestic ATP innovation to compete with—let alone surpass—the U.S., contributing to Soviet foreign technology dependence. "Ironically, the Soviet Union's very success became a liability. It optimized its R&D system for imitation rather than innovation. Because the Soviets designed foreign dependence into the heart of their [science and technology] apparatus, truly disruptive innovation was priced out of reach."[29]



Since the U.S. focused on restricting access to specific technologies throughout the Cold War, those most sensitive technologies—and the technical knowledge they represented—could achievably be kept from the U.S.S.R. by maintaining an accurate and limited export control list. Attempting to protect every ATP from spillage via espionage or third parties (non-COCOM states) would not have been feasible. Hypothetically, Soviet researchers might have been able to gain a comparative advantage by absorbing non-sensitive technologies from the U.S., but since the U.S.S.R. ATP industry and academia were not organized to encourage innovation, the Soviet apparatus could only attempt to reduce the gap. "Consequently, so long as Soviet policies for technological innovation remain as ineffective as they [were in 1981], the claimed benefits of any expansion of U.S. export controls should be examined carefully."[30] If Soviet scientists and professionals could not take advantage of U.S. technology, tightened export controls would only create marginal impact.

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[28] Gustafson, Thane. Selling the Russians the Rope? Soviet Technology Policy and U.S. Export Controls. Defense Advanced Research Projects Agency, 1981.
[29] Lindsay, J. R., Cheung, T. M. From Exploitation to Innovation: Acquisition, Absorption, and Application. *China and Cybersecurity: Espionage, Strategy, and Politics in the Digital Domain*, pg 51-86, 2015.
[30] Gustafson, Thane. Selling the Russians the Rope? Soviet Technology Policy and U.S. Export Controls. Defense Advanced Research Projects Agency, 1981.

Systemic disparities in national research and development landscapes

The gap in innovation capability between the U.S. and U.S.S.R. can in part be attributed to differences in the respective national R&D landscapes. Advanced technology and innovation generation in the U.S. benefited from diversified sources of R&D funding: venture capital, academic, non-profit, federal, and revenue-dependent. In 1984, the National Science Foundation assessed that U.S. corporations were spending about 25 to 30 percent of cash flow on R&D, amounting to $43 billion in 1983—the same as federal R&D obligations that year.[31] American federal and industry leaders in advanced technology and computer sciences advocated for explicit plans to create "a partnership between universities, government, and industry."[32] Mid-1980s reports on improving U.S. competitiveness recognized that innovation is cultivated through public-private-academic collaboration, particularly by combining academic long-term vision and talent, federal funding and direction, and private entrepreneurship and demand.[33,34] This held true outside the U.S. as well: a 1985 analysis on the Japanese supercomputing industry also identified organizational methods that facilitated cooperation among firms and "collaboration between the industrial and academic sectors and the concerned government ministries" as key factors to innovation success.[35] More so than the Soviet Union, the American ATP innovation environment balanced heavy cooperation and healthy competition among U.S. federal research agencies, academic institutions, and private sector firms.

The existence of competency in the public, private, or academic sectors alone was insufficient to cultivate national innovation; frequent information sharing was a necessary component for success. Unlike the Soviet system, in which most R&D was centralized in the state and jealously guarded to prevent spillage and suppress private-sector divergence, U.S. actors made a significant concerted effort to share resources and information. "With the exception of some military and space technology, technology on the U.S. side is the province of private industry, which initiates, develops, and provides technology in its own interest, thereby according to the U.S. ideology and experience aiding the national interest."[36] Although most advanced technology in the defense industry was government owned and financed, much of the technological infrastructure was similar or identical to the private sector, easing information transmission. A 1983 NSF report identifies key areas for maintaining national security and competitiveness, highlighting the importance of "the diffusion of knowledge and transfer of basic research from laboratory to marketplace technologies."[37] The NSF thus made concerted efforts to optimize information sharing with both private firms and academia. Furthermore, U.S. government and private industry were both compelled to protect American intellectual property from Soviet access in order to maintain their market share.[38] These aligned incentives, in conjunction with intentional efforts by government agencies to provide open access to industry, provided the U.S. an edge in cross-sector collaboration.

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[31] NSF. Project Summaries: FY1983. Directorate for Scientific, Technological, and International Affairs, National Science Foundation: Division of Science Resources Studies. June 1984.
[32] Hess, C. E. NSB-82-387, UCAR Site Visit. John Moore Archival Collection, Box 10, 13-050, Hoover Institution Library and Archives, Oct 1982.
[33] Buzbee, B. L., Sharp, D. H. Perspectives on Supercomputing. Science, Volume 227, Number 4687, Feb 1985.
[34] NSB-84-43. Memorandum to Members of the National Science Board: Minigroup Comments on Directorate Long-Range Plans. National Science Board. Feb 1984.
[35] Buzbee, B. L., Sharp, D. H. Perspectives on Supercomputing. Science, Volume 227, Number 4687, Feb 1985.
[36] National Technical Information Service. Review of the US/USSR Agreement on Cooperation in the Fields of Science and Technology. Board on International Scientific Exchange, Commission on International Relations, U.S. Department of Commerce, May 1977.
[37] NSB-84-43. Memorandum to Members of the National Science Board: Minigroup Comments on Directorate Long-Range Plans. National Science Board. Feb 1984.
[38] National Technical Information Service. Review of the US/USSR Agreement on Cooperation in the Fields of Science and Technology. Board on International Scientific Exchange, Commission on International Relations, U.S. Department of Commerce, May 1977.

American academia and industry had another important advantage over Soviet counterparts: close ties with other technologically advanced nations. U.S. agencies advocated cooperation among allies in R&D with the explicit intent of improving the knowledge and skills of American scientists.[39] The NSF recognized the "substantial contributions that international cooperation in science and technology can make both to U.S. science and to long-term U.S. foreign policy interests."[40] These policy aims also sought to balance the import of ATP from abroad with support for burgeoning domestic industry, balancing collaboration with meager protectionism.[41] The U.S.S.R. did not have access to the same breadth of technologically advanced allies, nor did it have the same public-private-academia partnership or independent strength in the reinforcing sectors. A 1983 study from Berkeley found that the global impact of Soviet Science in the late 1970s and early 1980s was low, reflecting a relative lack of exported innovation. [42] This small impact internationally likely reflected general trends in Soviet science: scientists were left behind in fields that rapidly evolved, particularly with the introduction of sophisticated technologies and radical conceptual change, and were unable to "maintain their lead" if they did acquire it.[43] Whether due to excessive secrecy or bureaucratic mis-management, poor inter- and intra-sector communication exacerbated these broad shortfalls: "Soviet managerial reforms and Soviet technological import programs do not appear to be directly related to one another or mutually reinforcing; high-technology imports by themselves do not enable the Soviets to achieve independence in innovation."[44] Even when research science succeeded, "the Soviet system simply [was] not rigged to take in, and profit by, Western technology."[45] Soviet organizational methods in managing human capital and cross-sector communications hindered innovation in advanced technology, regardless of how much foreign intellectual property or ATP the U.S.S.R. obtained.

During the same period, the R&D landscape in the People's Republic of China (PRC) was not dissimilar to the Soviet Union. By 1996, only 27 percent of R&D in the PRC occurred in the private sector, with the rest conducted in centralized research institutes; for comparison, the U.S., Japan, Korea, and even Taiwan conducted 80 percent of R&D in the private sector and 12 percent in universities in the same year.[46] According to China's National Bureau of Statistics, 2019 R&D spending by both state-owned enterprises and companies with mixed ownership (run by private individuals and government officials) made up 67.6 percent of enterprise R&D expenditure, although private firms played a significantly greater role than a decade prior.[47] Institutions of higher education performed only about 7.4 percent of total Chinese R&D in 2018.[48] Restrictions on intellectual freedom, broad focus on the graduate employment rate over scientific output, and a lack of well-established linkages between businesses and universities have impeded innovation and knowledge transfers in the PRC. Times Higher Education examined academia-industry research collaboration and found that, in 2016, the U.S. had more than double the proportion of joint projects than China.[49] Modern Chinese researchers recognize the potential value of university-industry collaboration on innovation and advanced sciences in China, specifically noting that technological diversity strengthens the influence of academia-private sector

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[39] NSB-84-43. Memorandum to Members of the National Science Board: Minigroup Comments on Directorate Long-Range Plans. National Science Board. Feb 1984.
[40] NSB-83-368. Memorandum to Members of the National Science Board: Planning Environment Statement. National Science Board, Nov 1983.
[41] Hess, C. E. NSB-82-387, UCAR Site Visit. John Moore Archival Collection, Box 10, 13-050, Hoover Institution Library and Archives, Oct 1982.
[42] La Brie, R., Sessler, A. M. Impact on World Science of Soviet Science as Measured by Journal Citations. Lawrence Berkeley Laboratory, University of California, Berkeley, May 1983.
[43] Gustafson, T. Why Doesn't Soviet Science Do Better Than It Does? The Social Context of Soviet Science, L. L. Lubrano & S. G. Solomon eds., Westview Press, Page 31, 1980.
[44] Gustafson, Thane. Selling the Russians the Rope? Soviet Technology Policy and U.S. Export Controls. Defense Advanced Research Projects Agency, 1981.
[45] National Bureau of Standards. Technology and World Trade: Proceedings of a Symposium. U.S. Department of Commerce. November 1966.
[46] U.S. Embassy Beijing. Chinese Challenges in Absorbing and Producing New Technology. U.S. Department of State, 1996.
[47] China Power Team, "Is China a Global Leader in Research and Development?", Center for Security and International Studies, 31 January 2018, Updated 28 January 2021.
[48] China Power Team. 2021.
[49] China Power Team. 2021.

exchange,[50] and that market incentives bolster optimization of university-industry research cooperation,[51,52] including intellectual property protections.[53] The degree to which this awareness will influence changes in the PRC R&D landscape remains to be seen.

The current state of U.S.-PRC trade in high technology

Since the Tiananmen Square massacre in 1989, the U.S. has led and maintained an arms embargo on the PRC, preventing the export of all items on the U.S. Munitions List. Special attention has been paid to suspending licenses related to energy export, satellites, technology integrated on Chinese launch vehicles, and "crime control and detection" technologies.[54] Following the establishment of COCOM, several multilateral export regimes have formed to uphold international norms against supplying states with advanced military technologies, but none directly target the PRC. After the dissolution of the Soviet Union, the rationale for a strong multilateral export control regime faded. The Wassenaar Arrangement emerged as a relaxed successor to COCOM, covering dual-use information technologies. Under Wassenaar, states are obligated to report transactions and denials, but ultimately retain their sovereign right on the decision to transfer and do not possess the authority to impose their own denial policies on other members.[55] Unlike COCOM, there is no agreed action for violating the Wassenaar Arrangement. Despite U.S. pressure, dual-use technologies are traded between the EU and PRC largely without control. In practice, export control coordination with allies is complicated by differences in politics and economic interdependence. While countries like Japan and Taiwan have generally supported the arms embargo, they are not at liberty to adopt similar uncompromising restrictions due to their reliance on the PRC as a major trading partner. As a result, the U.S. pursues more restrictive unilateral controls than those established within the multilateral framework.

Export, re-export, and transfer of commodities from the U.S. require licenses administered by federal agencies. Dual-use items are controlled through Export Administration Regulations administered by the Department of Commerce, and defense articles and services are controlled through International Traffic in Arms Regulations administered by the Department of State. In 2020, the U.S. rolled out a series of controls barring manufacturers anywhere in the world from supplying chips made using U.S. technology to Huawei and its affiliates, citing engagement in "activities determined to be contrary to the national security or foreign policy interests of the United States" and "deceptive and obstructive acts designed to evade U.S. law and to avoid detection by U.S. law enforcement."[56] Some technology corporations suspected of participating in PRC civil-military fusion were also restricted with a presumption of denial for export licenses.[57] In 2021, Commerce added 23 more companies, primarily information technology and electronics firms, to the Entity List for both national security and human rights enforcement purposes."[58]

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[50] Tian, M. Y., Su, Y. W., Yang, Z. University-industry collaboration and firm innovation: an empirical study of the biopharmaceutical industry. The Journal of Technology Transfer, 47, 1488-1505, Aug 2021.
[51] Chen, L., Wu, J., Sheng, Y. X., Hu, J., Shi, Q. F. Research on Optimization of Industry-University-Research Cooperation Based on Enterprise Incentive. Journal of Physics: Conference Series, Second International Symposium on Big Data and Applied Statistics, Volume 1437, Sept 2019.
[52] Yangdong, Q. Research on innovation incentive effect of industry-university research cooperation—Analysis based on different regulation mechanisms. Economic Systems Reform, %, 107-112, 2020.
[53] Li, J. J., Sun, X. H., Dai, X., Zhang, J. Y., Liu, B. F. Knowledge Map Analysis of Industry—University Research Cooperation Policy Research Based on CNKI and WOS Visualization in China. Sustainability, 14 (13), 7862, Jun 2022.
[54] Foreign Relations Authorization Act, Fiscal Years 1990 and 1991, Public Law 101-246
101st Congress (H.R. 3792)
[55] Evron, Y. The Enduring US-led Arms Embargo on China: An Objectives–Implementation Analysis, Journal of Contemporary China, 28:120, 995-1010, 2019.
[56] Addition of Huawei Non-U.S. Affiliates to the Entity List, the Removal of Temporary General License, and Amendments to General Prohibition Three (Foreign-Produced Direct Product Rule), Bureau of Industry and Security, Department of Commerce, 20 August 2020.
[57] Addition of Entities to the Entity List, Revision of Entry on the Entity List, and Removal of Entities From the Entity List, Bureau of Industry and Security, Department of Commerce, 22 December 2020.
[58] Addition of Certain Entities to the Entity List; Revision of Existing Entry on the Entity List; Removal of Entity From the Unverified List; and Addition of Entity to the Military End-User (MEU) List, Bureau of Industry and Security, Department of Commerce, 12 July 2021.

The number of dual-use export restrictions under the Export Administration Regulations remained relatively constant between 2000 and 2012. During this time, the majority of high-tech exports were exempt from restrictions or approved for transfer to China. Since 2012, the number of export restrictions have more than doubled amid growing concerns of military-civil fusion in the PRC and great-power rivalry. Concurrently, the share of U.S. advanced technology exports to China also increased. In 2020, ATP constituted roughly 19 percent ($30.8 billion) of U.S. exports to China,[59] nearly three times the figure from 2008.[60] In 2021, high-tech exports constituted around 33 percent ($49.6 billion) of total exports to China. Of these, about 13 percent ($18.8 billion) were considered sensitive ATP exports. China is not solely or even primarily reliant on the U.S. for ATP imports, however. The U.S. currently ranks fifth in advanced and new technology exports into China, following the EU (more than half of imports), Taiwan (approximately one third), South Korea (one fourth), and Japan (one fifth).[61]

U.S. and allied ATP exports constitute critical components in Chinese supply chains due to both quantity and quality. As of 2021, the U.S. earned 47 percent of global revenue in semiconductor sales.[62] Virtually every advanced semiconductor is touched by manufacturing equipment, software, or inspection tools made by the U.S., making it costly and technologically challenging to produce the same level of high-performance chips without access to American technology.[63] In 2018, China surpassed the US to gain the largest share of the global computer, electronic, and optical products market.[64] Accordingly, semiconductors are the PRC's largest import at over $300B annually,[65] and cutting off this supply would directly harm downstream industries that need semiconductors to produce smartphones, communications, and consumer electronics—all major products of the PRC. The PRC's dependence on the U.S. and allies in the high-technology market extends beyond the import of individual products. The U.S. has long been China's largest source of intellectual property. While U.S. exports of intellectual property to China tripled in the last decade, imports of Chinese intellectual property totaled $3 million in 2020, a fraction of the nearly $8.3 billion of U.S. exports to China.[66] "Analysis of PRC and U.S. patenting activity shows that China's tech dependence on the U.S. rose until and peaked in 2009, then began to decline as China developed its own R&D and innovative capacity."[67] Though the modern PRC is by no means as dependent on foreign imports as in the past, U.S. and allied products and intellectual property are still crucial components, creating an opportunity for targeted intervention in the development of Chinese advanced technology.

Effectiveness of U.S. export restrictions on the PRC

According to publicly available data from the U.S. Department of Commerce Bureau of Industry and Security (BIS), the U.S. generally approves or returns without action almost all license requests. This trend held in the Soviet era as well: "less than 5 percent of license applications filed with the Department of Commerce for exports to the U.S.S.R. in 1978 were denied."[68] Today, the U.S. requires licenses for just a small fraction of dual-use technologies included in export control lists. In 2020, only 2.1 percent of commodities on the CCL required licenses,[69] and in 2021, just one percent of the $151 billion total U.S. exports to China were subject to a license requirement.[70] American expansion of

[59] United States Bureau of Industry and Security. *U.S. Trade with China* (Bureau of Industry and Security, 2020) 3-4.
[60] Alex Hammer, Robert Koopman, and Andrew Martinez, *Overview of U.S. China ATP Trade*, Brookings, 2012.
[61] Trading Economics. *China Imports of High-&-new-tech Products,* Trading Economics, 2022.
[62] Jeanne Whalen and Chris Alcantara. *Nine charts that show who's winning the U.S.-China tech race*. The Washington Post, 2021.
[63] Agathe Demarais, How the U.S.-Chinese Technology War Is Changing the World, Foreign Policy, 19 November 2022.
[64] Amanda Lee. *China gains ground on US in hi-tech 'tug of war', as Beijing spends billions on national champions*, The Star, 2022.
[65] Agathe Demarais, How the U.S.-Chinese Technology War Is Changing the World, Foreign Policy, 19 November 2022.
[66] Min-Hua Chiang. *China More Dependent on U.S. and Our Technology Than You Think,* The Heritage Foundation, 2022.
[67] Freeman Spogli Institute and Stanford Institute for Economic Policy Research. *SCCEI China Briefs: Annual Recap* Freeman Spogli Institute, 2022.
[68] U.S. Senate. Transfer of Technology to the Soviet Bloc. *Hearing before the Permanent Subcommittee on Investigations of the Committee on Governmental Affairs.* University of Michigan Library, 1980.
[69] U.S. Export Controls and China, Congressional Research Service, updated 24 March 2022.
[70] U.S. Trade with China, Bureau of Industry and Security, Department of Commerce, 2021.

licensing requirements in 2020 did not discourage China from purchasing licensed technology from the U.S., although restrictions did raise the cost and time Chinese companies needed to expend to acquire license approvals.[71] According to BIS, the number of licensed applications from China for purchasing "tangible items, software, and technology" increased from 3,747 in 2020 to 5,923 in 2021, and the total amounts paid for those applications increased from $106 billion to $545 billion.[72] Even though the total number of applications from China went up, the total volume of approvals from China declined significantly. This gap, despite stable or increased applications, demonstrates that the license approval process in the U.S. is tightening for Chinese applicants. Trends towards stricter control, accompanied by prolonged processing time and increased license denials, may lead to a greater observed effect on the Chinese ATP industry as American firms cut ties to China and supply chains are stressed.

In addition to export controls, changes in technology trade between the U.S. and China are also influenced by wider economic decoupling, with market-driven shifts reinforcing existing federal policy. During the Cold War, the American private sector and academia balanced national security pressures to decouple from the U.S.S.R.; the U.S. government acknowledged the costs to industry of export regulations and attempted to mitigate them. Generally, however, American firms did not publicly counter U.S. export restrictions: "there are complaints from American high-technology industry, of course, but these are outweighed by testimony to the loyalty and compliance of that industry."[73] Today, U.S. firms are either less vocal or less successful in pressuring Congress to counter defense and protectionism aims. Considering that U.S. firms are more engaged with the Chinese market and more global, the relative silence speaks volumes. This disparity is likely due at least in part to competition from Chinese firms and the Chinese Communist Party's increasing limitations on the tech industry. In 2002, the PRC pressured domestic industry to adopt Linux over Microsoft. Microsoft capitulated and agreed to invest 6.2 billion yuan "to help develop China's software industry and China's e-government initiative."[74] Global firms are attempting to alter their supply chains away from China. Susan Shirk claims in *Overreach* that American businesses are no longer pushing for policies that allow greater engagement with China, as the PRC enacts greater prices (such as technology transfer as the cost for access to the Chinese market) and is more assertive in its goal of training domestic companies to replace foreign firms. She also argues that American business executives might not challenge the PRC for fear of retaliation, but they are also not incentivized to fight restrictions on Chinese engagement imposed by the U.S. government.[75]

Compared to the Soviet era, U.S. enforcement of modern export restrictions is complicated by the tremendous speed of information and innovation in the digital age. Controlling information flow, not just from one country to another but also from one federal agency to another, is increasingly challenging. Even in the late Cold War, when the speed of information transfer and the rate of progress in high-technology innovation were both substantially lower, the U.S. bureaucratic system struggled to keep up. When COCOM members states (Japan and then-NATO, minus Iceland and Spain) agreed in 1979 to allow no exceptions to the export list in response to the Soviet invasion of Afghanistan, the high-technology items had not been significantly updated, and a decade later, the list was still woefully out of date.[76] Given the amount of technological change that occurred between the early 1970s and mid-1980s, some of the items on the list were no longer considered "advanced," and the maintenance of these unnecessary restrictions pulled resources from the more critical cases, reducing overall effectiveness. One commentor in 1986 railed that "the inability of those export controls employed by the government of the United States to cope adequately with information flow is a fundamental

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[71] Min-Hua Chiang. *China More Dependent on U.S. and Our Technology Than You Think*, The Heritage Foundation, 2022.
[72] U.S. Trade with China, Bureau of Industry and Security, Department of Commerce, 2021.
[73] Macdonald, Stuart. Controlling the Flow of High-Technology Information from the United States to the Soviet Union: A Labour of Sisyphus? Minerva, Vol 24, No 1, pg 39-73, 1986.
[74] Cao, C. Challenges for Technological Development in China's Industry: Foreign investors are the main providers of technology. *China Perspectives*, 2004.
[75] Shirk, S. *Overreach*. Oxford University Press, 2023.
[76] Macdonald, Stuart. Controlling the Flow of High-Technology Information from the United States to the Soviet Union: A Labour of Sisyphus? Minerva, Vol 24, No 1, pg 39-73, 1986.

weakness. It has both seriously impaired the effectiveness of operations, and also engendered the necessity—and the opportunity—for measures of re-enforcement."[77] In today's even-higher-speed networked world, ATP loses its shine and innovations are outmoded on a daily basis. Moreover, a greater degree of information and intellectual property is spread via the internet, allowing much wider dissemination and vastly increasing the complexity of restricting access. Even more so than during the Cold War, the U.S. today is ill-equipped to handle a lengthy and cumbersome export control list.

PRC tech absorption capacity

The PRC benefited from Soviet lessons-learned and invested greatly in technology adoption and absorption. Thirty years ago, a U.S. Department of State analysis of a PRC report highlighted that manufacturing technology was hindered by poor infrastructure and strong, centralized political demands for quantity of production over quality of results. The PRC report indicated that the country faced significant hurdles to smooth tech absorption, including "poor organization, resource shortages, mindless directives to expand production at all costs, the divorce of S&T [science and technology] from manufacturing, insistence on importing technology which cannot be absorbed by Chinese industry at its present stage of development, military secrecy that prevents spinoffs of military technology from reaching the civilian sector, poorly educated workers, and demoralized, severely underpaid S&T personnel."[78] The lack of autonomy, responsibility, and competition stalled innovation among industrial organizations, preventing the expansion of the private sector. By 1975, Chinese capacity for tech absorption was given more favorable assessments by U.S. observers than analyses of the Soviet industry. Economic gains between the mid-1960s and 1970s, achieved with a relatively low amount of foreign assistance, demonstrated "that, despite the obvious limits to technical sophistication in all branches of industry, China developed an effective mechanism for implanting foreign innovations into Chinese industry, for spreading new techniques and products from advanced to backward enterprises and regions, and, in some areas, for devising solutions to uniquely Chinese technological problems."[79] While Western analysis praised technological adoption, the same reports recognized the difficulty in translating adopted technology to domestic innovation.

In 2004, the Chinese industry had only recently moved to making consumer electronics, and doubt remained as to "whether China will be able to develop an indigenous technological capability, in the near and medium term, to support its capacity to be competitive in the world markets."[80] Much of the economic gains in the 1990s and 2000s for Chinese manufacturing came from assembly, which does not levy much technology transfer. The comparative advantage came in cheap labor, not in technical components or intellectual property. Moreover, foreigners were granted most of the invention patents in China between 1991 and 2002. Spending on foreign licenses was low compared to ATP imports, and nearly all licenses were for hardware. "Large- and medium-sized enterprises spent more on technology importation than R&D until 1999."[81]

Covert operations to acquire technology can circumvent export restrictions, but they do not ease the burden of absorption or innovation. After the collapse of the Soviet Union, PRC espionage campaigns garnered know-how and human capital in science and technology, especially relating to industrial engineering and military equipment. As aforementioned, however, the Soviet science and engineering programs were dependent on the West, and while the PRC benefitted from this technological acquisition, it was not necessarily a boon for innovation in China. Although the PRC is likely indeed running an "aggressive industrial espionage campaign," there is less evidence that this is an effective

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[77] Macdonald, Stuart. Controlling the Flow of High-Technology Information from the United States to the Soviet Union: A Labour of Sisyphus? Minerva, Vol 24, No 1, pg 39-73, 1986.
[78] U.S. Embassy Beijing. Chinese Challenges in Absorbing and Producing New Technology. U.S. Department of State, 1996.
[79] Rawski, T. G. Problems of Technology Absorption in Chinese Industry. *The American Economic Review*, Vol. 65, No. 2, pp. 383-388. American Economic Association, 1975.
[80] Cao, C. Challenges for Technological Development in China's Industry: Foreign investors are the main providers of technology. *China Perspectives*, 2004.
[81] Cao, C. 2004.

"shortcut" to innovation or that this espionage provides an economic advantage to the PRC.[82] Furthermore, espionage is, by its nature, not prevented by legal restrictions. "The contribution of espionage is only one small part of an ambitious foreign technology transfer effort, so spying cannot be given exclusive credit for Chinese advances."[83] More severe export restrictions run the risk of inadvertently encouraging greater investment in covert acquisition by the PRC.

In evaluating the contemporary implications of ATP acquisition for the PRC industry, the ability to adopt and absorb foreign technology is an insufficient metric in isolation. Generally, the PRC follows an acquisition-absorption-"re-innovation" process with foreign ATP, in which "re-innovation" is closer to reverse engineering than the development of novel procedures and products. As discussed in the Soviet case, technology absorption does not necessarily lead to innovation. Technological leapfrogging can rob domestic industries of the knowledge gained during "widespread participation in the task of designing, manufacturing, and repairing new types of equipment."[84] A 2015 report found that the Chinese ATP industry was not bridging the gap between absorbing new technologies—which includes the ability to produce, maintain, and distribute foreign ATP—and innovation. "There is heavy reliance on imitative techniques and processes such as copying and reverse engineering."[85] PRC-produced reports acknowledge that the PRC was "dependent on foreign technology and knowledge to make major advances in technological development."[86]

PRC systemic innovation capacity

A Chinese study on innovation in advanced technology indicated that the "innovation process has the characteristics of openness, dynamic (sic), nonlinearity, and fluctuation."[87] These are the fundamental characteristics of complex systems, and much like similar complex systems,[88] this ATP innovation process is hypothetically most healthy and productive when balancing redundancy, diversity, adaptability, resilience, and sustainability. Open communications within and across borders, adaptable and resilient human capital, inter-sector cooperation and competition, and redundant, diversified (public, private, and academic) sources of funding and intellectual property all contribute to stronger national systems of innovation. As exemplified in the study of respective national R&D landscapes, managing the mutable interactions within and among complex systems is no small task, and national strategies aimed at efficiency can produce higher-order effects with unintended consequences. For instance, both Soviet and PRC regimes generally prioritize homogeneity with the intent of retaining centralized control, in this case at the expense of cultivating an environment that fosters innovation.

The PRC's command approach can provide long-term sustainability via state funding, owing to the domination of the market by state-backed sources. However, redundancy (multiple actors working on the same problem so that if one gets it wrong, the other can perhaps move toward a better direction), diversity (differentiated approaches in competition creating potential synergistic effects, which cannot exist in a homogenous environment), and adaptability (rapid response to market forces rather than delayed response to political aims) are all hampered. Combined, this creates a low-resilience environment, wherein the innovation process and high-tech sector are not organized to respond well to shocks. In the PRC defense innovation system, the primary focus is imitation, leadership is top-down and

[82] Lindsay, J. R., Cheung, T. M. From Exploitation to Innovation: Acquisition, Absorption, and Application. *China and Cybersecurity: Espionage, Strategy, and Politics in the Digital Domain*, pg 51-86, 2015.
[83] Lindsay, J. R., Cheung, T. M. 2015.
[84] Rawski, T. G. Problems of Technology Absorption in Chinese Industry. *The American Economic Review*, Vol. 65, No. 2, pp. 383-388. American Economic Association, 1975.
[85] Lindsay, J. R., Cheung, T. M. From Exploitation to Innovation: Acquisition, Absorption, and Application. *China and Cybersecurity: Espionage, Strategy, and Politics in the Digital Domain*, pg 51-86, 2015.
[86] Cheung, T. M. The Role of Foreign Technology Transfers in China's Defense Research, Development, and Acquisition Process. *Policy Brief, Study of Innovation and Technology in China*, University of California Institute on Global Conflict and Cooperation, 2014.
[87] Li, X., Huang, L., Ren, A., Li, Q., Zeng, X.. The Effect of Production Structure Roundaboutness on the Innovation Capability of High-Tech Enterprises—The Mediating Role of Technology Absorption Path. *Sustainability*, 14, 5116, 2022.
[88] Levin, S. A. The Architecture of Robustness. *Global Challenges, Governance, and Complexity*, pp.16-23, 2019.

rigidly hierarchical, information flow is restricted, and management is largely state-controlled.[89] As in the Soviet case: "the continuing Soviet need for Western technology results directly from the weaknesses of its centralized, state-run, command economy, [and] the system, because of its stifling rigidity, is structurally resistant to technological innovation."[90] The state directly managed most advanced technology development, and academic institutions were isolated from foreign collaborators, losing many of their top mathematicians and scientists in the wake of restrictive Soviet policies.[91] A 1985 CIA report concluded that the Soviets would remain dependent due to "the lack of adequate incentives, inflexible bureaucratic structures, excessive secrecy, and insularity from the West."[92] While the PRC has not thus far replicated the conditions of the late-Cold War U.S.S.R., "brain drain," homogenization, private sector subjugation to political aims, and increasing isolation from external sources of advanced science and technology still hinder national ATP development.

The U.S., on the other hand, emphasizes independence, open communication, diversification, and a reliance on "informal, personal relationships for the flow of information," contributing to the rapid rate of change spurred by distributed actors.[93] University-corporate cooperation on innovation yields positive feedback benefits: more integration (in terms of frequency, depth, and breadth) leads to greater trust and familiarity, which leads to greater integration.[94] Although the Chinese corporate sector and academic institutions are relatively more advanced than the Soviets in comparison to their contemporary American counterparts, Chinese Communist Party involvement in both the private and academia realms might reduce the marginal endogenous technological gains. Strong integration between private, public, and academic sources of funding and innovation likely creates systemic advantages only when each sector is providing diversity, redundancy, and adaptability.

Even if the Chinese industry can utilize U.S. advanced technology to bolster domestic innovation, the degree to which this translates to military innovation is unclear. Some areas of PRC military technology are better situated to integrate and apply foreign ATP and intellectual property. For instance, PRC progress in military artificial intelligence (part of the wider effort to "intelligentize" warfare) is at least partially reliant on American technology and capital.[95] Yet with the exception of direct-application advanced military technology, dual-use technologies designed for the private sector are not always readily accessible for military use. Civil-military fusion is greatly emphasized in PRC planning documents and strategy of the People's Liberation Army (PLA), the military arm of the Communist Party of China, but this emphasis reflects a recognized weakness, not a central organizing theme. A 2017 top-down push for greater integration, which was accompanied by an increase in funding for civil-military projects, has spurred some progress in private sector engagement. Companies such as Baidu, Alibaba, and Tencent are engaged in artificial intelligence research to benefit civil-military engagement in China.[96] Yet the characterization of all Chinese entities as potential accomplices in PRC efforts to extract dual-use technology is undermined by the inchoate nature of the current civil-military condition. Recent high-level analysis finds PRC civil-military fusion to be still relatively underdeveloped, both in terms of integration across the private sector and depth of public-private ties.[97] Civil-military fusion has been a

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[89] Cheung, T. M. The Role of Foreign Technology Transfers in China's Defense Research, Development, and Acquisition Process. *Policy Brief, Study of Innovation and Technology in China*, University of California Institute on Global Conflict and Cooperation, 2014.

[90] U.S. Senate. Transfer of Technology to the Soviet Bloc. *Hearing before the Permanent Subcommittee on Investigations of the Committee on Governmental Affairs*. University of Michigan Library, 1980.

[91] La Brie, R., Sessler, A. M. Impact on World Science of Soviet Science as Measured by Journal Citations. Lawrence Berkeley Laboratory, University of California, Berkeley, May 1983.

[92] Lindsay, J. R., Cheung, T. M. From Exploitation to Innovation: Acquisition, Absorption, and Application. *China and Cybersecurity: Espionage, Strategy, and Politics in the Digital Domain*, pg 51-86, 2015.

[93] Macdonald, Stuart. Controlling the Flow of High-Technology Information from the United States to the Soviet Union: A Labour of Sisyphus? Minerva, Vol 24, No 1, pg 39-73, 1986.

[94] Bruneel, J., D'Este, P., Salter, A. Investigating the factors that diminish the barriers to university-industry collaboration. Research Policy, Volume 39, Issue 7, Sept 2010.

[95] Ryan Fedasiuk. *We Spent a Year Investigating What the Chinese Army is Buying. Here's What We Learned* (Politico, 2021).

[96] Kania, E. B. Chinese Military Innovation in Artificial Intelligence. *Testimony before the U.S.-China Economic and Security Review Commission Hearing on Trade, Technology, and Military-Civil Fusion*. Center for a New American Security, 2019.

[97] Kania, E. B., Laskai, L. *Myths and Realities of China's Military-Civil Fusion Strategy*. Center for a New American Security, 2021.

priority for two decades; "however, the Chinese military and defense industry had seemingly struggled to overcome prior stove-piping and bureaucratic obstacles that had limited its capacity to leverage commercial stakeholders and technologies."[98]

The PLA seeks to emulate American civil-military fusion; PRC leadership likely regards U.S. military-civil fusion as better integrated and more successful at leveraging the dynamic innovation in the private sector. "Chinese reporting on Pentagon outreach to Silicon Valley characterizes the two as 'hand in hand,' even as the U.S. national security community expresses dismay about the gap and distance that remain."[99] Moreover, "companies with foreign investors [are] disqualified from acquiring the necessary licenses to participate in" PRC civil-military fusion programs. "Chinese analysts believe being a 'purely domestically funded enterprise' is an important prerequisite for a company that intends to compete for sensitive national security contracts."[100] Thus, firms that acquire U.S. technology might be disqualified from PRC programs regardless. Ultimately, civil-military fusion concerning emerging technology will continue to face hurdles in the form of bureaucratic constraints, slow reform of doctrine, human capital issues, and lack of combat experience across the PLA, leading to unrealistic expectations.[101]

Impacts to the U.S. of ATP export control toward the PRC

The PRC aims to become more self-reliant in an active attempt to avoid the Soviet case, but the degree to which that goal will become a reality remains uncertain. Internal failures likely drive the PRC's inability to surpass the U.S. technologically more so than U.S. export policies, both due to a relatively low capacity for innovation and a trend of private sector isolation. Export restriction policies are most effective when implemented via coordinated multilateral controls to achieve clear, achievable policy aims.[102] Moreover, export control can only preserve military lead-time in areas where the U.S. has a clear and unbridgeable advantage over other (even Western) nations and where the U.S. stands to make military gains in the near term.[103] With the exception of direct-use military technologies, broadening export control lists to include a wider selection of items incurs trade-offs, reducing realistic enforcement capability and potentially harming domestic markets.

While it is yet unclear what direct effect Chinese imports have on the U.S. ATP market, data from the Bureau of Industry and Security demonstrates that Information and Communications (which consists of both hardware and software) constituted 91.2 percent of U.S. total ATP imports from China between 2016 and 2020.[104] American firms that decouple from Chinese counterparts "do experience a drop in valuation, though only half as large as the decrease incurred by China's firms after decoupling."[105] So far, the immediate impact of semiconductor policy is limited to U.S. manufacturers of leading-edge chips, resulting in significant but manageable cost: nine to 19 percent of U.S. firms' sales in China and three to six percent of global sales.[106] Some corporations, such as NVIDIA, released statements assuring that U.S. export controls would not substantially impact their performance,[107] but firms are incentivized to reassure shareholders, and certain high-tech sectors are affected more than others. As the largest portion of the high-tech export economy and the industry with the most products controlled by export

[98] Kania, E. B. Chinese Military Innovation in Artificial Intelligence. *Testimony before the U.S.-China Economic and Security Review Commission Hearing on Trade, Technology, and Military-Civil Fusion*. Center for a New American Security, 2019.
[99] Kania, E. B., Laskai, L. *Myths and Realities of China's Military-Civil Fusion Strategy*. Center for a New American Security, 2021.
[100] Kania, E. B., Laskai, L. 2021.
[101] Kania, E. B. Chinese Military Innovation in Artificial Intelligence. *Testimony before the U.S.-China Economic and Security Review Commission Hearing on Trade, Technology, and Military-Civil Fusion*. Center for a New American Security, 2019.
[102] Henshaw, John H. The Origins of COCOM: Lessons for Contemporary Proliferation Control Regimes. The Henry L. Stimson Center, Report No. 7, 1993.
[103] Gustafson, Thane. Selling the Russians the Rope? Soviet Technology Policy and U.S. Export Controls. Defense Advanced Research Projects Agency, 1981.
[104] United States Bureau of Industry and Security. *U.S. Trade with China*, Bureau of Industry and Security, 2020.
[105] Freeman Spogli Institute and Stanford Institute for Economic Policy Research. *SCCEI China Briefs: Annual Recap*, Freeman Spogli Institute, 2022.
[106] Goujon, Reva et al. Freeze-in-Place: The Impact of US Tech Controls on China. Rhodium Group, 21 October 2022.
[107] Stephen Nellis, Nvidia says it does not expect new U.S. export hit its business. Reuters, 7 October 2022.

restrictions, aerospace is expected to absorb the greatest damage.[108] Immediate effects may be seen in loss of global high-tech market share and price increases, threatening U.S. job stability. Jobs in California, Texas, and Washington are most affected as they account for a combined 41.7 percent of U.S. high-tech output.[109] ATP exports to China comprise 10 percent of all U.S. exports of ATP, accounting for just two percent of all U.S. exports in 2020.[110] However, the long term impacts on domestic innovation may become more severe as U.S. commercial and military technology industries are "constrained from expanding into new fields and from applying new scientific developments."[111]

The human capital element is also indirectly affected by export controls, especially those which restrict access to information. American academics and professionals have expressed concern that "poorly targeted policies [might] disrupt scientific engagements critical to American competitiveness, while not adequately addressing actual threat actors and vectors."[112] Although "there is no detectable relation between decoupling and innovation output or innovation quality"[113] for specific American firms, severe restrictions on U.S.-China exchange could produce long-term impacts to American academic and private-sector innovation. Intellectual property controls can have tangible and prescient impacts on Chinese citizens living in America or working with Americans and can discourage immigration. Over time, reduced immigration from and collaboration with Chinese talent could harm U.S. innovation; American immigrants generally produce more patents than U.S.-born counterparts.[114] PRC leadership recognizes this opportunity and is attempting to counter "brain drain" to the U.S. through programs to entice returning students and nationalistic narratives regarding domestic academia and industry. By restricting academic, business, and intellectual exchange between the U.S. and China, "the United States may be losing one of its greatest competitive advantages—namely, its ability to attract and retain scientific and technological talent from China and around the world."[115]

In addition to other policy aims, export restrictions are a messaging tool. In 1979, Carter implemented an embargo "designed to hurt the Soviet Union's industrial modernization efforts in hopes of persuading it to withdraw its military troops from Afghanistan and to show that the United States will not idly stand by when such military intervention occurs."[116] This measure did not ultimately prevent the Soviet invasion, but leadership in the U.S.S.R. likely viewed export restrictions as a barometer of U.S.-Soviet relations.[117] The U.S. bolstered export control against the PRC during the Cold War for messaging purposes as well. Following the Tiananmen Square crackdown, the PRC lost its special privileges and was in fact denied access to telecommunications technology while some former Soviet states were allowed.[118] The sanctions were received mainly as a political response signaling Washington's condemnation of the Tiananmen Square massacre, as the PRC was not considered a military threat at the time. In the modern case, PRC human rights abuses motivated the timing of some restrictions: "building resilience in critical supply chains, preventing human rights abuses, protecting US citizens' sensitive data, and bolstering US cybersecurity are all big objectives that overlap with the national security goal of preserving US technology leadership."[119] Yet the historical record does not

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[108] Stephen Ezell and Caleb Foote. How Stringent Export Controls on Emerging Technologies Would Harm the U.S. Economy, Information Technology & Innovation Foundation, May 2019.
[109] Stephen Ezell and Caleb Foote. 2019.
[110] Trade in Goods with Advanced Technology Products Data, United States Census Bureau, 2022.
[111] Impacts Of U.S. Export Control Policies On Science And Technology Activities And Competitiveness, 111 Congress House Hearing, Committee on Science and Technology, 25 February 2009.
[112] Kania, E. B., Laskai, L. *Myths and Realities of China's Military-Civil Fusion Strategy*. Center for a New American Security, 2021.
[113] Freeman Spogli Institute and Stanford Institute for Economic Policy Research. *SCCEI China Briefs: Annual Recap*, Freeman Spogli Institute, 2022.
[114] Bernstein, S., Diamond, R., Jiranaphawiboon, A., McQuade, T., Pousada, B. The Contribution of High-Skilled Immigrants to Innovation in the United States, Working Paper No. 3748, Stanford Graduate School of Business, Dec 2022.
[115] Shirk, S. *Overreach*. Oxford University Press, 2023.
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support the claim that these economic measures can "prevent" or even "deter" undesirable actions by adversary states in most cases.[120] Generally, export controls are a less provocative tool than sanctions and leave the PRC with few options to meaningfully respond. Still, if the goal of export restrictions is twofold—delaying access to the specific technology and also expressing diplomatic rebuke via economic means—then broad restrictions are not necessarily more effective in achieving either end.

Targeted, flexible lists bolster export control efficiency and can achieve policy aims at lower cost to U.S. competitiveness,[121] particularly in controlling access to dual-use technologies.[122] Recent U.S. federal policy indicates a strategic shift from restrictions on specific entities (corporations or individuals) to targeted technologies and enabling functions like manufacturing and technical knowledge. These policies reflect an intent not just to widen the gap but to freeze the PRC's development in advanced computing by cutting off access to high-performing integrated circuits.[123] Since the most advanced circuits require American designs, processes, machines, and technical expertise, these specific restrictions will more effectively hinder the PRC in advancing high-performing computing and manufacturing capabilities, stagnating long-term development.

Conclusions

Much of the analysis included in this work is based on U.S. assessments of Soviet and PRC economic capacity. These reports not only reflect institutional biases, they also inherently draw on incomplete datasets. Due to the secretive nature of both the Soviet and PRC regimes, exacerbated by internal cultures that prioritized output over honesty, an accurate reflection of either economy may not be possible. Regardless, the higher-level trends over the historical record point to systemic challenges in the Soviet—and likely also in the PRC—organization of advanced technology development across public, private, and academic sectors.

There is a narrow window in which U.S. advanced technology export controls can effectively constrain another nation's technological advancement. If that nation is too underdeveloped in the technology sector to be able to absorb U.S. technology efficiently, as with the Soviet Union, then export restrictions are not likely to have a substantial impact. On the other hand, if a nation is advanced enough to be able to innovate endogenously, then that nation hypothetically would not be dependent on U.S. technology. The advanced technology sector is not a monolith, and a nation can be highly dependent on foreign imports in some areas while maintaining independent innovation in others. Focused export controls on key enabling technologies for the PRC are likely more effective in restricting access to dual-use items while limiting adverse impacts to the U.S. economy.

To achieve effective export restrictions on the PRC, the U.S. will need to produce and maintain a limited list of critical sensitive advanced technologies and intellectual property. Buy-in and cooperation from federal agencies, international partners, and private industry are crucial to creating an enforceable list. In addition to targeted, multilateral export controls, the U.S. can maintain lead time by bolstering existing strengths in the innovation landscape by encouraging open communication among public, private, and academic organizations. Just as in the Cold War era, human capital is paramount in advanced computer technology. Encouraging talented researchers and industry professionals to stay in the U.S. through legal protections, pathways to citizenship, and visa incentive programs would therefore also substantially impact American innovation. A resilient, redundant, diversified domestic environment likely did more to preserve American technological dominance over adversaries during the Cold War than any export controls, and it could very well be the decisive factor in modern competition.

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