Economic Studies at BROOKINGS

POLICY BRIEF | JULY 2024

EXPORT CONTROLS AND US-CHINA TECHNOLOGY COMPETITION IN AN INTERDEPENDENT WORLD

LEE BRANSTETTER, PROFESSOR, CARNEGIE MELLON UNIVERSITY

Introduction

AMERICA'S NEW TRADE AND INDUSTRIAL POLICY INTERVENTIONS IN THE SEMICONDUCTOR INDUSTRY

OVERVIEW

The export controls on semiconductor technologies adopted by the Biden administration and enforced by key allies represent a significant shift in the technological competition between the U.S. and China. Unlike many past efforts, these sanctions are designed not to change Chinese behavior but to inhibit the development of China's technological capabilities. These sanctions have been paired with extensive subsidies designed to build up U.S. firms' technical capabilities and "reshore" semiconductor manufacturing. This essay argues that current sanctions and subsidies will likely prove inadequate to meet the policy goals of the Biden administration or future administrations. It suggests alternatives that will reinforce the impact of sanctions and make the achievement of those underlying policy objectives more likely, including a significant increase of STEM-trained immigrants.

PROLOGUE: THE U.S.-JAPAN CHIP WARS OF THE 1980S

During the 1980s, U.S. firms that invented and dominated the semiconductor industry lost global market share to Japanese manufacturers. Influential pundits (Prestowitz (1988)) warned that the U.S. risked hollowing out its economic base by allowing this critical manufacturing industry to move offshore. The Reagan administration limited Japanese chip exports to the U.S., tried to force Japan to import more U.S. semiconductors, and engaged in limited industrial policy interventions (continued in the Bush and Clinton administrations) to promote U.S. semiconductor manufacturing through federal support of the SEMATECH consortium.[1]

GLOBALIZATION OF PRODUCTION, JAPANESE DECLINE, AND THE RESURGENCE OF U.S. IT FIRMS

Despite the U.S. policies, fabrication of semiconductor products continued to shift to Asia. At the same time, the structure of the industry shifted. The early dominance of integrated device manufacturers who undertook nearly all the main stages of semiconductor manufacturing within a single firm declined. Firms that specialized in particular stages of that process grew in size and importance. Of note was the rise of foundry manufacturers, a model pioneered by Taiwan's TMSC and its founder, Morris Chang. By committing not to produce their own branded products and instead manufacture chips for others, foundries enabled the rise of "fabless" semiconductor firms that focused on product design and product innovation and outsourced manufacturing [2] As the semiconductor trade wars of the 1980s faded, information-technology exporters committed to nearly tariff-free trade in IT products and components (Feenstra et al., 2013), and the World Trade Organization provided stronger protection for intellectual property of fabless firms (Bown and Wang, 2024), this international and interfirm division of labor gathered steam. While leading U.S. firms like Intel and Micron remained committed to manufacturing their own products in their own plants, a new generation of U.S. semiconductor firms embraced the fabless model.

Figure 1 shows a simplified breakdown of the modern semiconductor value chain. While American firms are present in nearly all these segments, they tend to be concentrated in design and in the provision of design software tools and semiconductor manufacturing equipment. Figure 2a and 2b illustrate the importance of U.S. firms in the global industry. Figure 2a categorizes the sales of global semiconductor firms by headquarters country in 2021. American firms accounted for a greater share of the revenues of the global industry than those based in any other country, despite accounting for a small fraction of global fabrication. Figure 2b makes a similar point using the market capitalization of the top 100 publicly traded firms in the industry as of April 2024. American firms account for nearly two-thirds of this stock market capitalization. This underscores how vibrant and important American semiconductor firms are in the 2020s.

American semiconductor and other IT firms plowed cost savings generated by offshoring into investments in product innovation and technological leadership (McKendrick, Doner, and Haggard, 2000; Branstetter and Kwon, 2018). A new generation of U.S. tech firms thrived as the Japanese electronics giants of the 1980s withered, caught between American innovative dynamism on the one side and the low production costs in less developed Asian countries on the other (Branstetter and Kwon, 2018). The rise of a global value chain with specialized manufacturers allowed U.S. firms to double down on investment in the most productive and remunerative technology opportunities. The rise of the internet in the 1990s was driven predominantly by U.S., not Japanese, firms and technologies, although the actual hardware was increasingly manufactured in Asia. The rise of China as an IT manufacturing site was initially welcomed by industry leaders, as China's low costs and vast labor resources promised decades of cost savings in manufacturing.

Reinforcing the resurgence of Silicon Valley and the relative decline of Japan's once-vaunted IT sector was the shift in the loci of technological opportunity from hardware to software (Aora et al., 2013). Even new generations of hardware components, including advanced semiconductors, were increasingly reliant on software for their design, manufacturing, and effective operation. In the broader IT sector, the rise of the internet and e-commerce created opportunities for businesses to succeed on the strength of software innovation. Responding to these new opportunities required increases in the ranks of software engineers that far outstripped the ability of schools in the U.S., Europe, or Japan to meet. Fortunately, the U.S. was able to "import" large numbers of software engineers that significantly exceeded the number of U.S.-born, U.S-educated engineers. This played a key role in the ability of U.S. firms to out-innovate their Japanese competitors (Arora et al., 2013; Bound, Khanna, and Morales, 2018).

THE CHIP WARS RETURN

During the 2010s, geopolitical tension between China and the United States dramatically escalated, making policymakers and industry leaders increasingly nervous about reliance on Taiwan and China. Then, global supply chain shocks generated by the COVID-19 pandemic and the ensuing global semiconductor shortage illustrated the risks posed by a protracted cutoff of semiconductors from East Asia. The CHIPS and Science Act, passed with bipartisan support, was sold in part by the Biden administration as a national security hedge against dependence on imported advanced semiconductors.[3]

SEMICONDUCTOR SANCTIONS: EXPORT CONTROLS IMPOSED ON CHINA

National security officials worried that the rising technological capabilities of Chinese firms could translate into intelligence gathering or military capabilities that could be wielded against the U.S. and its allies. The U.S. government began trying to hamper the expanding technological capabilities of Chinese firms by limiting their access to U.S. technology. Huawei was an early target (Bown and Wang, 2024; Miller, 2022). American policymakers used American dominance of key segments of the semiconductor value chain to effectively control a globalized supply chain that extended far beyond the borders of the United States. The U.S. now accounts for a very small fraction of global semiconductor fabrication. However, firms that dominate fabrication are dependent on U.S. design software, U.S. semiconductor manufacturing equipment, and other inputs. By threatening these firms with loss of access to key U.S. inputs, the U.S. was able to enlist them in its effort significantly cut off the access of selected Chinese companies such as Huawei to advanced semiconductors (Bown and Wang, 2024). These sanctions initially presented Huawei with a first order challenge. The next step in this escalation was for the U.S. to cut off exports of the most advanced semiconductors to all Chinese firms. This policy was implemented in October 2022 and expanded and tightened a year later. This required close coordination with allies who controlled critical stages in the semiconductor value chain, such as the the Netherlands, home of ASML, now the sole global supplier of the key machine used to make the world's most sophisticated semiconductors, and Japan, home of the most important semiconductor fabrication equipment manufacturers based outside of the U.S. or the Netherlands (Miller, 2022).

As time passed, the lasting efficacy of U.S. sanctions appeared less clear. Huawei managed to create homegrown chips and an indigenous operating system, enabling it to introduce new advanced smartphones that competed well with Apple products in the Chinese market. Loss of overseas markets was offset by the speed and scale of China's domestic 5G telecom buildout, to which Huawei had preferential access. American sanctions created strong incentives to replace components under export controls with domestic alternatives. Huawei accomplished this substitution with unanticipated speed.[4] Insiders in China's semiconductor industry have become much more optimistic that they can survive—even thrive—without access to key U.S. inputs. As the U.S. seeks to weaponize its dominance of key stages in the semiconductor chain to impede Chinese technological progress, it risks undermining the sources of that dominance. Continuing reliance on escalating rounds of widening sanctions are likely to reach a limit of effectiveness sooner rather than later.

The U.S. also has sought to limit dependence on Taiwan with significant subsidies for semiconductor fabrication facilities in the United States through the CHIPS and Science Act. However, the practical impact of these expenditures is likely to be limited and will, in the best of cases, only emerge many years from now. The facilities under construction or planned in the U.S. will not have the same degree of sophistication as the most advanced plants in Taiwan—and may therefore do little to substantially relieve American reliance on that source. The long decline of semiconductor fabrication in the U.S. means the skilled, specialized workforce needed to operate the new plants does not exist, and shortages of key workers have already emerged as a key source of delays. Even if the planned fabrication facilities are built, they will not reduce American imports very much. TSMC's Morris Chang, whose firm is cooperating with the CHIPS Act, has declared it an "expensive exercise in futility."[5]

Proposal

BUILDING ON STRENGTH—FLEXIBLE STRATEGIES FOR REINFORCING AMERICAN TECHNOLOGICAL LEADERSHIP

If the most important policy goal of the sanctions regime is to maintain—and even extend—American technological leadership, then policies adopted to attain that goal should be founded in the following realities.

First, U.S. firms are productively embedded in a multinational supply chain that has delivered more innovation and more cost-effective manufacturing than could have been possible if the entire value chain had been confined to one country. As the industry continues to evolve, the U.S. should not forsake the benefits of this international division of labor. In a purely bilateral investment/technology race, the U.S. may be at a long-run disadvantage relative to China given its vast human resources and scale. If U.S. firms can draw upon the resources and capabilities of their international suppliers and partners, that evens the match.

Second, within that international division of labor, U.S. firms hold a strong position in the highest-return, highest-value-added parts of the supply chain. Policies meant to support and strengthen U.S. technological leadership should invest in our strengths rather than mostly attempt to shore up weaknesses. Recent policy measures have probably overemphasized semiconductor fabrication and underemphasized investment in parts of the semiconductor (and IT more broadly) value chain in which American firms are world leaders.

Third, the largest single barrier to the further advancement of America's leading IT and semiconductor firms is a shortage of trained engineers.

Fourth, the risk of overreliance on Taiwan is real, and it is reasonable for the U.S. to invest in efforts to diversify its supplies of key semiconductor products away from that island given the current threat of military action in the Taiwan Strait.

This author is not opposed to the current technology sanctions regime but takes the position that they are not sufficient to achieve the goal of maintaining and extending a U.S. (and U.S. ally) technological lead.

Additional, finely targeted sanctions, such as those proposed in Branstetter (2018), are unlikely to contribute significantly to this overarching goal of protecting, maintaining, and even extending Western technological leadership; they were never designed to do so. Branstetter (2018) focused solely on the problem of forced technology transfer: situations in which foreign multinationals are effectively coerced into transferring strategically significant technology to indigenous Chinese entities over which they have no control. It laid out a strategy of using government investigations and precisely targeted sanctions to punish specific Chinese entities that engaged in or benefitted from forced technology transfer while explicitly permitting technology transfers that were truly voluntary. This strategy exemplifies a more conventional use of sanctions: inducing a change of behavior by the sanctioned party by imposing sanctions when objectionable behavior occurs, then ending sanctions when the objectionable behavior stops. In the present circumstance, however, the U.S. government policy objective is not better enforcement of foreign multinationals' intellectual property rights in the Chinese market but rather the maintenance and even expansion of a technological gap between the U.S. and China. The fundamental changes in Chinese behavior the Biden administration or any future U.S. administration might seek to allay its underlying concerns—e.g., the end of threats to forcibly unify Taiwan or the cessation of challenges to the U.S.-led international order—are unlikely to be embraced by China's current leadership under almost any conceivable circumstances.

If finely targeted sanctions are inadequate, then additional, broad-based sanctions that seek to deny an expanding array of advanced semiconductor technologies to all Chinese parties regardless of their identity and corporate behavior will likely incur increasing costs with ever more limited benefits. An effective sanctions regime requires foreign allies and private firms to forego financial gain to further U.S. foreign policy objectives. The greater the cost, the greater the likelihood that leaks or gaps will emerge in the sanctions regime. In addition, the rapid advance of Chinese semiconductor capabilities could render sanctions not targeted on the most sophisticated technologies moot within a few years.

Given these limitations, the single most effective step the United States could take to maintain and extend its technological lead would be a "national security STEM visa" program that relaxes the greatest barrier to industry advancement: the human resource constraint. The greatest advantage the United States possesses over China is arguably the much greater desirability of the United States to the world's top scientists and engineers as a place to live. STEM immigration reform could include a large increase in the number of H-1B visas (up to 500,000 per year for at least five years), automatic provision of an H1-B visa to foreign students at U.S. universities studying advanced technologies, and large increases in the number of green cards made available to H-1B visa holders, regardless of their national origin. Economist Giovanni Peri (2012) outlined a phased reform of the U.S. immigration system in a 2012 Hamilton Project policy brief. A key idea is the implementation of an H-1B visa auction that leverages market forces to identify the workers with skills most in demand and prioritizes their admission into the U.S. labor market. Research suggests that access to skilled immigrants was an important component of U.S.-based firms' abilities to out-innovate their Japanese competitors in the 1990s and early 2000s—this policy would reflect that lesson (Arora et al., 2013). Unlike the CHIPS and Science Act, a national security STEM visa program would not require large deficit-financed expenditures—it could raise revenue through visa auctions that could be spent, in part, on better training programs for U.S. citizens.

Current policy implicitly recognizes the inadequacy of sanctions alone and introduces extensive subsidies to promote technological advancement and workforce development. However, the current allocation of subsidies across semiconductor industry market segments places greatest emphasis on those segments where U.S. firms are currently weakest (especially semiconductor fabrication) and makes fewer investments in the chip design, design software, and semiconductor manufacturing equipment segments where U.S. firms are the strongest. If the goal is to maintain or extend America's technological lead, then a better balance of investments across market segments that places greater emphasis on American strengths would be advisable.

While a significant increase in STEM immigration would have a powerful impact on American technological capabilities, especially in the longer run, and a better balance of research and workforce development subsidies could reinforce this impact, neither policy would address the short-run problem of overreliance on Taiwan for high-end semiconductor fabrication. American allies and trading partners share this concern and the objective of diversifying the supply of semiconductor fabrication away from Taiwan.

However, America and its allies all appear to be subsidizing the shift of semiconductor production to their own territories with little regard for comparative advantage. To the extent that these policies wind up pushing manufacturing to sub-scale, high-cost sites lacking skilled labor, they could perpetuate rather than ameliorate overreliance on Taiwan.

The U.S. should therefore consider supporting efforts to friendshore high-end semiconductor fabrication rather than insist on a reshoring strategy that is unlikely to succeed. U.S. willingness to invest even modest resources in the production capabilities of its allies and trading partners could be useful in maintaining the solidarity and goodwill among allies that a lengthy period of technological competition with a geopolitical adversary may require. It seems clear that the most competitive alternative sites for advanced semiconductor fabrication are likely to lie elsewhere in East Asia. South Korea is the one country that currently operates foundry semiconductor fabrication at levels of sophistication that are equal to those in Taiwan. While South Korea is not without geopolitical risks, no Chinese government has claimed mainland South Korea as its territory, and, unlike Taiwan, South Korea is a defense treaty ally of the United States with a substantial U.S. troop presence inside its borders. Japan is not nearly the semiconductor powerhouse it was back in the 1980s, but it is likely to be a more plausibly competitive site for advanced fabrication than the U.S. Japan is even less likely to face a direct military threat than South Korea and is also a defense treaty ally of the U.S. A given level of expenditure is likely to purchase more real diversification away from Taiwan for the entire semiconductor supply chain if that money is invested in Asia.

Impact

MORE EFFECTIVE MANAGEMENT OF GEOPOLITICAL RISK AND TECHNOLOGICAL CHANGE

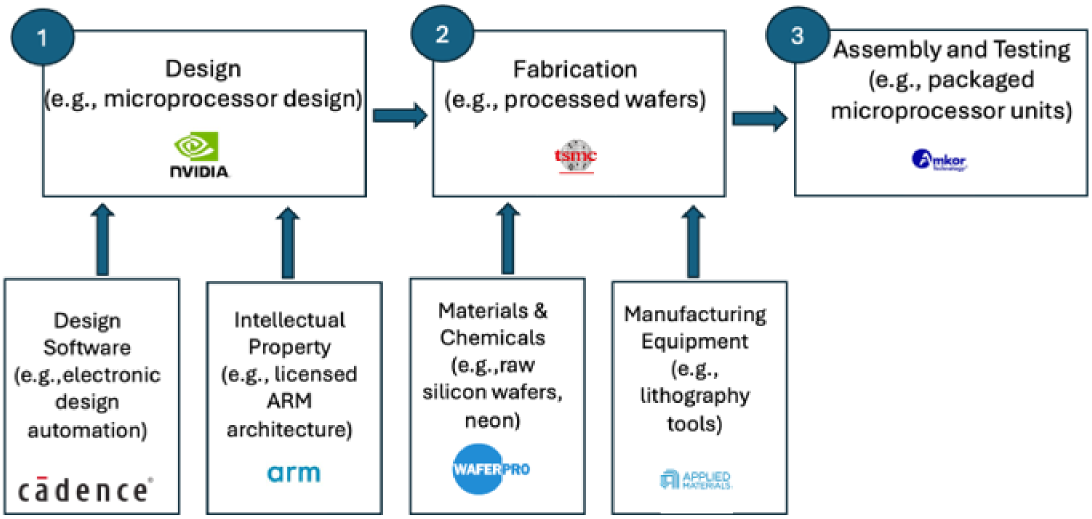
Rising geopolitical tensions with China have created legitimate concerns about China's growing technological capabilities and the security of supply of key semiconductor products and components elsewhere in Asia—especially Taiwan. Along many dimensions, the policy response delivered by the Biden administration has been impressive. Large amounts of money have been procured to subsidize domestic production, build up a domestic workforce, and promote further research. At the same time, the Biden administration has coordinated closely with key allies to limit exports of the most advanced semiconductors to Chinese firms, instituting a policy of technology sanctions that are unprecedented in the post-Cold War era.

However, these policies may do little to advance the central goal of maintaining an enduring position of technological leadership for the United States and its allies in the longer run. New resources are being invested in the parts of the global semiconductor supply chain where the United States has been the weakest and has the least likelihood of obtaining competitiveness. The sanctions regime is likely to have a limited, short-run effect on the technology gap between the U.S. and its allies, on the one hand, and China on the other. Even well-run sanctions regimes have leaks, inevitably punish the innocent, generate costly side effects (including on allied nations), and create powerful incentives for the targets of the sanctions to find substitutes for the sanctioned products. All of these features are evident in careful studies of the current sanctions regime (Bown and Wang, 2024).

The policy shifts proposed here would build on the impressive strengths of the U.S. semiconductor industry, generate government revenue rather than deficits, and relax the most critical constraint holding back U.S. technological advance—people. They would also raise the effectiveness of investment in diversification of key supply linkages while strengthening ties with key allies and trading partners.

FIGURE 1

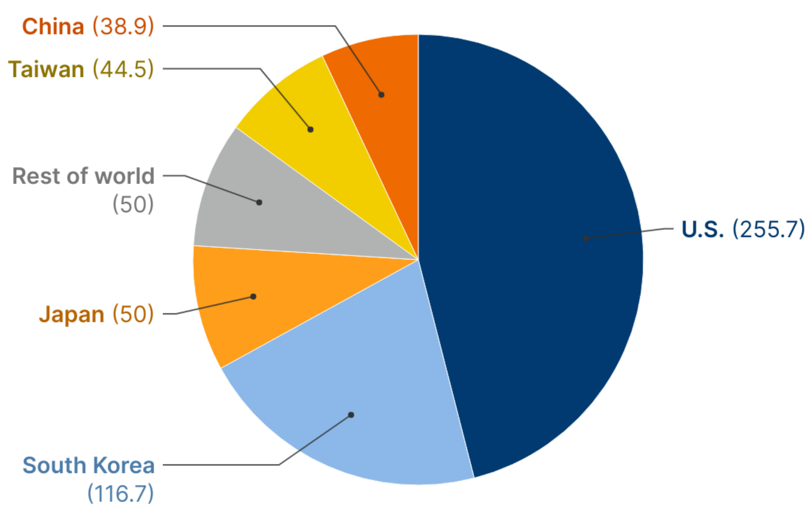
The semiconductor value chain



SOURCES: Mapping the Semiconductor Supply Chain: The Critical Role of the Indo-Pacific Region, Akbil Thadani and Gregory Allen, CSIS, 2023; Semiconductor Supply Chains: A Political Economy Perspective, Theresa Bowen, UCSD and NBER, 2023

FIGURE 2A

Semiconductor sales in U.S. $ billion by corporate headquarters country



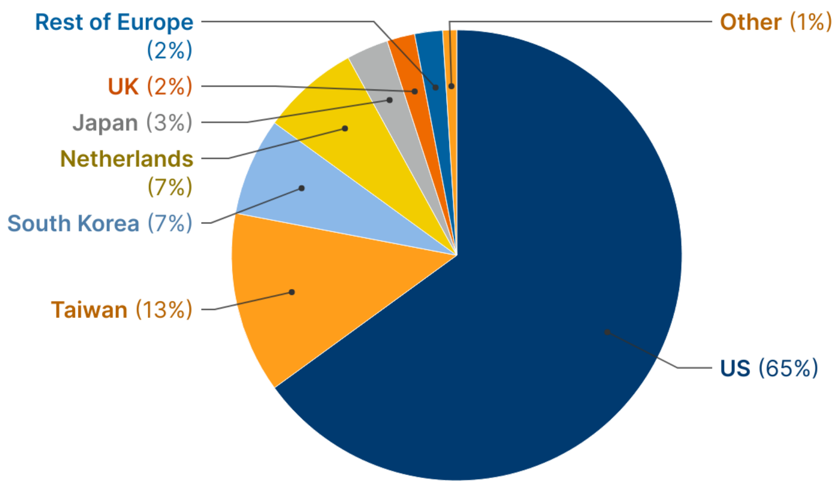
Source: Mapping the Semiconductor Supply Chain: The Critical Role of the Indo-Pacific Region, Akbil Thadani and Gregory Allen, CSIS, 2023; Semiconductor Supply Chains: A Political Economy Perspective, Theresa Bowen, UCSD and NBER, 2023

BROOKINGS

FIGURE 2B

Semiconductor firms' market cap by headquarters country

Top 100 firms as of April 2024



Source: Companiesmarketcap.com, April 2024; Authors calculations

BROOKINGS

Endnotes

1 Miller’s (2022) best-selling history of the semiconductor industry reviews the policy developments of this era, as does the essay by Bown and Wang (2024).

2 See Bown and Wang (2024).

3 See CRS (2023) for a detailed description of this legislation.

4 See Xiang (2024) and Lin and Huang (2024).

5 See Wang (2022).

References

Arora, A., Branstetter, L., and Drev, M., 2013. "Going Soft: How the Rise of Software-Based Innovation Led to the Decline of Japan's IT Industry and the Resurgence of Silicon Valley." Review of Economics and Statistics, vol. 95, no. 3, July 2013, pp. 757-775.

Bound, J., Khanna, G., and Morales, N., 2018. "Understanding the Economic Impact of the H-1B Program on the United States," in G. Hanson, W. Kerr, and S. Turner, (Eds.), High-Skilled Migration to the United States and Its Economic Consequences, Cambridge, MA: University of Chicago Press.

Bown, C. and Wang, D., 2024. "Semiconductors and Modern Industrial Policy," Draft Prepared for the Journal of Economic Perspectives.

Branstetter, L., 2018. "China's Forced Technology Transfer Problem -- And What to Do About It," Peterson Institute Policy Brief PB 18-13.

Branstetter, L., and Kwon, N., 2018. "Invention, Productivity, and the Evolution of East Asia's Innovation Systems," in J. Cohen-Setton, T. Hebling, A. Posen, and C. Rhee (eds.), Sustaining Economic Growth in East Asia, Peterson Institute for International Economics.

Congressional Research Service, 2023. Frequently Asked Questions: CHIPS Act of 2022 Provisions and Implementations.

Feenstra, Robert C., Benjamin R. Mandel, Marshall B. Reinsdorf, and Matthew J. Slaughter, 2013. "Effects of Terms of Trade Gains and Tariff Changes on the Measurement of US Productivity Growth." American Economic Journal: Economic Policy, 5 (1): 59-93.

Li, G., and Branstetter, L., 2024. "Does Made in China 2025 Work for China? Evidence from Chinese Firms," conditionally accepted, Research Policy.

Lin, L. and Huang, R., 2024. "Huawei Bounces Back From U.S. Sanctions As Profit Doubles," Wall Street Journal, March 29, 2024.

McKendrick, D., Doner, R., and Haggard, S., 2000. From Silicon Valley to Singapore: Location and Competitive Advantage in the Hard Disk Industry. Palo Alto: Stanford.

Miller, Chris, 2022. Chip War. New York: Scribner.

Peri, Giovanni, 2012. "Rationalizing U.S. Immigration Policy: Reforms for Simplicity, Fairness, and Economic Growth," Hamilton Project Discussion Paper 2012-01, The Brookings Institution.

Prestowitz, C., 1988. Trading Places: How We Allowed Japan to Take the Lead. New York: Basic Books.

Xian, N., 2024. "U.S. Should Learn From Its Failure to Take Down Huawei," Nikkei Asia, Feb. 2, 2024.

Wang, L. 2022. "U.S. Chip Bid 'Futile,' Morris Chang Says," Taipei Times, April 22, 2022.

Disclosures and acknowledgements

This policy brief was produced as part of a May 2024 event organized by Brookings' Economic Studies and Foreign Policy programs entitled, "Sanctions on Russia: What's working? What's not?" This report and others presented at the event can be found online at https://www.brookings.edu/events/sanctions-on-russiawhats-working-whats-not/.

The Brookings Institution is financed through the support of a diverse array of foundations, corporations, governments, individuals, as well as an endowment. A list of donors can be found in our annual reports published online. The findings, interpretations, and conclusions in this report are solely those of its author(s) and are not influenced by any donation.

BROOKINGS

1775 Massachusetts Ave NW,
Washington, DC 20036
(202) 797-6000
www.brookings.edu