National Defense and Global Industries: Taiwan and the Game of Diversification in the Global Semiconductor Supply Chain

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December 2022

Paper prepared for Ministry of Foreign Affairs
Taiwan Fellowship 2022

中華民國外交部
MINISTRY OF FOREIGN AFFAIRS
REPUBLIC OF CHINA (TAIWAN)

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Abstract

Supply chain networks in the Indo-Pacific are selectively reconfiguring and diversifying from China, due to vulnerabilities from black swan events such as the Covid-19 pandemic and risks regarding weaponization of sensitive technologies, supply chains and rare earth materials. Of particular concern have been semiconductors broadly and Taiwan Semiconductor Manufacturing Company (TSMC) specifically. Given its dominant position of producing over ninety percent of world market share for advanced semiconductors, and after the Covid-19 pandemic exposed vulnerabilities and shortages in the chip supply chain, TSMC suddenly found itself in the spotlight amid U.S.-China technology rivalry. Because the desire to maintain, or acquire, production capability in key military related industries can easily insert a national security requirement into the management of the economy, threats to such supplies can feed quickly through into military capability and thus almost be seen in the same light as military threats. As such, Taiwan is emerging as a key player in the game of semiconductor supply chain diversification, as policymakers in U.S., Europe and Asia face the dilemma of how to maintain national security in the face of an increasingly globalized defense and high-tech industrial base.

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Acknowledgements

I would like to express my deep gratitude to the Ministry of Foreign Affairs, Republic of China (Taiwan) for providing support through the Taiwan Fellowship program without which this report is not possible. Sincere thanks also to the National Central Library as well as the National University of Kaohsiung which hosted me during my sojourn in Taiwan. Special thanks to my faculty sponsor Professor Yung-Kai Yang at the Department of Asia-Pacific Industrial and Business Management who provided valuable support during my research in Kaohsiung, as well as Dean Hsing-Hao Wu at the Office of International Affairs and Director of the International Relations Research Center who provided generous time and assistance for my project. I am especially indebted to former Taiwan Deputy Defense Minister Dr. Chong-Pin Lin and Dr. Kongdan Oh Hassig who recently retired from Institute for Defense Analyses, for their support for this Fellowship as well as precious mentorship, inspiration and encouragement throughout the years. Thanks also to Taipei Economic and Cultural Office in Los Angeles for shepherding me through the Fellowship process, and the Global Taiwan Institute for graciously providing a virtual parking space for me to learn all things Taiwan prior to the program.

Introduction

Supply chain networks in the Indo-Pacific are selectively reconfiguring and diversifying from China, due to vulnerabilities from black swan events such as the Covid-19 pandemic and risks regarding weaponization of sensitive technologies, supply chains and rare earth materials. Of particular concern have been semiconductors broadly and Taiwan Semiconductor Manufacturing Company (TSMC) specifically. Given its dominant position of producing over ninety percent of world market share for advanced semiconductors, and after the Covid-19 pandemic exposed vulnerabilities and shortages in the chip supply chain, TSMC suddenly found itself in the spotlight amid U.S.-China technology rivalry. As policymakers in U.S., Europe and Asia face the dilemma of how to maintain national security in the face of an increasingly globalized defense and high-tech industrial base, Taiwan is emerging as a key player in the game of semiconductor supply chain diversification.

Historically, scholars have argued for the underlying long run harmony between the national pursuit of wealth and power and the primacy of productive capacity on which power rests.[1] Given military power and influence derive from economic power, economic stability and growth in general become central national security concerns.[2] Yet, the traditional dilemma facing statesmen since the 17th century has been precisely to disentangle the two objectives—that is, how to determine the trade-off between guns and butter, between national defense and economic objectives, and translate these priorities into a coherent set of foreign policies.

As current policymakers in Taiwan, the U.S. and other allied countries grapple with this question in the face of a rising China and her aspirations to become a dominant global high-tech powerhouse, it may be instructive to look back at history to gauge what is the appropriate role for the government to play in managing the health and vitality of the defense industrial base. Especially within the context of contemporary trade rivalry over semiconductors as manifested in the U.S.-China "chip war", this case actually has a precedent during the 1980s during the U.S.-Japan chip war.

U.S. economic history has traditionally been one of a *lassize faire* model, and policymakers have been reluctant to utilize industrial policy to support the defense industrial base. However, in the late 1980s, due to declining defense budgets, increasing globalization of U.S. (including defense) industries, growing U.S. dependence on foreign sources of supply for vital defense inputs, all brought a new urgency to the problem of foreign dependence for defense planners. At the same time, increasing sophistication in the analytical

[1] Jacob Viner, "Power versus Plenty as objectives of statecraft in the seventeenth and eighteenth centuries", *World Politics,* Vol. 1, No. 1 (October 1948), pp. 1-29; Friedrich List, *The National System of Political Economy* (Philadelphia: J.B. Lippincott, 1856); Paul Kennedy, "The First World War and the international power system", *International Security,* Vol. 9, No. 1 (Summer 1984), p.7-40); Edward Mead Earle", "Adam Smith, Alexander Hamilton, Friedrich List: The Economic Foundation of Military Power", in Peter Paret, Ed., *Makers of Modern Strategy* (Princeton: Princeton University Press, 1986).
[2] Robert Gilpin, *War and Change in World Politics* (Cambridge: Cambridge University Press, 1981); Paul Kennedy, *The Rise and Fall of British Naval Mastery* (London: Ashfield Press, 1976).

community—e.g., emergence of strategic trade theory in the 1980s, and rigorous appreciation that concentration among external suppliers can constitute a genuine national security threat—raised the level of debate. Thus, the growing challenge from abroad to the competitiveness of a broad array of U.S. industries suggested to many that a more interventionist approach might be needed in sectors where the U.S. was becoming dependent on external sources of supply—especially in the semiconductor industry. This eventually culminated in the formation of SEMATECH in 1987—a joint Department of Defense-private sector consortium to revitalize the U.S. domestic semiconductor manufacturing industry.[3] Now, history appears to be repeating itself with government intervention in the semiconductor industry once more to form another international consortium—the Chip 4 alliance.[4]

The purpose of this paper is thus to explore why governments often intervene in the semiconductor industry, and the paper will be divided into five parts. It will first cover rationales of why there is so much focus on semiconductors—the economic rationale supported by strategic trade theory, as well as the politico-military rationale of increasing defense dependence on foreign suppliers. Part two will examine U.S.-Japan chip war during the 1980s and the formation of SEMATECH, followed by comparison with the current U.S.-China chip war and various attempts for semiconductor alliance formation such as CHIP 4 Alliance, Quad plus and NATO plus.[5] Part four will analyze how and why Kaohsiung in southern Taiwan is emerging as a key hub in U.S. and allies attempts to remap the chip supply chain, and its strategic significance as a potential cooperative security location for NATO partners in the Indo-Pacific. The final part will address remaining challenges of water, energy and talent shortage facing the semiconductor industry, and current efforts to redress these issues.

1 | Why so much focus on semiconductors?

This paper puts forth a suggestive argument—that government intervention[6] in the national economy is driven by military research and development (R&D) priorities, which are imputed by the underlying military rivalry of the international political system. The desire to maintain, or acquire, production capability in key military related industries can easily insert a national security requirement into the management of the

[3] Sematech stands for SE-miconductor MA-nufacturing TECH-nology, and was established in 1987 as a joint government-industry research consortium. Larry D. Browning and Judy C. Shetler, *Sematech: Saving the Semiconductor Industry* (Texas: Texas A&M University Press, 2000).

[4] The Chip 4 alliance was first proposed in March 2022 and consists of the U.S., Taiwan, Japan and South Korea to build resilience in the semiconductor supply chain. Che Pan, "US-China tech war: Washington said to eye chip alliance with Japan, South Korea, Taiwan to squeeze China", *South China Morning Post,* March 30, 2022, https://www.scmp.com/tech/tech-trends/article/3172418/us-china-tech-war-washington-said-eye-chip-alliance-japan-south; Sarah Wu, "Taiwan says U.S.-led 'Chip 4' group discussed supply chain resilience", *Reuters,* September 30, 2022, https://www.reuters.com/technology/taiwan-says-us-led-chip-4-group-discussed-supply-chain-resilience-2022-09-30/

[5] Robert Van Steenburg, "With CHIPS Down, SEMATECH Gets Second Look", *National Defense Magazine,* June 2, 2022, https://www.nationaldefensemagazine.org/articles/2022/6/2/with-chips-down-sematech-gets-second-look

[6] Modes of intervention in strategic industries include direct subsidy and tariffs, public ownership, preferential procurement, discriminatory taxation, export subsidies, education and research. See Gautam Sen, *Military Origins of Industrialisation and International Trade Rivalry* (London: Pinter, 1984), pp. 87-89.

economy, since threats to such supplies feed quite quickly through into military capability, and can thus almost be seen in the same light as military threats.[7]

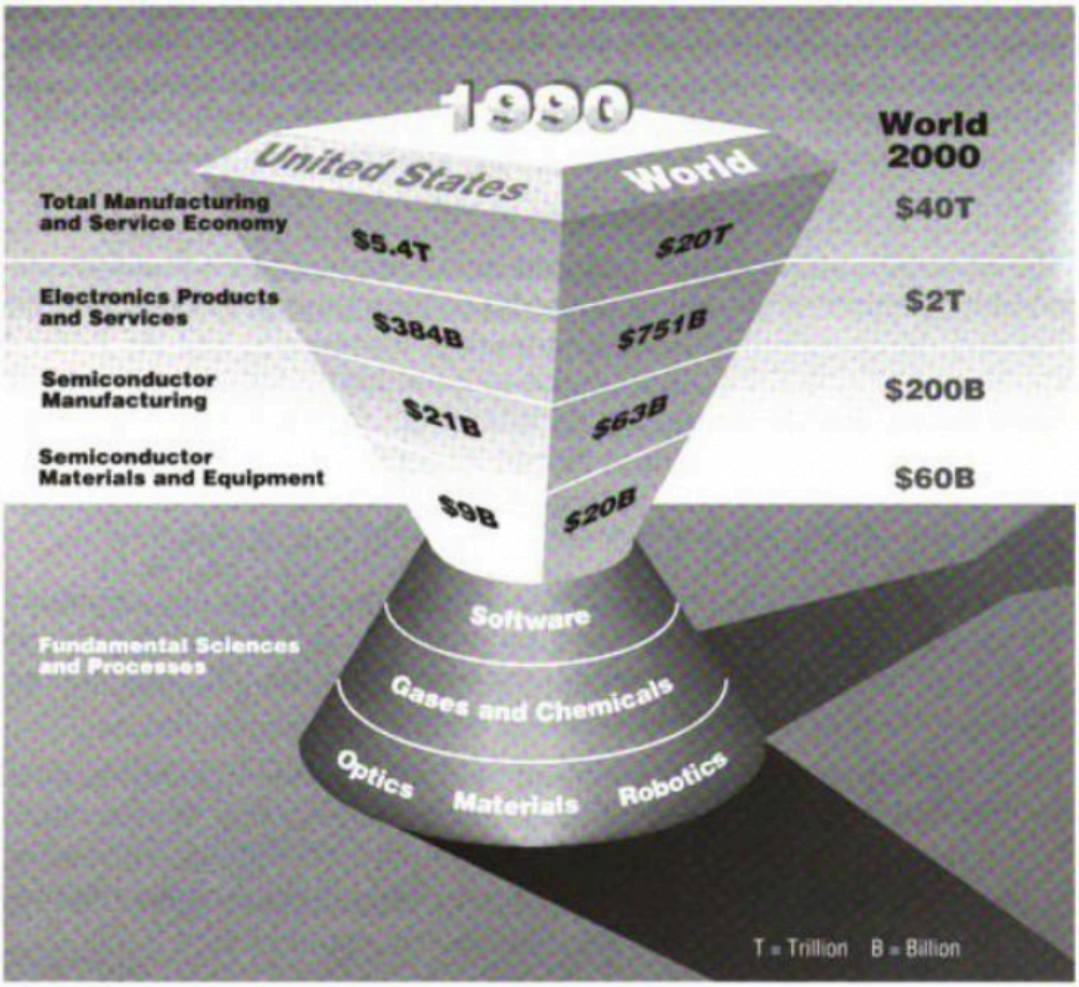
Economic rationale: strategic industry and externalities

The semiconductor industry in particular is subject to frequent government intervention due to its dual-use application in both the commercial and military sectors, and also as a "strategic" or "critical" industry.[8] In general, a strategic industry is one characterized by high R&D expenditure and a steep learning curve, thereby creating barriers to entry for firms lacking sufficient capital. It is also a technology driver, which is generally a high-volume product with a relatively simple design. When a firm has mass produced a technology driver, it would hone its manufacturing skills and then transfer its learning to more complicated, lower volume, high value-added devices.[9] The relatively fixed sunk cost of R&D and capital equipment investments and the decreasing unit costs with improved yields create first mover advantage, in which a privileged position in one market can create scale economies over rivals and capture more technological externalities (positive externalities) in future generations of semiconductor products. These characteristics provided justifiable and perhaps even desirable economic rationales for intervention to sustain a "strategic" industry in the 1980s.[10]

However, the U.S. National Advisory Committee on Semiconductors (NACS) had different concepts of "strategic" in mind, namely its linkage to national security. The committee asserted that American national security depended on the capabilities of its domestic semiconductor industry due to two main factors: (1) its linkages to the rest of the economy; and (2) the possibility of monopoly profits in this high-tech sector. In terms of the linkage argument, the simplest form is the "food chain" theory.[11]

[7] Barry Buzan, 2nd edition, *People, States and Fear: An Agenda for International Security Studies in the Post-Cold War Era* (Essex: Pearson Education Limited, 1991), p.126. For a more explicit link between industrial policy and defense concerns, see Gautam Sen, *Military Origins.*
[8] National Advisory Committee on Semiconductors (NACS). *A Strategic Industry at Risk: A Report to the President and the* Congress (Washington, D.C.: 1989).
[9] Laura "D'Andrea Tyson, *Who's Bashing Whom? Trade Conflict in High-Technology Industries* (Washington, D.C.: Institute of International Economics, 1992), p. 89.
[10] Kenneth Flamm, *Mismanaged Trade? Strategic Policy and the Semiconductor Industry* (Washington, D.C.: Brookings Institution Press, 1996), p. 377.
[11] NACS, *Strategic Industry at Risk,* p.9.

Figure 1: Semiconductors: A Foundation for Preeminence



Sources: National Advisory Committee on Semiconductors, Dataquest, and American Electronics Association.

According to the food chain theory, upstream and downstream industries competitive fortunes are interlinked in a complex ecological system that makes each dependent on the health of the others. As a report by the Semiconductor Industry Association (SIA) posits, "The elements of the electronics industry are analogous to a "food chain", in which each component level, from silicon wafers up to finished electronics products, is dependent on the others. If one link is damaged, the others are automatically injured." Indeed, the German auto industry suffered loss during the Covid-19 pandemic and chip shortages, culminating with German Economy Minister Peter Altmaier writing to his Taiwanese counterpart Wang Mei-hua for TSMC to ramp up production.[12] Advanced (smaller than 10 nanometer) chip shortages from TSMC also pose a serious risk to other high-tech sectors given they are inputs in smartphones, computers, military and space equipment.[13]

[12] "TSMC ramps up chip production as carmakers wrestle with shortages", *Reuters,* January 28, 2021, https://www.reuters.com/article/us-tsmc-autos-idUSKBN29X03F

[13] Eric Platt, "Warren Buffett's Berkshire Hathaway buys $4bn stake in chipmaker TSMC", *Financial Times,* November 15, 2022,

The second argument of why the semiconductor industry is "strategic" hinges on the fact that monopoly profits may be earned in high-tech sectors. The role of semiconductors as an important input to many other sectors makes the potential exercise of monopoly power an extremely important concern, since market power in such an input may be extended downstream into user industries, by acquisition or vertical integration, allowing even greater monopoly rents to be collected.[14] Thus, the argument that the semiconductor industry is "strategic" (e.g., characterized by externalities and monopoly rents) provided fertile ground for policymakers to formulate a policy of intervention in the industry during the 1980s.

What is less visibly compelling, however, is a case for government intervention in the semiconductor industry for non-economic reasons—for politico-military[15] reasons. This is not to say economic costs and benefits do not factor into the equation for this type of government intervention, but there are cases when they are not the overriding priority and merely reinforce the politico-military reason for intervention.

Politico-military rationale: security of defense industrial base (DIB)

As Sen (1984) suggests, the state and military impulse propel many governments to intervene in certain industries, either because of technological linkages and/or inter-industry supply-demand interdependence.[16] These "industrializing industries" thus are inputs for almost all other industries in the national economy, and are also of strategic significance for military self-sufficiency and relative economic self-sufficiency.[17] The importance of the semiconductor industry as a key input in the national industrial base is evidenced in a 1991 report published by U.S. Congress's Office of Technology Assessment.

https://www.ft.com/content/6d4bb1f4-270a-46bd-8069-81148b636647

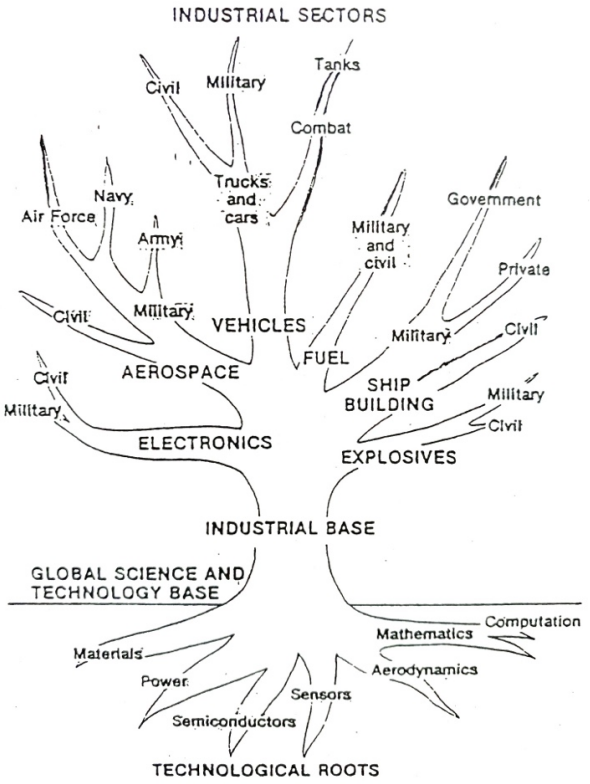
[14] Otherwise, the downstream user could normally substitute other inputs for the monopolized input as prices is raised and dissipate some of the monopolists' potential rent in inefficient production. John M. Vernon and Daniel A. Graham, "Profitability of Monopolization by Vertical Integration", *Journal of Political Economy, Vol. 79* (July-August 1971), pp. 924-23.

[15] I use the term "politico-military" as defined by Buzan and Sen (1990) to mean concerns "of direct military relevance" in the international political system. Barry Buzan and Gautam Sen, "The impact of military research and development priorities on the evolution of the civil economy in capitalist state" in *Review of International Studies* 16 (1990), p.325.

[16] Gautam Sen, *Military Origins.*

[17] These industries are generally viewed as the defense industrial base (DIB), with its implication for both the commercial and defense sectors. The importance of a viable semiconductor industry for military R&D priorities is highlighted in a cover letter from Norman Augustine, chairman of the Defense Science Board (DSB) Task Force on semiconductor dependency to Charles Fowler, chairman of the DSB. In the letter Augustine wrote, 'The Task Force concludes that procurement by the Department of Defense is a relatively insignificant factor to the semiconductor industry, but, in contrast, the existence of a healthy U.S. semiconductor industry is critical to the national defense." U.S. Department of Defense, "Report of the Defense Science Board Task Force", cited in Larry D. Browning and Judy C. Shetler, *Sematech: Saving the U.S. Semiconductor Industry* (Texas: Texas A&M University Press, 2000), p.26.

Figure 2: Technology Tree: Relationships among Defense Sectors and the Broader National Industrial Base



Source: U.S. Congress, Office of Technology Assessment (July 1991), p.40.

Looking at the figure, the position of the semiconductor industry at the very bottom of the technological roots in this tree underscores the importance of the industry in the perspective of the U.S. government. According to Pages (1996), who was Congressional staff member during the mid 1980s, this report reflected the perspectives among policymakers of supporting industries not just with military significance, but rather industries with importance on both commercial and military grounds.[18] The industries designated as "technological roots" were most frequently cited on various critical technology list in the U.S. government.[19]

The economic rationales, as presented in the strategic trade literature in the 1980s, and the politico-military rationales as presented in the strategic implications of the DIB, thus provided a mutually reinforcing impulse for government intervention in the semiconductor industry. To summarize, there are three overlapping reasons for the semiconductor industry's importance: (1) the economic welfare significance in terms of rents and externalities; (2) its importance for the economy as a vital intermediate input (a quasi-security rationale); and (3) its importance as a direct input for producing weapons.

[18] Erik R. Pages, *Responding to Defense Dependence: Policy Ideas and the American Defense Industrial Base* (Westport, Conn.: Praeger, 1996).
[19] U.S. Congress, Office of Technology Assessment (July, 1991), p.40.

During the 1980s, due to the integration of commercial and defense sectors and the globalization of an increasingly commercial defense industrial base, U.S. policymaker were impelled to intervene in the semiconductor industry to form SEMATECH due to growing defense dependence on foreign—especially Japanese—sources of supply.

2 | Creation of SEMATECH and U.S.-Japan chip war in 1980s

Several macroeconomic trends occurred in the 1980s that set the scene for the eventual adoption of strategic trade policy to intervene in the semiconductor industry. The Reagan Administration's macroeconomic policies, a combination of expansive fiscal policy with tight monetary policy, resulted in a highly overvalued dollar in overseas markets that created the largest trade deficits in U.S. history. As a result, foreign investors and products flooded the U.S. so that by the mid 1980s, a number of new pressure groups began pushing an industrial policy agenda that found a fertile intellectual climate in strategic trade theory.[20] As David Yoffie noted, "For the first time since David Ricardo published Principles of Comparative Advantage in 1817, the classical theory of international trade has been challenged by well-respected academic economists."[21]

At this time, the Japanese semiconductor industry emerged as a major force in world markets. [22] By the early 1980s, Japan had become a dominant market player, culminating in the "semiconductor winter" of 1984 and 1985. During this 14-months period, Japanese dumping[23] of 256K devices crippled the remnants of the U.S. dynamic random access memory (DRAM) chip industry, securing 90% of the world DRAM market for Japan.[24] Additionally, 1985 was the year of the "crossover", when Japan's share of global market in DRAM first surpassed that of the U.S.[25] The eroding U.S. semiconductor world market share, coupled with the trend of globalization of the U.S. DIB in the 1980s, promulgated policy debates centering on revitalizing the semiconductor industry. As defense technologies became more intertwined with the commercial industrial

[20] For background see I.M. Destler, *American Trade Politics: System Under Stress* (Washington, D.C.: Institute of International Economics, 1986), pp.177-96; Robert Z. Lawrence and Charles L. Schultz, eds., *An American Trade Strategy: Options for the 1990s* (Washington, D.C.: The Brookings Institution, 1990), esp. pp. 2-10.
[21] David B. Yoffie, American Trade Policy: An Obsolete Bargain," in John Chubb and Paul Peterson, eds., *Can the Government Govern?* (Washington, D.C.: The Brookings Institution, 1989), p.131.
[22] On the development of the Japanese semiconductor industry, see Borrus, *Competing for Control: America's Stake in* Microelectronics (Cambridge, Mass.: Ballinger, 1988), pp. 139-90
[23] Krugman (1990) defines dumping as "selling exports at less than the domestic price". Paul Krugman, *Rethinking International Trade* (Cambridge, Mass.: The MIT Press, 1990), p. 242. It may be a sign of predatory behavior designed to encourage other firms to exit the market, or of preemptive behavior designed to deter other firms from entering the market. Paul Milgrom, "Predatory Pricing", in J. Eatwell, M. Milgate, and P. Newmann, ed., *The New Palgrave: A Dictionary of Economics,* Vol. 3 (London: Macmillan, 1987), pp. 937-38.
[24] "More Japan firms accused: U.S. Contends 5 Companies Dumped Chips", *Los Angeles Times,* March 14, 2986, https://www.latimes.com/archives/la-xpm-1986-03-14-fi-20761-story.html; Christine Winter, "U.S. May Sue Japan Over Chip Dumping," *Chicago Tribune,* December 5, 1985, https://www.chicagotribune.com/news/ct-xpm-1985-12-05-8503240237-story.html; "Outbreak of the Japan-U.S. Semiconductor War", The original version of this article was first published, in Japanese, on the Semiconductor Industry News (Sangyo Times Co., Ltd.) from July 12, 2006 to January 9, 2008. https://www.shmj.or.jp/makimoto/en/pdf/makimoto_E_01_12.pdf
[25] By 1986, U.S. firms captured 40% of global revenue, Japan at 46%. D'Andrea Tyson, Who's Bashing Whom? Pp. 104f.

base, the globalization of the commercial sector and the growing weakness of U.S. industries in the 1980s brought the issue of defense dependence to the fore.

Defense dependence

Historically, defense dependence and security of supply line are important issues for the State's goal to ensure defense surplus capacity. States will aim to ensure the existence of an installed capacity in the group of strategic industries that contains sufficient surplus to satisfy potential wartimes levels of demand, and provide incentives to ensure the existence of this surplus. As such the ability for a state to quickly mobilize its DIB into weapons production is a strong deterrent against a military attack, which is weakened if the DIB is deemed to be eroding. This is evidenced in the 1987 Defense Science Board's (DSB) report on semiconductor dependency that quoted a comment made by Shintaro Ishihara, an ultranationalist member of the Japanese Diet who threatened to cut off semiconductors to the U.S. and sell them to the Soviet Union instead:

> "In short, without using new generation computer chips made in Japan, the U.S. Department of Defense cannot guarantee the precision of its nuclear weapons. If Japan told Washington it would no longer sell computer chips to the United States, the Pentagon would be totally helpless. Furthermore, the global military balance could be completely upset if Japan decided to sell its chips to the Soviet Union instead of the United States."[26]

The fear of Japan cutting off the semiconductor supply line to the U.S. was exacerbated by the "obituary" circulated by IBM throughout early 1986, highlighting dangerous weakness in the industry and advocating creation of a private consortium where firms would pool funds for joint R&D efforts.[27] Various firms, led by Charlie Sporck of National Semiconductor, had long entertained this option. Subsequently, the following year in 1987, SEMATECH, was created with a $200 million annual operating budget for five years to help revitalize U.S. domestic semiconductor manufacturing industry.

It was a marriage of strange bedfellows between the Defense Advanced Research Projects Agency (DARPA) and 14 semiconductor manufacturing companies,[28] and the DSB report was instrumental in its creation. The

[26] Shintaro Ishihara, *The Japan that can say no: Why Japan will be first among equals* (New York: Simon and Shuster, 1991), p.21; "A Japan that can Take Credit", *Newsweek,* July 14, 1991, https://www.newsweek.com/japan-can-take-credit-204840; Michael Lewis, "The samurai behind the bow: The Japan That Can Say No: Why Japan Will Be First Among Equals by Shintaro Ishihara", *Los Angeles Times,* January 20, 1991 https://www.latimes.com/archives/la-xpm-1991-01-20-bk-1028-story.html
[27] Browning and Shetler, *Sematech, p.14.*
[28] The 14 founding members were AT&T Microelectronics, Advanced Micro Devices, International Business Machines, Digital Equipment, Harris Semiconductor, Hewlett-Packard, Intel, LSI Logic, Micron Technology, Motorola, NCR, National Semiconductor, Rockwell International, and Texas Instruments. Douglas Irwin and Peter Klenow, "Sematech: Purpose and Performance", *Proceedings of the National Academy of Science (PNAS),* Vol. 93, No. 23, November 12, 1996, https://www.pnas.org/doi/10.1073/pnas.93.23.12739

report findings were alarming from a national security viewpoint as IBM's obituary had been from an industrial one, and the primary recommendation was for a collaborative effort under the auspice of a Semiconductor Manufacturing Technology Institute, sponsored and funded jointly by the government and industry. The DSB supported its recommendation with the observation that "a direct threat to the technological superiority deemed essential to U.S. defense system exists." [29] It further noted that, "U.S. defense will soon depend on foreign sources for state-of-the-art technology in semiconductors. The Task Force views this as an unacceptable situation."

According to James Lewis, former U.S. negotiator for the Wassenaar Arrangement from 1993-1996, the semiconductor manufacturing industry was kept intact because the U.S. does not want countries, for example, China, to build better quality chips and to manufacture chips to go into weaponry. Furthermore, he emphasized the importance of keeping a technological edge and added, "Do we want to find ourselves in a situation whereby we are completely dependent on foreign sources for our defense needs?" [30] The answer appears to be no, as we currently face the U.S.-China chip war, with Taiwan's TSMC caught in the middle.

3 | Creation of Chip 4 alliance and U.S.-China chip war in the 2020s

As stated earlier in the paper, the Covid-19 pandemic exposed vulnerabilities in the global supply chain especially from China, and now supply chain networks in the Indo-Pacific are selectively reconfiguring and diversifying. Due to various factor such as cost-related comparative advantages in southeast and south Asia, awareness of disruptions in the supply chain, concerns about weaponization of supply lines and sensitive technologies, countries are attempting to build supply resilience and diversify to new destinations.

There is also growing preference for less reliance on imports and expanding indigenous sources of supply in what James Lewis, Director of Strategic Technologies Program at Center for Strategic and International Studies (CSIS) coins "supply chain sovereignty."[31] The aim is to assert more sovereign control over globalized industrial and technology base, especially ones pertaining to military needs. Of particular concern have been semiconductors broadly and Taiwan Semiconductor Manufacturing Company (TSMC) specifically. Given its dominant position of producing 92% of world market share for advanced (10 nanometer or below) chips, and after the Covid-19 pandemic exposed vulnerabilities and shortages in the chip supply chain, TSMC suddenly found itself in the spotlight amid U.S.-China technology rivalry.[32] As such, U.S. and Taiwan are resorting to

[29] U.S. Department of Defense, *Report of the Defense Science Board Task Force on Defense Semiconductor Dependency (*Washington D.C., DoD, Office of the Under Secretary for Acquisition, 1987).
[30] Author interview with James Lewis, Director of Technology Policy, Center for Strategic and International Studies (CSIS) on February 15, 2002, at the CSIS, Washington, D.C.
[31] James Lewis, "Supply Chain Sovereignty and Globalization", *CSIS Commentary,* October 19, 2022, https://www.csis.org/analysis/supply-chain-sovereignty-and-globalization
[32] Katie Tarasov, "A first look at TSMC"s giant 5-nanometer chip fab being built in Phoenix", *CNBC,* October 16, 2021, https://www.cnbc.com/video/2021/10/16/secretive-giant-tsmcs-100-billion-plan-to-fix-the-chip-shortage.html

policies of "homeshoring" and "friendshoring" their chip supply chain.

Remapping the chip supply chain: homeshoring and friendshoring

In a March 2022 Center for New American Security (CNAS) report entitled *The Tangled Web We Wove—Rebalancing America's Supply Chains,* the authors discussed different options to diversify high-tech supply chains from China and other adversarial competitors. They listed four options of homeshoring, friendshoring, nearshoring, and regionalization.[33] Homeshoring is to bring production and manufacturing, especially high-end technologies, back to U.S. soil. Admittedly economic autarchy is not possible and some level of external dependency will remain, which may be mitigated by enhanced alliances and partnership with key countries in friendshoring. That is, ensure that "strategic supply chains are based in allied and highly trusted partner countries and have minimal to no reliance on inputs from potential adversarial countries."[34] The report listed allies that are candidates for such a technology alliance for semiconductors—Australia, Canada, the EU, India, Israel, Japan, South Korea, Taiwan and the United Kingdom could form such an alliance with the U.S. for a diversified supply chain.

A third option of nearshoring is related to friendshoring, where production and manufacturing is geographically closer to home in a nearby country, while the fourth concept of regionalization is to have production capacity to meet regional demand, such as in the Indo-Pacific which is supported by U.S. Indo-Pacific Economic Framework as well as Taiwan's New Southbound Policy. Already U.S. and Taiwan are resorting to homeshoring and friendshoring, with TSMC building a new fab in Phoenix, Arizona, as well as in Kaohsiung. Both Washington and Taipei are also forming a semiconductor alliance with Seoul and Tokyo to build the "Chip 4 alliance."

Chip 4 alliance

The U.S.-led Chip 4 alliance is to ensure a resilient semiconductor supply chain involving the four countries of Taiwan, South Korea, Japan and the U.S., and the American Institute in Taiwan (AIT) hosted its first virtual meeting on September 28, 2022.[35] Back in 2021 Washington had called for like-minded nations to coordinate semiconductor activities, but progress has been slow due to the fact that Taiwan is not a member of the Quadrilateral Security Dialogue (the "Quad" which includes Japan, India, Australia and Japan) nor the Indo-Pacific Economic Framework (IPEF).[36] Nor is it a NATO partner despite calls to include Taiwan in a "NATO-

[33] Megan Lamberth, Martijn Rasser, Ryan Johnson, and Henry Wu, *The Tangled Web We Wove—Rebalancing America's Supply Chains* (Washington D.C.: Center for New American Security, 2022), p.11.
[34] *Ibid.*
[35] Sarah Wu, "First US-led 'Chip 4' meeting held, featuring Taiwan", *Taipei Times,* October 1, 2022, https://www.taipeitimes.com/News/front/archives/2022/10/01/2003786225
[36] "Quad alliance joins hands to secure semiconductor, 5G tech supply chain", *Transported Asset Protection Association,*

plus" arrangement.[37] Following the passage of the CHIPS and Science Act of 2022 and the establishment of the Chip Program Office in the U.S. Department of Commerce, the Biden administration will coalesce the White House, Commerce Department, State Department and other government agencies to coordinate semiconductor policies among allies.[38]

The Chip 4 alliance looks promising given the four members cover all the major areas of the global semiconductor supply chain. The U.S. specializes in chip design and holds all Electronic Design Automation (EDA) tools licenses, and also has the most chip fabrication facilities in the world. Taiwan of course is the main player in semiconductor manufacturing, consisting of over 60% world market share and 92% for advanced semiconductors dominated by chip giants TSMC and UMC.[39] Moreover it is a hub for all Assembly, Testing, Marking, and Packaging (ATMP) processes. South Korea's chip behemoth Samsung has both design and manufacturing capacity, while Japan is a dominant supplier for critical manufacturing equipment and materials such as photoresists.[40] With this coalition in place, Taiwan is also consolidating Kaohsiung as a new hub for President Tsai's New Southbound Policy (NSP) of diversifying supply chain from China to the Indo-Pacific.[41]

4 | Kaohsiung S Corridor—remapping a new hub in the Indo-Pacific

On August 8, 2022, TSMC and Kaohsiung city government held a groundbreaking ceremony at Nanzih Technology Industrial Park, where its new plant will be built.[42] This is followed in September by visits from Taiwan President Tsai Ing-wen and former U.S. Secretary of State Mike Pompeo to promote Kaohsiung as a

September 28, 2021, https://tapa-apac.org/quad-alliance-joins-hands-to-secure-semiconductor-5g-tech-supply-chains/; "Quad leaders to call for securing chip supply chain", *Nikkei Asia,* September 18, 2021, https://asia.nikkei.com/Politics/International-relations/Indo-Pacific/Quad-leaders-to-call-for-securing-chip-supply-chain; Misha Lu, "US might build emergency chip stockpile, in Indo-Pacific, but Taiwan remains excluded", *Digitimes Asia,* September 8, 2022, https://www.digitimes.com/news/a20220908VL201/chip-shortage-chips+components-ipef.html; Reiko Miki, Satsuki Kaneko and Masaya Kato, "U.S.-led Indo-Pacific nations to consider emergency chip stockpile", *Nikkei Asia,* September 28, 2021, https://asia.nikkei.com/Politics/International-relations/Indo-Pacific/U.S.-led-Indo-Pacific-nations-to-consider-emergency-chip-stockpile

[37] Radio Taiwan International, "US proposes bill to include Taiwan in 'NATO plus' group", March 24, 2021, https://en.rti.org.tw/news/view/id/2005057

[38] The White House, "Biden-Harris Administration Announces CHIPS for America Leadership", September 20, 2022, https://www.whitehouse.gov/briefing-room/statements-releases/2022/09/20/biden-harris-administration-announces-chips-for-america-leadership/; U.S. Department of Commerce, "Commerce Department Launches CHIPS.gov for CHIPS Program Implementation", August 25, 2022, https://www.commerce.gov/news/press-releases/2022/08/commerce-department-launches-chipsgov-chips-program-implementation;

[39] Arjun Gargeyas, "The Chip 4 Alliance Might Work on Paper, but Problems will Persist", *The Diplomat,* August 25, 2022, https://thediplomat.com/2022/08/the-chip4-alliance-might-work-on-paper-but-problems-will-persist/

[40] *Ibid.*

[41] "Taiwan's New Southbound Policy—Deepening Taiwan's Regional Integration", *Center for Strategic and International Studies,* July 2019, https://southbound.csis.org; Ministry of Foreign Affaairs, ROC (Taiwan), "New Southbound Policy Portal", https://nspp.mofa.gov.tw/nsppe/

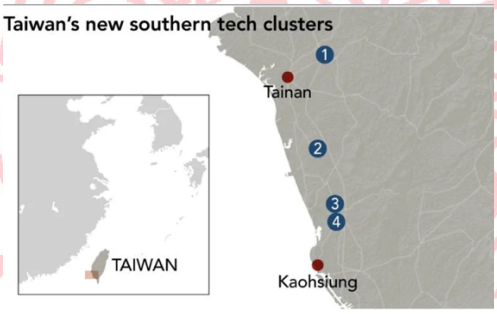
[42] Chen Cheng-hui, "Groundbreaking begins on Kaohsiung chip park", *Taipei Times*, August 8, 2022, https://www.taipeitimes.com/News/biz/archives/2022/08/08/2003783141; Eric Chang, "Taiwan's TSMC to start construction in new Kaohsiung fab later this year", *Taiwan News*, August 2, 2022, https://www.taiwannews.com.tw/en/news/4614083

new hub for high-tech business investments.[43] TSMC's Kaohsiung fab would produce 7 nanometer and 28 nanometer chips, the latter used mainly in the automotive industry which will be especially important for German auto manufacturers. The chip giant is planning to spend $100 billion in the next years to expand its production capacities within Taiwan, as well as abroad in the U.S and Japan.

New high-tech hub

Nanzih Technology Industrial Park will become the core zone of Taiwan's "Southern Semiconductor S Corridor", a policy priority envisioned by Kaohsiung Mayor Chen Chi-mai's administration of forming a new technology industrial cluster in Kaohsiung.[44] The project will connect Tainan Science Park, Renwu Industrial Park, Ciaotou Science and Technology Park, and Nanzih Technology Industrial Park in an S-shaped corridor. Besides TSMC, it has attracted other major technology companies such as Germany-based Merck Group, Netherlands-based NXP, Win Semiconductors Corp, and Nanzih Technology Industrial Park is already home to Advanced Semiconductor Engineering (ASE)—Taiwan's second largest semiconductor company.

Figure 3: Kaohsiung S Corridor: Taiwan's new southern tech clusters



	Location	Sectors	Major companies
1	Tainan Science Park	Chip manufacturing, equipment, displays, electronics components	TSMC, UMC, ASML, Applied Materials, Innolux, Delta Electronics
2	Lujhu District, Kaohsiung	Chip manufacturing, materials, equipment	Merck, Entegris, Winbond, PSA, Win Semiconductors, Innolux, Tongtai Machine & Tool
3	Ciaotou District, Kaohsiung	EV manufacturing, electronics components	Foxconn, Yageo, ASE, Phison Electronics
4	Nanzih District, Kaohsiung	Chip manufacturing and packaging, testing, electronics components	TSMC, ASE, NXP, Lite-On, Yageo

Source: *Nikkei Asia research* ©CGIAR-CSI

Source: *Nikkei Asia*, April 20, 2022.

[43] Office of the President, Republic of China (Taiwan), "President Tsai attends WTCC board of directors and supervisors meeting", September 28, 2022, https://english.president.gov.tw/NEWS/6335; Huang Liang-chieh, Ko Yu-hao and Kayleigh Madjar, "Pompeo in Kaohsiung for forum", *Taipei Times,* September 27, 2022, https://www.taipeitimes.com/News/taiwan/archives/2022/09/27/2003786003

[44] "Kaohsiung to become the world's highest-valued semiconductor industry cluster", *Businesswire*, June 9, 2022, https://www.businesswire.com/news/home/20220608006211/en/Kaohsiung-to-Become-the-Worlds-Highest-valued-Semiconductor-Industry-Cluster

With well-established high-technology clusters in Hsinchu and Tainan, Kaohsiung may seem an odd choice for TSMC given its historic reputation as a "rust belt city" and industrial zone.[45] However, various factors converged over the past year that promulgated Kaohsiung to the fore as TSMC's choice for domestic expansion.

TSMC already has Fab 18 in Tainan Science Park, and looked to a nearby 300-hectare plot for the next phase of its expansion process. According to a *Commonwealth Magazine* article, the Southern Taiwan Science Park scheduled expropriation of the land for expansion in 2023, but Kaohsiung's site offer came in earlier.[46] Kaohsiung is also a traditional stronghold for President Tsai's Democratic Progressive Party (DPP), as well as for the current Kaohsiung mayor Chen Chi-mai. However, the city's water supply may be the key reason for TSMC's selection. In 2021 Taiwan faced its worst drought in 56 years, sending TSMC and other chipmakers scrambling for water needed in their manufacturing process, including using tanker trucks to transport water from Kaohsiung.[47] This incident brought to the fore the real challenge of water scarcity facing the semiconductor industry, including TSMC and Intel fabs in Phoenix, Arizona, as chip companies continue to grapple with scarce supplies of land and water for expansion.[48]

As an emergency measure the government diverted some water from agriculture to industry, causing resentment among Taiwanese farmers towards the chipmakers.[49] Given the emerging challenge of food insecurity as highlighted by the conflict in Ukraine, this policy is not sustainable.[50] However, to redress this, Kaohsiung and Tainan are linking reservoirs and building an interconnected network of water supply to hedge against any potential water shortage in the future.[51] Efforts are also underway to build additional water reclamations centers, which already has a lauded history in Israel and Singapore, but just beginning to garner more attention in Taiwan.[52]

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[45] Hannah Chang, "Poor, polluted Kaohsiung's return to glory", *Commonwealth Magazine*, Vol. 731, September 17, 2021, https://english.cw.com.tw/article/article.action?id=3081
[46] Elaine Huang, Hannah Chang, "How TSMC may change Kaohsiung, Taiwan's 'Rust Belt City'?", Commonwealth Magazine, Vol. 731, September 9, 2021, https://english.cw.com.tw/article/article.action?id=3076
[47] Emanuela Barbiroglio, "No Water No Microchips: What Is Happening in Taiwan?", *Forbes*, May 31, 2021, https://www.forbes.com/sites/emanuelabarbiroglio/2021/05/31/no-water-no-microchips-what-is-happening-in-taiwan/?sh=1882b69622af; Yu Nakamura, "Taiwan drought at 'most critical' phase for chip sector", *Nikkei Asia*, April 28, 2021, https://asia.nikkei.com/Business/Tech/Semiconductors/Taiwan-drought-at-most-critical-phase-for-chip-sector.
[48] Justine Calma, "Water shortages loom over future semiconductor fabs in Arizona", *The Verge,* August 18, 2021, https://www.theverge.com/22628925/water-semiconductor-shortage-arizona-drought
[49] Raymond Zhong and Amy Chang Chien, "Drought in Taiwan pits Chip Makers Against Farmers", *New York Times*, April 13, 2021, https://www.nytimes.com/2021/04/08/technology/taiwan-drought-tsmc-semiconductors.html
[50] Arif Husain, "The Ukraine War is Deepening Global Food Insecurity—What Can Be Done?", United States Institute of Peace, May 16, 2022, https://www.usip.org/publications/2022/05/ukraine-war-deepening-global-food-insecurity-what-can-be-done
[51] Teng Kai-Yuan, "How Taiwan's expanding semiconductor industry deals with water shortages", *Commonwealth Magazine* Vol. 750, June 13, 2022, https://english.cw.com.tw/article/article.action?id=3236
[52] *Ibid.*

Key trade logistics hub

With the entry of TSMC in the S Corridor, Kaohsiung and southern Taiwan are emerging as a critical node not only in the global semiconductor supply chain, but also as a key logistics hub in support of President Tsai's NSP for further trade integration in the Indo-Pacific region. The City Government is actively supporting infrastructure projects of logistics parks, additional water reclamation centers, light rail stations, adding new MRT lines, and boosting arts and cultural centers to attract tourism.[53] Kaohsiung port also the largest port in Taiwan and ranks as the 15th largest port in the world, ahead of Germany's Hamburg at 17 and America's Long Beach at 22. As the S Corridor and related tertiary sectors of business and services expand, Kaohsiung is poised to become a key trade logistic hub in the Indo-Pacific.[54]

NATO cooperative security location (CSL)?

Taiwan defense analysts have also proposed that Kaohsiung Port could become a cooperative security location (CSL) now that the U.S. no longer has access to Hong Kong port.[55] This may work in conjunction with NATO's current exploration for cooperative security and Enhanced Opportunities Partner (EOP) roles for Asian partners such as Japan and South Korea, and possibly Singapore and Taiwan, given they are world leaders in multiple emerging and disruptive technologies (EDT) sectors.[56] Singapore, despite not being a NATO Asian partner, has already been involved in NATO Science and Technology Organization (STO) events. Likewise, Taiwan as a *de facto* major non-NATO ally (MNNA), could potentially engage in similar cooperative security exchanges especially in the field of maritime technologies.[57]

Some U.S. analysts propose a step further, such as former Secretary Pompeo's China advisor Miles Yu, who proposed enlarging the NATO alliance to include Indo-Pacific countries into a broader NAIPTO (North Atlantic Indo-Pacific Treaty Organization) in order to confront a rising China. However, others express doubts this would come to fruition at this juncture.[58] In an email interview, NATO Defense College Foundation

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[53] George Liao, "Light rail station construction in Taiwan's Kaohsiung to be completed ahead of schedule", *Taiwan News*, July 10, 2022, https://www.taiwannews.com.tw/en/news/4593195; "New Kaohsiung MRT line approved; construction to start later this year", *Focus Taiwan*, March 20, 2022, https://focustaiwan.tw/politics/202203200006; Joyce Kuo, "Kaohsiung—An Emerging Arts & Cultural Hub of Taiwan", *Taiwan Times*, November 8, 2020, https://thetaiwantimes.com/kaohsiung-an-emerging-arts-cultural-hub-of-taiwan/

[54] World Shipping Council, "The Top 50 Container Ports" https://www.worldshipping.org/top-50-ports

[55] Ou wei-chun, "Kaohsiung should host US Navy", *Taipei Times,* June 25, 2020, https://www.taipeitimes.com/News/editorials/archives/2020/06/25/2003738816

[56] Christina Lin, "NATO, Emerging Technologies, and Taiwan's Potential Cooperative Security Role in the Indo-Pacific", *Global Taiwan Brief,* Vol. 6, Issue 13, June 30, 2021, https://globaltaiwan.org/2021/06/nato-emerging-technologies-and-taiwans-potential-cooperative-security-role-in-the-indo-pacific/; Nusrat Ghani, "Enhancing NATO S&T Cooperation with Asian Partners", Preliminary Draft General Report 023 STC 21 E, Science and Technology Committee (STC), NATO Parliamentary Assembly, April 15, 2021, https://www.nato-pa.int/download-file?filename=/sites/default/files/2021-04/023%20STC%2021%20E%20-%20ST%20COOPERATION%20-%20GHANI%20-%20FINAL.pdf

[57] U.S. House of Representatives, 22 USC 2321k: Designation of major non-NATO allies, https://uscode.house.gov/view.xhtml?req=(title:22%20section:2321k%20edition:prelim)

[58] "Miles Yu On Taiwan: NAIPTO—Toward a Eurasian, transoceanic multilateral collective defense alliance", *Taipei Times,*

Director Alessandro Politi noted that, "China, unless it follows the path of Russia regarding Taiwan, will not be considered a threat" by many NATO members and surely not a priority as long as the Ukraine conflict is ongoing. He added, "NATO has a very precise geographic definition of its treaty and on this hinges Article 5, even in Kiev's case."[59]

As such, the more realistic scenario to enhance security of Transatlantic and Indo-Pacific supply chain for now may not be an expanded NAIPTO military alliance, which would denote decoupling from China, but rather targeted "high-tech alliance" proposed by former NATO Secretary General Anders Fogh Rasmussen.[60] NATO can engage Asian partners in cooperative security of EDT sectors, while continuing economic interdependence and selective diversification from China given it remains a top trading partner for Taiwan, Japan, and other Asian as well as European countries. Indeed even Taiwan's TSMC recently received an exemption from Washington's new semiconductor export control regulations, to continue expanding its Nanjing manufacturing facility in China.[61] As James Lewis from the Center for Strategic and International Studies (CSIS) observed, increasing diversification and supply chain sovereignty "does not mean the end of interdependence, but more emphasis on indigenous production and regional supply chains."[62] To that end, the role of Kaohsiung will likely continue to rise in the ongoing regionalization of the Indo-Pacific high-tech supply chain.

However, challenges remain, as TSMC's 2021 sustainability report warned of precarious power and water supplies in Taiwan that could potentially impact its production as well as battle for engineering talent that is gripping the chip industry.[63]

5 | Remaining Challenges—Water, Energy and Talent

Water

As discussed earlier in the paper, water scarcity is an ongoing challenge for chip production, but Kaohsiung could perhaps serve as a model for the semiconductor industry as they grapple with this issue. Finding space for new foundries will also be problematic as TSMC and other semiconductor companies continue to grow at

July 11, 2022, https://www.taipeitimes.com/News/editorials/archives/2022/07/11/2003781525

[59] Alessandro Politi, E-mail interview, October 12, 2022.

[60] Anders Fogh Rasmussen, "Building a democratic high-tech alliance", *Taipei Times*, April 1, 2021, https://www.taipeitimes.com/News/editorials/archives/2021/04/01/2003754872

[61] Cheng Ting-Fang, "TSMC gets 1-year U.S. license for China chip expansion", *Nikkei Asia*, October 13, 2022, https://asia.nikkei.com/Business/Tech/Semiconductors/TSMC-gets-1-year-U.S.-license-for-China-chip-expansion

[62] James Lewis, "Supply Chain Sovereignty and Globalization", Center for Strategic and International Studies Commentary, October 19, 2022, https://www.csis.org/analysis/supply-chain-sovereignty-and-globalization

[63] Cheng Ting-Fang and Lauly Li, "TSMC struggles to keep new hires, warns of power supply risks", *Nikkei Asia,* June 30, 2022, https://asia.nikkei.com/Business/Tech/Semiconductors/TSMC-struggles-to-keep-new-hires-warns-of-power-supply-risks; Taiwan Semiconductor Manufacturing Company, "TSMC 2021 Sustainability Report", June 30, 2022, https://esg.tsmc.com/en/update/general/news/13/index.html

a rapid pace and available agricultural or undeveloped land declines in Taiwan, as noted by Elaine Huang and Hannah Chang in *Commonwealth Magazine*.[64] As such, rather than pitting farmers against chipmakers whether over water rights or land, perhaps a new form of "urban renewal" of renovating old industrial parks into technology parks such as Kaohsiung's S Corridor, could be an innovative solution to meet these critical challenges.

Energy

Energy is another concern, and questions remain whether TSMC can meet its declared sustainability goal of having 40% green energy in its total energy mix by 2030.[65] This is pushed by its biggest client Apple, which in its 2019 sustainability report aim to be carbon neutral across its entire business and manufacturing supply chain by 2030.[66] As such the Taiwanese government has been promoting green energy such as wind and solar, but will this be sufficient for TSMC to meet its 40% goal in eight years? Moreover, what is the trade-off between semiconductor favoritism and other sectors in the face of scarce natural resources?

Writing in *The Diplomat* on November 9, 2022, some observers such as Frederik Kelter expressed concern that semiconductor favoritism actually has negative externalities on the agricultural sector and may result in increasing food insecurity for Taiwan.[67] For example, Taiwan Council of Agriculture (COA) in a 2020 report said the food sufficiency rate is only 35%, meaning Taiwan imports almost 70% of its food.[68] When coupled with the government diverting water from farmers whenever there is water scarcity, Kelter argued that this food insecurity will leave Taiwan vulnerable to possible blockade by China in order to weaken the country.[69]

Some farmlands are also being used for solar panels rather than food production in the push for green energy. Professor Yang Yung-kai, Direct or Asia-Pacific Industrial and Business Management at the National University of Kaohsiung, said that many landowners in rural area rent their land to build solar panels rather than to farmers because it is more lucrative.[70] Indeed Wei Jung-hua, a landowner in Guanmiao District in Tainan, said "The rent solar operators are paying me is at least 10 times higher than what I could get from

[64] Elaine Huang, Hannah Chang, "How TSMC may change Kaohsiung, Taiwan's 'rust belt city", *Commonwealth Magazine*, Vol. 731, September 9, 2021, https://english.cw.com.tw/article/article.action?id=3076
[65] Liang-rong Chen, "Can TSMC really hit its renewable energy goals?", *Commonwealth Magazine,* September 15, 2022, https://english.cw.com.tw/article/article.action?id=3296
[66] Apple, "Apple commits to be 100 percent carbon neutral for its supply chain and products by 2030", Press Release, July 21, 2020, https://www.apple.com/newsroom/2020/07/apple-commits-to-be-100-percent-carbon-neutral-for-its-supply-chain-and-products-by-2030/
[67] Frederik Kelter, "The Battle Over Semiconductors Is Endangering Taiwan", *The Diplomat,* November 9, 2022, https://foreignpolicy.com/2022/11/09/tsmc-taiwan-battle-semiconductors-water-resource-scarcity/
[68] Tsai Chia-Shen, *"Crops, Houses, or Panels? The Land-Use Conversions of Taiwan Farmland", Taiwan Insights,* February 10, 2022, https://taiwaninsight.org/2022/02/10/crops-houses-or-panels-the-land-use-conversions-of-taiwan-farmland/; "Review of Taiwan's Food Security Strategy", Food and Fertilizer Technology Center for the Asian and Pacific Region, September 10, 2020, *https://ap.fftc.org.tw/article/2570*
[69] Kelter, *Ibid.*
[70] Yang Yung-Kai, personal interview, October 5, 2022.

farmers."[71] Additionally, solar panels also have negative environmental impacts in its life cycle—specifically difficulty with disposal and recycling of panels which contain toxic materials of lead and cadmium.[72] As such, is the Taiwanese government considering the full environmental impact of all stages of the product cycle?

According to Professor Hsing-Lung Lien, Director of New Energy & Electricity Development Center (NEED) at the National University of Kaohsiung, Taiwan Environmental Protection Administration (EPA) does consider the whole picture and uses what is called a Life Cycle Assessment (LCA).[73] In support of circular economy policy goals, Taiwan EPA also asks producers to pay a one-time recycling fee of NT$1,000 per KW capacity to the government, so that at the end of the solar panel life cycle, that money will be used to properly recycle the panels, or at least some of the useful materials of the solar panels.[74]

Moreover, Professor Lien recommended that "Taiwan EPA should take the food, energy and water (FEW) nexus into consideration in order to better balance the needs between energy and environment" in its sustainable development assessments. The Food-Energy-Water (FEW) nexus is a tool for improving security of these resources via an interdisciplinary approach, highlighting their interdependence and potential synergies and tradeoff within the nexus.[75] As for the current state-of-play regarding solar panel recycling in Taiwan, Lien said that most solar panels in Taiwan are installed after the year 2010, so the 20-year mark of how to properly dispose and recycle solar panels is not yet a big issue.

Regarding whether TSMC needs alternative green energy sources not prone to weather conditions, Professor Lien believes that geothermal energy is probably the best of all four options--wind, solar, geothermal and biomass. Wind and solar are weather-dependent and not very reliable, and countries like Philippines for example already has 13-14% geothermal energy in its total energy mix because it is a stable source of supply. Taiwan is also looking into geothermal sources in the north by Taipei, but they are located in national parks under conservation and thus not possible to exploit these sources at this juncture. Lien added that Ministry of Economic Affairs (MOEA) believe geothermal energy is a good option, "but the location selection and the impact of stakeholder's concerns on the environment may be major challenges." However, if economic

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[71] Kwangyin Liu, Kuo-Chen Lu; Research: Sophie Lin, Sylvia Lee, Daniel Kao, "'Solar Power Fat Cats': Green Energy Reduced to Money-making Game", *Commonwealth Magazine,* January 8, 2021, https://english.cw.com.tw/article/article.action?id=2896

[72] Michael Shellenberger, "If Solar Panels Are So Clean, Why Do They Produce So Much Toxic Waste?", *Forbes,* May 23, 2018, https://www.forbes.com/sites/michaelshellenberger/2018/05/23/if-solar-panels-are-so-clean-why-do-they-produce-so-much-toxic-waste/?sh=2cc188e8121c; Rachel Kisela, "California went big on rooftop solar. Now that's a problem for landfills", *Los Angeles Times*, July 15, 2022, https://www.latimes.com/business/story/2022-07-14/california-rooftop-solar-pv-panels-recycling-danger; "Solar Panels Are Starting To Die, Leaving Behind Toxic Trash", *Wired*, August 22, 2020, https://www.wired.com/story/solar-panels-are-starting-to-die-leaving-behind-toxic-trash/

[73] Lien, Hsing-Lung, personal interview, November 2, 2022.

[74] Steven Crook, "Environmental Impact Assessment: From e-waste to asset: recycling solar panels", *Taipei Times,* April 27, 2022, https://www.taipeitimes.com/News/feat/archives/2022/04/27/2003777291; Lien, Hsing-Lung, personal interview, November 2, 2022.

[75] Kyle Proctor, Seyed M.H. Tabatabaie, Ganti S.Murthy, "Gateway to the perspectives of the Food-Energy-Water Nexus", *The Science of the Total Environment*, April 10, 2021, https://pubmed.ncbi.nlm.nih.gov/33092840/

cost for a particular environmental policy becomes too high, MOEA would likely put the economy first. [76]

Talent

Another challenge is talent shortage in the chip industry.[77] According to a Deloitte report, in 2021 the global semiconductor industry had revenues of over $550 billion, which is expected to rise by over 80% in 2030 to more than a trillion dollars.[78] In 2021 there was an estimated two million direct employees worldwide, and Deloitte predicts by 2030 more than one million additional skilled workers would be needed. This equates to an additional 100,000 workers annually, yet Taiwan is faced with talent shortage due to what the chip industry cites are lack of academic research funding, poor working conditions, and talent poaching from China.[79]

Regarding the latter, a 2019 *Nikkei Asia* article revealed that China has lured over 3,000 chip engineers from Taiwan, especially to support its "Made in China 2025" plan to foster self-sufficiency in high-tech industries.[80] Many observers have labeled China's aggressive recruitment of chip engineers as "talent poaching", and according to a 2020 Australian Strategic Policy Institute report entitled "Hunting the Phoenix—the Chinese Communist Party's Global Search for Technology and Talent," China has used talent recruitment stations to gain access to technology through covert and non-transparent means.[81] The report revealed that China has 600 stations around the world that identify and recruit scientists and technologists who would be valuable to China's quest for technological dominance, and in response Taiwan authorities are cracking down on Chinese firms suspected of illegal poaching of chip engineers.[82] Taiwan's government is also resorting to new national security legislation to help safeguard chip talent.[83]

As for the lack of academic research funding, to redress this issue, Kaohsiung City Government is cultivating

[76] Lien, Hsing-Lung, personal interview, November 2, 2022.
[77] Monica Chen, "Talent shortage facing Taiwan semiconductor industry, says TSMC chairman", *Digitimes Asia,* September 19, 2019, https://www.digitimes.com/news/a20190919PD200.html
[78] Karen Weisz, Teresa Lewis, Brandon Kulik, Duncan Stewart, "The global semiconductor talent shortage", *Deloitte Perspectives,* 2022, https://www2.deloitte.com/us/en/pages/technology/articles/global-semiconductor-talent-shortage.html
[79] *Ibid*; Kayleigh Madjar, "FEATURE: How semiconductor firms are tackling a talent shortage", *Taipei Times,* October 3, 2021, https://www.taipeitimes.com/News/taiwan/archives/2021/10/03/2003765445
[80] Kensaku Ihara, "Taiwan loses 3,000 chip engineers to 'Made in China 2025", *Nikkei Asia,* December 3, 2019, https://asia.nikkei.com/Business/China-tech/Taiwan-loses-3-000-chip-engineers-to-Made-in-China-2025
[81] Alex Joske, "Hunting the Phoenix: The Chinese Communist Party's global search for technology and talent", *Policy Brief Report 35,* Australian Strategic Policy Institute, August 20, 2020, https://www.aspi.org.au/report/hunting-phoenix; Christina Lin, "Luring the Phoenix: China's Strategy to Recruit Taiwan Semiconductor Talent", *Global Taiwan Brief,* Vol. 6, Issue 6, March 24, 2021, https://globaltaiwan.org/2021/03/luring-the-phoenix-chinas-strategy-to-recruit-taiwan-semiconductors-talent/
[82] Kate O'Keeffe and Aruna Viswanatha, "How China Targets Scientists via Global Network of Recruiting Stations", *Wall Street Journal,* August 20, 2020, https://www.wsj.com/articles/how-china-targets-scientists-via-global-network-of-recruiting-stations-11597915803; "Taiwan raids Chinese firms in latest crackdown on chip-engineer poaching", *Reuters,* May 26, 2022, https://www.reuters.com/technology/taiwan-raids-chinese-firms-latest-crackdown-chip-engineer-poaching-2022-05-26/
[83] "Taiwan, with eye on China, to boost protection for its semiconductor secrets", *Taiwan News,* February 17, 2022, https://www.taiwannews.com.tw/en/news/4446472; "Minister links national security to supply of chips", *Taipei Times,* October 3, 2022, https://www.taipeitimes.com/News/front/archives/2022/10/13/2003786930

local talent by collaborating with nearby universities and taking advantage of the 2021 Act for National Key Fields Industry-University Cooperation and Skilled Personnel Training (國家重點領域產學合作及人才培育創新條例), which allows universities to seek industrial partners to set up academies.[84] For example, National Sun Yat-sen University will establish the College of Semiconductor and Advanced Technology Research, and in 2021 the City Government joined forces with National Cheng Kung University to establish the Academy of Innovative Semiconductor and Sustainable Manufacturing.[85] In fact, this industry-academia cooperation model has a decade-old precedent when in September 2010, TSMC, National Cheng-Kung University, and National University of Kaohsiung in Nanzih signed an agreement to promote the Industry and Academic Corporation Program (IACP) in order to cultivate semiconductor technology experts.[86]

This collaborative model offers an effective real-time feedback process as witnessed by this author while attending a meeting with TSMC contractors and National University of Kaohsiung academics. In a November meeting at the University, TSMC contractors AECOM, ApolloTech, Cleanaway and Jetpro provided updates to professors from the Department of Civil and Environmental Engineering regarding ongoing remediation efforts of TSMC's new fab site in Nanzih, which sits on the former oil field of CPC Corporation.[87] They also discussed various other topics related to the progress of TSMC's new factory. Faced with limited academic funding, this industry-academia joint venture seems to be an effective way to augment knowledge/resource-sharing and problem-solving capabilities, and could be a good template for other countries facing similar constraints.

Conclusion

This paper puts forth a hypothesis that causes of international trade disputes in manufacturing hinge on the division of the international political system into competitive nation-states. Due to the underlying military rivalry of this system, the desire to maintain or acquire production capability in key military-related industries can easily insert a national security requirement into the management of the economy. This is especially evident in the semiconductor industry, which is a technological root supporting the broader national industrial

[84] "Kaohsiung to become the world's highest-valued semiconductor industry cluster", *Focus Taiwan,* June 9, 2022, https://focustaiwan.tw/ad/202206090935l4; Monica Chen, Jessie Shen, "Talent shortage facing Taiwan semiconductor industry, says TSMC chairman", *Digitimes,* September 19, 2019, https://www.digitimes.com/news/a20190919PD200.html; Wu po-hsuan, "Universities apply to set up academies", *Taipei Times*, January 10, 2022, https://www.taipeitimes.com/News/taiwan/archives/2022/01/10/2003771082

[85] Wu po-hsuan, *Ibid.* "The Academy of Innovative Semiconductor and Sustainable Manufacturing", National Cheng Kung University, https://highlights.ncku.edu.tw/innovation/ncku-established-the-academy-of-innovative-semiconductor-and-sustainable-manufacturing/

[86] "TSMC, National Cheng Kung University, and National University of Kaohsiung Collaborate to Launch Semiconductor Technology Talent Development Plan", https://pr.tsmc.com/english/news/1636; "TSMC, NCKU and NUK Signed Cooperation Agreement to Promote Industry and Academic Corporation Program", *Business Wire,* September 14, 2010, https://www.edacafe.com/nbc/articles/1/863843/TSMC-NCKU-NUK-Signed-Cooperation-Agreement-Promote-Industry-Academia-Corporation-Program; https://highlights.ncku.edu.tw/innovation/ncku-established-the-academy-of-innovative-semiconductor-and-sustainable- manufacturing/

[87] Roundtable discussion at the Department of Civil & Environmental Engineering, National University of Kaohsiung, November 2, 2022.

base and defense sectors as discussed in section one. This is underscored by policymakers' statements, such as U.S. National Security Advisor Jake Sullivan who in September 2022 emphasized the technological root and "foundational nature of certain technologies, such as advanced logic and memory chips", and argued the U.S. "must maintain as large of a lead as possible."[88] Back in July 2022, U.S. Commerce Secretary Gina Raimondo also highlighted Washington's impulse to intervene in the semiconductor industry is even more pressing given "We purchase 90% of the most sophisticated chips that are used in the military from Taiwan."[89] She warned that "if, God forbid, China were to—in any way—disrupt our ability to buy these chips from Taiwan, it would really be an absolute crisis in our ability to protect ourselves."[90]

As such with TSMC's near monopoly on global production of advanced chips and as a critical supplier for the U.S. defense industry, Taiwan found itself in the spotlight amid U.S.-China technology rivalry. Coupled with supply chain vulnerabilities highlighted by the Covid-19 pandemic, the global semiconductor ecosystem is currently undergoing a reconfiguration. And as firms and industry recalibrate business models, develop new shared standards, and forge new partnerships up and down the supply chain, Taiwan's Kaohsiung is emerging as a new hub in the Indo-Pacific.

However, as the U.S. intervenes in the semiconductor industry with new subsidies, friendshoring via international consortiums, and export controls aimed at restricting China's access to high-end chip devices with potential military applications, there is risk of *decoupling*, rather than *diversifying*, from China. China remains the largest trading partner for Taiwan and other allies such as Japan and South Korea, thus they are cautious about the potential harm to their economic growth if they sever too much trading relations with this market. As Taiwan's Deputy Economic Affairs Minister Chen Chern-chyi observed, in the face of China being Taiwan's top trading partner, "I don't see [how] we can completely decouple from China. That's not realistic. So we will continue to see our companies working with their Chinese counterparts, or in business that the government is pleased to see [flowing]."[91] Rather, Chen emphasized collaboration with partners to build a resilient supply chain for selective diversification in certain industries, while continuing to maintain overall economic relations with China.

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[88] "Remarks by National Security Advisor Jake Sullivan at the Special Competitive Studies Project Global Emerging Technologies Summit", White House Briefing Room, September 16, 2022, https://www.whitehouse.gov/briefing-room/speeches-remarks/2022/09/16/remarks-by-national-security-advisor-jake-sullivan-at-the-special-competitive-studies-project-global-emerging-technologies-summit/

[89] "Commerce Secretary Raimondo on why we need to produce chips in the U.S.", *The Marketplace,* July 27, 2022, https://www.marketplace.org/shows/marketplace-tech/commerce-secretary-raimondo-on-why-we-need-to-produce-chips-in-the-u-s/

[90] *Ibid.* Security of military supply lines gets to the heart of logistics in warfare. Israeli military historian Martin Van Creveld explored the oft-overlooked dimension of logistics in military campaigns, and argued for emphasis on logistics rather than more traditional tactics and strategy in military planning. For further information see Martin Van Creveld, "Supplying War: Logistics from Wallenstein to Patton" (Cambridge University Press, 1977). https://www.hgwdavie.com/blog/2017/5/3/supplying-war-logistics-from-wallenstein-to-patton-40th-anniversary

[91] Thompson Chau, "Taiwan vows to safeguard interests amid U.S.-led 'Chip 4' talks", *Nikkei Asia,* October 5, 2022, https://asia.nikkei.com/Business/Tech/Semiconductors/Taiwan-vows-to-safeguard-interests-amid-U.S.-led-Chip-4-talks

Major Jessica Taylor, a logistics readiness officer in the U.S. Air Force Reserve and Jonathan Corrado, Director of Policy at the Korea Society, echoed this view. Writing in *The National Interest* in October 2022, they argue that the best course of action to strengthen and secure the supply chain is "a coordinated approach with allies and partners that avoids completely excluding China, so long as it refrains from destabilizing behaviors such as invading Taiwan."[92] Due to the globalized nature of the semiconductor supply chain, they argued that decoupling would be expensive and potentially alienate some U.S. partners, as well as inhibit the innovative capacity of U.S. companies. Hence at this juncture, the Chip 4 alliance and friendshoring seem to be a prudent way forward to build resilience in reconfiguring the semiconductor supply chain so it is not so concentrated.

Nonetheless, the U.S. Department of Commerce's new export restrictions are aggressively decoupling semiconductor trading relations with Beijing, including blocking expert assistance by U.S. nationals, tightening licensing requirements, scrutinizing investments, and exercising a presumption of denial for chip export licenses destined for China.[93] Even TSMC and South Korea's Samsung and SK Hynix view the one-year license extension granted by the Commerce Department as a "warning" rather than an "olive branch."[94] As such, it remains to be seen how policymakers in Taiwan, U.S. and allied countries continue to balance the trade-off between maintaining national defense and innovation in an increasingly globalized defense industrial base.

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[92] Jessica Taylor, Jonathan Corrado, "America Needs an Asian Chip Alliance, Not Decoupling", *The National Interest,* October 6, 2022, https://nationalinterest.org/blog/techland-when-great-power-competition-meets-digital-world/america-needs-asian-chip-alliance-not

[93] Sujai Shikakumar, Charles Wessner, and Thomas Howell, "A Seismic Shift: The New U.S. Semiconductor Export Controls and the Implications for U.S. Firms, Allies, and the Innovation Ecosystem", CSIS Report, November 2, 2022, https://www.csis.org/analysis/seismic-shift

[94] *Ibid,* p.4; Kim Jaewon and Cheng Ting-Fang, "Samsung and SK Hynix face China dilemma from U.S. export controls", *Nikkei Asia,* October 25, 2022, https://asia.nikkei.com/Business/Tech/Semiconductors/Samsung-and-SK-Hynix-face-China-dilemma-from-U.S.-export-controls