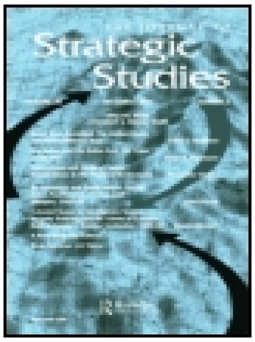

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China's defence semiconductor industrial base in an age of globalisation: Cross-strait dynamics and regional security implications

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ABSTRACT
The globalisation of semiconductor production has helped China improve its defence microelectronics capability. By analysing primary and secondary data, this paper examines semiconductor globalisation across the Taiwan Strait and shows the flow of resources from Taiwan to its Chinese counterparts linked to the People's Liberation Army (PLA). This flow of resources has improved the PLA's capabilities, including for Trojan Horse attacks, and affected security dynamics in the Sino-US-Taiwan relationship. This paper sheds fresh light on an understudied aspect of PLA modernisation and contributes to the study of the globalisation-security nexus and pertinent policy debates.

KEYWORDS Semiconductor; globalisation; PLA's modernisation; Taiwan; civil-military integration; regional security

Introduction

The semiconductor industry has recently become a central theatre of US-Chinese rivalry. Washington has exploited China's dependence on foreign supplies of semiconductor technology and stiffened export controls, affecting Chinese military end-users of technology and inhibiting PLA modernisation. This policy is based on the dual-use[1] nature of semiconductors and the premise that information technology (IT) and the Internet of Things, of which semiconductors are building blocks, help define power in international relations.

The importance of semiconductors to China's national security is evident in China's endeavours to indigenise the sector so as to foster economic

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[1]A technology is dual-use when used by the military and the civilian sectors. See Theodore H. Moran, 'The Globalization of America's Defense Industries: Managing the Threat of Foreign Dependence', *International Security* 15/1 (1990), 57–99; Lewis M. Branscomb, John A. Alic, Harvey Brooks, Ashton Carter, and Gerald Epstein, *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston, MA: Harvard Business School Press 1992).

competitiveness, pursue technological innovation, further modernise the military and mitigate vulnerabilities associated with foreign dependence.[2]

China's emphasis on the relationship between security and microelectronics is predicated on four arguments: 1) A strong chip industry will help modernise the PLA and enhance its ability to conduct conventional warfare; 2) The PLA can wage information warfare (IW) by exploiting home-grown advanced semiconductor technologies that enhance its ability to wage unconventional warfare; 3) As regards defensive IW, a strong indigenous industry can mitigate the risks of dependence on unreliable foreign supplies of critical semiconductors[3]; and 4) China recognises semiconductors' dual-use nature and the trend of spin-on[4] in its policy of using commercial off-the-shelf (COTS)[5] items in military systems to integrate its rising commercial chip industrial base into its military counterpart.[6]

However, China has struggled to develop a solid microelectronics industrial base comprising both its defence and commercial subsectors. Despite improvements since the 2000s, China trails world leaders in semiconductor capability. Nevertheless, sectoral globalisation – including globalisation across the Taiwan Strait – and the trend of spin-on have helped boost China's semiconductor might.

This topic remains under-explored, hence this paper seeks to fill a gap in the literature by considering how cross-strait semiconductor globalisation has affected Chinese defence microelectronics capability and influenced regional security. Based on a triangulation of primary and secondary data, this paper contributes to debates on the connection between globalisation and security,[7]

[2]Ming-chin Monique Chu, *The East Asian Computer Chip War* (London: Routledge 2013), 112–21.

[3]The Electronics and Information Base Department of General Armaments Department, People's Liberation Army, *Junyong Dianzi Yuanqijian* [Military Electronics Parts and Components] (Beijing: Defence Industry Publishing House 2009), 4.

[4]Spin-on refers to a technology development trajectory in which technology diffuses from the civilian to the defence sector. See Richard J. Samuels, *Rich Nation, Strong Army: National Security and the Technological Transformation of Japan* (Ithaca, NY: Cornell University Press 1994), 18& 26; Glenn R., Fong, 'Breaking New Ground or Breaking the Rules: Strategic Reorientation in U.S. Industrial Policy', *International Security* 25/2 (2000), 162–4.

[5]The 1994 Perry COTS Initiative resulted in greater use of commercial chips, practices, and standards in the US military systems. Other countries have followed suit.

[6]Editing Committee on Studies of Jiang Zemin's Thoughts on Defense Technology Industry Construction, *Jian zemin guofang keji gongye jianshe sixiang yanjiu* [Studies of Jiang Zemin's Thoughts on Defence Technology Industry Construction] (Beijing: Publishing House of Electronics Industry 2005), 94–5; Shaozhong Zhang, 'Xinxihua Wuqi Zhuangbei Yu Xinjunshi Biange' [Informationalisation of Weaponry and Equipment and Revolution in Military Affairs], in Chinese Academy of Sciences (ed.) *2004 Gaokeji Fazhan Baogao* [2004 High Technology Development Report] (Beijing: Science Publishing 2004), 312; Shi-liu Xu, 'Junyong Weidianzi Jishu Fazhan Zhanlue' [Random Thoughts on the Development Strategy for Military Microelectronics Technology], *Weidianzixue* [Microelectronics] 34/1 (2004), 1–6.

[7]Stephen G. Brooks, *Producing Security: Multinational Corporations, Globalization, and the Changing Calculus of Conflict* (Princeton, NJ: Princeton University Press 2005); Jonathan D. Caverley, 'United States Hegemony and the New Economics of Defense', *Security Studies* 16/4 (2007), 598–614; Michael C. Horowitz, 'Information-Age Economics and the Future of the East Asian Security Environment', in Avery Goldstein and Edward D. Mansfield (eds.) *The Nexus of Economics, Security, And International Relations in East Asia* (Stanford, CA: Stanford University Press 2012), 211–35.

contending that Taiwan has helped China upgrade its defence microelectronics capability with regard to Sino-US-Taiwan security relations.

The primary data includes more than 165 interviews with officials and industry insiders from 68 firms conducted between 2004 and 2005 and in 2009 and 2022, although only a small portion of this data is cited here. Particularly significant interviewees include Pentagon officials responsible for defence technology export controls, senior executives from world-leading semiconductor firms (including seven of the top eight chip-makers in China and Taiwan) and defence industry players with first-hand experience of defence microelectronics. The most relevant interviewees were identified through non-random sampling. Despite the topic's sensitivity, entry obstacles were surmounted through a snowballing strategy, as most of the interview targets belonged to a relatively organised professional referral network, especially those in the global chip industry. This is a network established through partnerships at the inter-agency or inter-individual levels in the global supply chain. Interview findings are supplemented with up-to-date Chinese- and English-language materials, much of it untapped by existing academic studies and helping to substantiate the major arguments.

To provide an institutional context for analysis, section two examines the evolution of the Chinese defence industrial base and the move towards civil-military integration (CMI). Section three examines globalisation across the Taiwan Strait and its impact on China's defence microelectronics capability. Section four explores the security implications of globalisation, and section five discusses policy implications.

Chinese defence semiconductor industrial base and CMI reform

Since 2001, the Chinese defence microelectronics industrial base has gone from an autarkic system to a system embracing CMI reform, with domestic supplies for military semiconductors being complemented by foreign counterparts constrained by export controls.

In the 1950s, China established an autarkic semiconductor production system to support military and aerospace objectives. Between 1964 and 1971, the system comprised state-owned research institutes, academies, factories and university labs.[8] Despite subsequent restructuring and downsizing, this industrial base continued to rely on indigenous fabrication plants, or 'fabs', with design and manufacturing facilities independent of outsider control, for internal chip supplies for the PLA.[9] System producers, such as defence electronics conglomerate China Electronics Technology Group Co.,

[8]Barry Naughton, 'The Third Front: Defence Industrialization in the Chinese Interior', *The China Quarterly* 115 (1988), 351–86.

[9]Interview with the chairman of a leading Chinese IC design house, who led the Very Large Scale Integration (VLSI) design project under the National 863 Program, 2 June 2005, Taipei, Taiwan.

Ltd. (CETC), supplied semiconductors to the military for end use in missiles, drones, radars, satellites and communication systems amid constraints common to the ossified state industrial system.[10]

According to the 5th Research Institute of the Ministry of Mechanical and Electronics Industry, 22 major Chinese military systems benefited from 530 million indigenously produced electronic parts between 1986 and 1990.[11] In 1991, the annual progress award in military science and technology was awarded to eight institutes for their semiconductor efforts.[12] Some of these parts continued to operate into the 2000s, appearing in the 2002 version of the Qualified Parts List (QPL), which identifies the types of military electronic components produced for the PLA by qualified manufacturing lines.

From 1991 to 1995, a *neibu* publication revealed how military semiconductors developed by state-run entities had become building blocks in the PLA's information-based systems.[13] Technologically, however, the central processing units (CPUs), digital signal processors (DSPs) and radiation-hardened ('rad-hard')[14] integrated circuits (ICs) of these institutions lagged a few generations behind their Western counterparts.

In 2002, another *neibu* publication[15] identified qualified Chinese manufacturers producing military semiconductors between 1992 and 2002, including 1,195 types of military electronic parts in 182 manufacturing lines. Twenty-four qualified chipmakers supplied 226 types of QPL semiconductors to the PLA. Additionally, the third version of the Qualified Manufacturers List (QML) identified six certified manufacturers that were running eight production lines for the PLA.

In 2007, the No. 214 Research Institute detailed its role as a QML and QPL producer. Five of its ICs had satisfied military standards, passing stringent tests and becoming part of a newly designed long-range precision strike weapon deployed by the Ground Forces.[16]

[10]Major problems include the lack of economy of scale in the production of military semiconductors, technological weakness, and the insufficient investment in the industrial infrastructure.

[11]Ye, Yuqing, 'Quanyu Junyong Dianzi Yuanqijian Kekaoxing Gongzuo De Yujian' [Opinions on the Task to Ensure the Reliability of Electronic Parts and Components for Military End Uses], *Dianzi Chanpin Kekaoxing Yu Huanjing Shiyan* [Electronic Product Reliability and Environmental Testing] 1 (1992), 7.

[12]China Machinery and Electronics Industry Yearbook Editing Committee (ed.), *Zhongguo Jixie Dianzi Gongye Nianjian 1992* [China Machinery and Electronics Industry Yearbook 1992] (Beijing: Electronics Industry Publishing House 1992), IV-14-IV-15.

[13]Keyun Hua (ed.), *Zhongguo Junyun Dianzi Yuanqijian* [Electronic Components and Devices for the Chinese Military End Use] (Beijing: Publishing House of Electronics Industry 1996).

[14]Through 'shielding', radiation hardening, also known as rad-hard, protects systems from radiation which degrades the reliability and performance of conventional electronics.

[15]Yu, Zhenxing (ed.), *Junyong Yuanqijian Shiyong Zhiliang Baozheng Zhinan* [Quality Assurance Guide on the Usage of Military Components] (Beijing: Aviation Industry Press 2002).

[16]No. 214 Research Institute of China North Industries Group Corporation, *Wo Suo BP1001 Deng Wuzhong Jicheng Dianlu Shunli Tongguo Sheji Dingxing* [Five Types of ICs Including BP1001 by the Institute Smoothly Completed Design Finalisation Tests], Dec. 2007, http://www.cngc.com.cn/MemberDetail.aspx?id=120&gt.

As of 2009, the Chinese defence industrial base was using 0.25-micron to 0.5-micron process technology to manufacture six-inch wafers for military ICs, narrowing the gap between China and advanced semiconductor countries in rad-hard processors and DSPs.[17] By 2021, the industrial complex had made further inroads into various ICs for military end use, including CPUs, field-programmable gate arrays (FPGAs) and infrared thermal imaging chips.[18]

China's security was enhanced in two ways. Firstly, home-grown chips were miniaturised and functioned better than their immediate predecessors, reducing the weight and size of PLA systems and improving the reliability and performance of these gadgets.

Secondly, these components replaced specific imports, thus mitigating security risks. For instance, China designed and fabricated DSPs for PLA end use lest use of foreign-made components in its military systems undermine its security. In 1995, China made its first home-grown DSP. In 2005, an insider substantiated this indigenous fabrication; the PLA did not purchase comparable DSPs from Texas Instruments out of fear of tampering via backdoor devices that would render the PLA systems ineffective.[19] More importantly, Beijing continued facilitating import substitution in the area of military ICs to safeguard its security in view of the US and its allies imposing export controls on the import of these ICs.[20] For instance, after the 2015 US ban on exporting Intel Xeon Phi Processors, which had powered what were then some of China's fastest supercomputers, used to model advanced weapons, Beijing replaced them with domestic alternatives, including *Sunway Taihu Light*, released in 2016 by the Jiangnan Institute of Computing Technology owned by the 56th Research Institute of the PLA.

Despite the West's stringent, albeit flawed, export controls, China's internal sourcing of military semiconductors continued to be complemented by foreign-sourced supplies, according to a military journal published by the PLA's then General Armaments Department (GAD).[21] According to a 2018 market report, China had spent RMB 30 billion annually on military ICs in the international market.[22] By 2020, imported military ICs accounted for about 2% of China's total military expenditure.[23]

[17]The Electronics and Information Base Department of General Armaments Department, *Junyong Dianzi Yuanqijian*, 1.

[18]Lujing Li, Mingyang Liu and Minglei Zhang, 'Guofang Jungong' [National Defence Industrial Base], TF Securities Research Report, 28 May 2021, https://dfscdn.dfcfw.com/download/A2_cms_f_20210615113336163561&direct=1&abc565.pdf&gt.

[19]Interview, 29 June 2005, Hsinchu, Taiwan.

[20]Tianyi Wang, 'Guofang Jungong Hangye' [National Defence Industrial Sector], Orient Securities Research Report, 19 April 2018. http://pdf.dfcfw.com/pdf/H3_AP201804201126832128_1.PDF#page27&gt.

[21]Yaxian Wang, 'Tan Dianzi Yuanqijian De Zhiliang Kengzhi' [On Quality Control of Electronic Components], *Junyong biaozhunhua* [Military Standardisation] 4 (1998), 38–9.

[22]Wang, 'Guofang Jungong Hangye', 34.

[23]Weiduo Shen and Xuanzun Liu, 'China's Military Manufacturing Unlikely Impacted by Semiconductor Ban: Insiders', *Global Times*, 24 Feb. 2020, https://www.globaltimes.cn/page/202002/1180619.shtml&gt.

As the Cold War ended and the West loosened export controls, China found it easier to purchase advanced military semiconductors.[24] However, intensification of export control measures since the Trump administration (e.g., the Export Control Reform Act of 2018)[25] and the 2019 revision of the Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies[26] limit Beijing's ability to obtain such military ICs externally.

Crucially, since 2001, China has used CMI reform to open up its enclosed defence production system to non-state-owned enterprises, with mixed security implications. The CMI strategy permits certified civilian firms to participate in weapons production, and the introduction of additional institutional changes since 2017 has further emphasised the importance of CMI to modernising the PLA.[27]

China has adopted a twofold modernisation of its defence industry, consisting, firstly, of re-engineering the industry by removing bureaucratic barriers and nurturing an entrepreneurial institutional culture and, secondly, of integrating the industry into the broader civilian economy to establish a dual-use industrial base serving both civilian and military needs. The tenth Five-Year Plan, promulgated in 2001, stressed the second pillar, pertaining to CMI. It introduced a new set of principles addressing China's economic and military modernisation,[28] replacing those introduced by Deng Xiaoping in 1982 for defence reform. In particular, the notion of *Yujun Yumin* (Locating Military Potential in Civilian Capabilities) encouraged spin-on to integrate the defence industry into the broader civilian economy for the benefit of modernising the PLA.[29]

Subsequent party congresses and defence white papers endorsed the notion of *Yujun Yumin*. The Party Congress of 2003 passed a policy document supporting the construction of a new dual-use industrial base,[30] and the 2004

[24]Jiajun Guo and Lihua Guo, 'Jinkou Junyong Yuanqijian De Zhiliang Huafen Biaozhun Yu Jiankong Yaodian' [Quality Differentiation Standards and Supervisory Controls of Imported Military Parts and Components], *Junyong Biaozhunhua* [Military Standardisation] 6 (1996), 29–31.

[25]C. P., Bown, 'Export Controls: America's Other National Security Threat', *Duke Journal of Comparative & International Law* 30/2 (2020), 283–308.

[26]The Wassenaar Arrangement, 'Statement issued by the plenary chair on 2019 outcomes of The Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies', 5 Dec. 2019, https://www.wassenaar.org/app/uploads/2019/12/WA-DOC-19-PUB-001-Statement-issued-by-the-Plenary-Chair-on-2019-Outcomes.pdf&gt.

[27]Department of Defense, *Military and Security Developments involving the People's Republic of China 2020* (Washington: Department of Defense 2020), 21-22. https://media.defense.gov/2020/Sep/01/2002488689/-1/-1/1/2020-DOD-CHINA-MILITARY-POWER-REPORT-FINAL.PDF.

[28]Xinhuanet, *Zhonghua Renmin Gongheguo Guomin Jingji He Shehui Fazhan Dishige Wunian Jihua Gangyao* [Outline of the 10th People's Republic of China Economic and Social Development Five Year Plan], Oct. 2001.

[29]Tai Ming Cheung, *Fortifying China: The Struggle to Build a Modern Defense Economy* (Ithaca, NY: Cornell University Press 2009).

[30]Xinhuanet, *Zhonggong Zhongyang Guanyu Wanshan Shehuizhuyi Shichang Jingji Tizhi Ruogan Wenti De Jueding* [Decision of the Chinese Communist Party Committee on Several Issues in Perfecting the Socialist Market Economy], Oct. 2003; Xiang Xue and Ting Chen, 'Tuozhan "Minpin Junyong" De Guofang Jianshe Xin Luzi' [Expanding the New Road of the 'Military Use of Civilian Products' in Defence Construction], *Guofang Keji Gongye* [Defence Science & Technology Industry] 5 (2004), 24.

Chinese Defense White Paper[31] included spin-on-related provisions for PLA armaments procurement to support state-owned and private high-tech firms entering the military products market.[32]

Moreover, the Commission for Science, Technology and Industry for National Defense (COSTIND), as it was then known, encouraged private firms to undertake defence production activities. Some private firms, however, pushed for government incentives before engaging in defence production operations.[33] Others urged the authorities to reform the military standardisation system by adopting mature commercial standards and thus eliminating obstacles to civilian enterprises' involvement in military undertakings.[34] Still others sought the finalisation of regulations to infuse defence production with civilian resources.[35] The lack of such regulations had prevented Jiangsu Changdian Advanced Packaging Technology Co. Ltd., China's leading semiconductor packaging and testing firm, from engaging in military undertakings.[36]

As stated by an official in 2005, Beijing intended to issue new licences for weapons development and production,[37] and a key defence industry segment to which civilian firms were expected to contribute was semiconductors. A Beijing-based IC design house led by five Chinese PhD returnees from the US was tipped as Beijing's intended partner. As it had designed cutting-edge ICs for PLA end use, including fighter aircraft and missiles, it seemed likely to be among the first private recipients of related licences. In 2007, Beijing specified procedures for private companies to become certified weapons producers.[38] These included applying for a quality assurance certificate,

[31]The State Council Information Office, *2004 Nian Zhongguo De Guofang* [White Paper on China's National Defence in 2004] (Beijing: The State Council Information Office 2004).

[32]Evan S. Medeiros, Roger Cliff, Keith Crane and James C. Mulvenon, *A New Direction for China's Defense Industry* (Santa Monica, CA: RAND 2005), 38–9.

[33]Xiang and Chen, 'Tuozhan "Minpin Junyong" De Guofang Jianshe Xin Luzi', 22–4.

[34]Zonglin Yu, 'Minyong Qiye Canyu Guofang Jianshe Shi Jianli Yujun Yumin Chuangxin Jizhi De Zhongyao Neirong' [The Participation of Civilian Enterprises in National Defence Construction as the Main Pillar Supporting the Establishment of an Innovation Mechanism Through Locating Military Potential in Civilian Capabilities], *Zhongguo Junzhuanmin* [Defence Industry Conversion in China] 4/2004, 10; Weiping Ye, 'Kaifa Junmin Liangyong Jishu' [The Development of Military-Civilian Dual-Use Technologies], *Guofang Keji Gongye* [Defence Science & Technology Industry] 10/2003, 36.

[35]Pingfan Qian, '"Mincanjun" Shi Tisheng Woguo Guofang Keji Gongye Guoji Jingzhengli De Zhongyao Tujing' ['Civilian Participation in Military Production' as the Major Pathway to Enhance the International Competitiveness of Our National Defence Technology Industry], *Zhongguo Junzhuanmin* [Defence Industry Conversion in China] 2/2005, 38; Yuguang Wu, 'Minyong Gaoxin Jishu Zhuan Junyong Wenti Pouxi' [An Analysis of Issues Pertaining to the Military Use of Civilian High Technologies], *Keji Chengguo Zongheng* [Perspectives of Scientific and Technological Achievement] 6/2004, 24–6.

[36]Wu, 'Minyong Gaoxin Jishu Zhuan Junyong Wenti Pouxi'.

[37]*Keji Ribao* [Science and Technology Daily], 'Minqi yi Gaoxin Jishu Qieru Jungong Lingyu Qianjing Kanhao' [Good Prospect for High-Tech Private Enterprises to Take Part in Defence Production Activities], 4 June 2005.

[38]Commission of Science Technology and Industry for National Defence, *Guanyu Yinfa Feigongyouzhi Jingji Canyu Guofang Keji Gongye Jianshe Zhinan De Tongzhi* [Circular on the Guide for Non-State-Owned Economic Entities to Participate in the Construction of the Defence Industry] (Beijing: Commission of Science Technology and Industry for National Defence 2007), http://www.costind.gov.cn/n435777/n435779/n435922/n1243973/112347.html&gt.

a security clearance and a permit to produce the weaponry listed in official catalogues.[39]

By 2017, Xi Jinping had created the Military-Civil Fusion Development Commission under his own leadership.[40] This was the highest-level decision-making and coordination body for CMI. CMI had also become prominent in Made in China 2025 and the Next-Generation Artificial Intelligence Development Plan.[41]

By 2021, CMI was having positive results in IC design and fabrication. So-called 'fabless' design firms (which outsource manufacture) such as Phytium, Jiangsu Micro and Shenzhen H&TT Intelligent had become qualified civilian firms serving PLA customers.[42] In particular, Jingjia Micro's Graphics Processing Units (GPUs) found end uses in Chinese military radar, drones and satellites. The latter is telling of the importance of GPUs in deep learning and other types of advanced computing.[43] Similarly, chips designed by Cambricon Technologies found end uses with defence-related supercomputer maker Sugon, and Semiconductor Manufacturing International Corporation (SMIC), China's flagship chip-maker, was offering fabrication services to many of the aforementioned IC design houses.[44]

Three factors have driven the formulation of CMI: deficiencies in Chinese defence industry, the attractive resources of a rapidly expanding Chinese civilian economy and Beijing's recognition of most technologies' dual-use nature and the trend of spin-on. Defence industry deficiencies forced policy-makers to revamp the industrial base. These deficiencies included the technological backwardness of many indigenously built weapons systems, the long R&D and production times for most locally built military gadgets and China's increasing reliance on foreign supplies of major weapons systems. Thus, the industry persistently failed to satisfy military requirements.[45] Secondly, much IT industry knowledge is located in the civilian economy and driven by civilian firms, which possess greater technological capability than their defence counterparts. Hence, it was desirable to use the civilian

[39] In Dec. 2002, COSTIND issued interim procedures regulating the application for a permit to research and to produce specific weaponry. By 2004, 318 permits were issued to implement the interim rules. On 16 Sept. 2005, COSTIND issued formal regulations governing the permit system. See Commission of Science Technology and Industry for National Defence, *Wuqi Zhuangbei Keyan Shengchan Xuke Shishi Banfa* [Measures for the Implementation of Weaponry Research and Production Permit] (Beijing: Commission of Science Technology and Industry for National Defence 2005), http://www.costind.gov.cn/n435777/n435943/n435949/n1593098/119138.html&gt.

[40] Elsa B. Kania, *Battlefield Singularity: Artificial Intelligence, Military Revolution, and China's Future Military Power* (Washington: Center for a New American Security 2017), 19.

[41] James Manyika, William H. McRaven and Adam Segal, *Innovation and National Security: Keeping Our Edge* (New York, NY: Council on Foreign Relations 2019), 43.

[42] Li, Liu and Zhang, 'Guofang Jungong'; Wang, 'Guofang Jungong Hangye'.

[43] James C. Mulvenon, *Blue Heron: Semiconductor Manufacturing International Corporation* (Vienna, VA: SOS International LLC 2020); Bradford Waldie, 'How Military-Civil Fusion Steps up China's Semiconductor Industry', Stanford DigiChina Project, 1 April 2022.

[44] Mulvenon, *Blue Heron: Semiconductor Manufacturing International Corporation*.

[45] Medeiros, Cliff, Crane and Mulvenon, *A New Direction for China's Defense Industry*, 8–11.

economy more effectively to meet PLA needs. Finally, the PLA's goal of increased use of COTS items in defence systems pushed policy change because it recognised spin-on and the dual-use nature of most technologies.[46]

Although the CMI initiative has sought to maximise the scope of the national technological base to modernise the PLA,[47] the policy has had a mixed security impact on semiconductors.

Firstly, a number of civilian semiconductor firms have become part of the defence chip industrial base in support of China's security. Shanghai Fudan Microelectronics, which has connections with Fudan University and is a member of the CETC conglomerate, is a case in point. In the early 2000s, half of the firm's revenue came from the PLA for IC work reliant on a reverse-engineering approach that had been commissioned by the military.[48] In 2002, with PLA funding, the company debuted *Shenwei I*, a 32-bit embedded CPU similar to the Intel 80,386 microprocessor.[49] This represented the highest level of home-grown microprocessor technology of the time[50] and won a first-class national defence technology award.[51] In 2006, Fudan University passed a security clearance check and was on course to obtain two further certificates and commence defence-related scientific research and production activities.[52] More recently, the firm has designed FPGAs for military end use.[53] Other civilian firms, such as the aforementioned Phytium and Jiangsu Micro, have also engaged in defence production activities. In sum, these civilian firms have transferred various technologies to the defence sector, much as Intel sold its microprocessor technology to Sandia to help build better-functioning chips for nuclear weapons.[54]

The second reason for the policy's mixed security impact is the major challenges in its implementation, the first being that, given technology advances, a decrease in COTS items' radiation hardness may cause the designers of defence systems and sub-systems to think twice about inserting COTS items. COTS chips are less resilient than most tailor-made defence chips,

[46]Yu, 'Minyong Qiye Canyu Guofang Jianshe Shi Jianli Yujun Yumin Chuangxin Jizhi De Zhongyao Neirong' 9; Ye, 'Kaifa Junmin Liangyong Jishu'; Qian, '"Mincanjun" Shi Tisheng Woguo Guofang Keji Gongye Guoji Jingzhengli De Zhongyao Tujing'.

[47]Seth Drewry and William Edgar, 'China Gambles with Private Sector', *Jane's Defence Industry*, 1 Nov. 2005.

[48]Virtual interview with a seasoned industry insider, 25 May 2022.

[49]Interview, 19 Aug. 2005, Hsinchu, Taiwan.

[50]Li, Heng, 'China Develops New 32-bit Micro Processor –"*Shenwei*" I', *People's Daily*, 21 Nov. 2002.

[51]Shanghai Fudan Microelectronics, '"*Shenwei Yihao*" *Huo Guojia Guofang Keji Yidengjiang*' ['Shenwei I' Won a First-Class National Defence Technology Award] (n.d.), http://www.fmsh.com/news_fb43.htm&gt.

[52]Department of Science and Technology, Fudan University, *Keji Jianbao* [Science and Technology Briefing], 2006, http://dst.fudan.edu.cn/UploadFiles/%e7%a7%91%e6%8a%80%e7%ae%80%e6%8a%a52006%e7%ac%ac%e4%ba%8c%e6%9c%9f.doc<dst.fudan.edu.cn/newsview.aspx?id=15046&gt.

[53]Li, Liu and Zhang, 'Guofang Jungong', 5; Wang, 'Guofang Jungong Hangye', 34.

[54]Chu, *The East Asian Computer Chip War*, 55.

so the growing use of COTS semiconductors in military systems may exacerbate these gadgets' susceptibility to electronic magnetic pulse (EMP), which causes semiconductors to lose most of their computing capabilities. This vulnerability is compounded by the fact that the radiation hardness of COTS chips drops as the technology plumbs the deep sub-micron regime.[55] The second implementation challenge is that, as some indigenous civilian firms lack capacity for innovation and depend on foreign technology, their engagement in defence production may deepen the PLA's dependence on foreign technology.[56]

Sectoral globalisation across the Taiwan Strait

Against this institutional backdrop, how have the forces of globalisation across the strait affected China's defence chip capability?

The sector's globalisation has involved three major production stages (i.e., IC design, fabrication, and packaging and testing) and has accelerated since the 2000s, as measured by flows of technology, investment and talent.[57] In 2000, SMIC was established by Richard Chang, an experienced Taiwanese American semiconductor executive. It benefited from its employees largely being Taiwanese, its acquisition of proprietary technologies from Taiwan's Taiwan Semiconductor Manufacturing Corporation (TSMC) – the world's leading chipmaker – and Taiwanese investment.[58] Today, SMIC's top management continues to rely on veteran Taiwanese expertise. In 2021, TSMC approved a budget of USD 2.8 billion to expand capacity for the 28 nm process at its China fab.[59] Moreover, skilled Taiwanese IC talent, described as holding a 'fatal attraction'[60] to Beijing, has continued to boost Chinese semiconductor capability. Between 2014 and 2018, around 1,500 senior engineers have relocated to work for Chinese chip firms.[61] Moreover, leading Chinese fabless design firms (including Hisilicon, the IC design division of

[55]T.A. Dellin, J.L. Jorgenson, P.S. Winokur, and A.D. Jr. Romig, *New Trends in the Commercial IC Industry and the Impact on Defense Electronics* (Albuquerque, NM: Sandia National Laboratories 1998), www.osti.gov/servlets/purl/634063-ffRYkO/webviewable/> Michael O'Hanlon, *Technological Change and the Future of Warfare* (Washington: The Brookings Institution 2000), 59.

[56]Weichao Zhang and Chun Li, 'The Access of Individually-Run Enterprises to National Defense Industry', *Junshi jingji yanjiu* [Military Economic Research] 1/2006, 41–5.

[57]Chu, *The East Asian Computer Chip War*, 177–88.

[58]Ibid, 203–212; Saif M. Khan and Carrick Flynn, *Maintaining China's Dependence on Democracies for Advanced Computer Chips* (Washington: The Brookings Institution 2020), 7, https://www.brookings.edu/wp-content/uploads/2020/04/FP_20200427_computer_chips_khan_flynn.pdf&gt.

[59]Yu Nakamura, 'TSMC to invest $2.8bn in China to ramp up auto chip production', *Nikkei Asian Review*, 26 April 2021, https://asia.nikkei.com/Business/Tech/Semiconductors/TSMC-to-invest-2.8bn-in-China-to-ramp-up-auto-chip-production&gt.

[60]Virtual interview with the head of a fabless design firm, 27 May 2022.

[61]Yimou Lee, 'China Lures Chip Talent from Taiwan with Fat Salaries, Perks', *Reuters*, 4 Sept. 2018, https://www.reuters.com/article/us-china-semiconductors-taiwan-insight-idUSKCN1LK0H1&gt.

Chinese tech giant Huawei and Bitcoin) have been illegally recruiting Taiwanese engineers to work for them since the 2010s.[62]

Furthermore, this migration has helped develop China's defence chip subsector, challenging the conventional view that the process has little to do with the PLA. The following nine cases illustrate the links that have ensued between Taiwanese actors and the Chinese defence production system. These cases have been selected on the basis of interaction patterns that suggest Taiwan contributing through globalisation processes, including flows of hardware and expertise, with hardware referring to the supply of semiconductors for PLA end use and expertise comprising manufacturing services, multi-project wafer (MPW) services at foundries, talent training, individual-to-individual knowledge transfers and joint ventures.

The first case involves three-fold links between SMIC and the Chinese defence chip industrial base. Firstly, SMIC offered its foundry services to several Chinese IC design firms, including Jingjia Micro, Loongson and Shanghai Zhaoxin, to manufacture semiconductors for end use in Chinese military systems. For instance, Jingjia Micro's GPUs were fabricated at SMIC using the latter's 65 nm and 28 nm process technologies; some of these GPUs were used in Chinese military systems such as drones, radar and satellites. Additionally, SMIC has ongoing ties with a subsidiary of CETC, which it helps test new manufacturing technologies. Lastly, SMIC has offered its process design kits to PLA university and defence industrial complex researchers to enable them to advance their research, including research on rad-hard ICs, which are used primarily in military and aerospace applications.[63] Several industry veterans contend that, given SMIC's position as China's leading chipmaker and the Chinese state's increasing control over the firm, SMIC benefits the Chinese military,[64] even though SMIC denies having PLA customers.[65]

[62]Kensaku Ihara, 'Taiwan loses 3,000 chip engineers to "Made in China 2025"', *Nikkei Asian Review*, 3 Dec. 2019, https://asia.nikkei.com/Business/China-tech/Taiwan-loses-3-000-chip-engineers-to-Made-in-China-2025> Ting-fang Cheng, 'China hires over 100 TSMC engineers in push for chip leadership', *Nikkei Asia*, 12 Aug. 2020, https://asia.nikkei.com/Business/China-tech/China-hires-over-100-TSMC-engineers-in-push-for-chip-leadership> Kathrin Hille, 'Taiwan accuses Bitmain of poaching its top chip engineers', *Financial Times*, 21 March 2021, https://www.ft.com/content/88642f11-8441-428b-b720-4948e00cdc1b; Hannah Chang, 'Why Are Chinese Companies in Taiwan Being Raided?' *CommonWealth Magazine*, 7 April 2022, https://english.cw.com.tw/article/article.action?id=3197&utm_source=web_cw&utm_medium=internal&utm_campaign=web_cw-internal-daily-220412–3197&gt.

[63]Waldie, 'How Military-Civil Fusion Steps up China's Semiconductor Industry'; Mulvenon, *Blue Heron: Semiconductor Manufacturing International Corporation*; Dan Strumpf, 'U.S. Sets Export Controls on China's Top Chip Maker', *Wall Street Journal*, 28 Sept. 2020, https://www.wsj.com/articles/u-s-sets-export-controls-on-chinas-top-chip-maker-11601118353&gt.

[64]Virtual interview with a veteran industry player with decades of experience in the industry development in China and Taiwan, 23 May 2022; virtual interview with a former chief operating officer of a leading Taiwanese IC design house, 24 May 2022; virtual interview with a seasoned industry executive, 26 May 2022.

[65]Interview with the CEO of SMIC, 7 Dec. 2004, San Jose, CA, USA.

The second case involves links between TSMC and two members of the Chinese defence chip industrial base. Initially, Phytium used TSMC's fabrication service to manufacture advanced chips for a supercomputer that simulated the performance of China's DF-17 hypersonic missiles, which were tested in 2021. These tests alarmed Washington. A US general described this as a 'Sputnik moment' because the missiles were capable of evading the ballistic missile defence systems deployed by the US and its allies in the Pacific.[66]

The second link between TSMC and members of the Chinese defence chip industrial base is between TSMC and Southwest Integrated Circuit Design Co. Ltd. (SWID), a fabless company spin-out from the 24th Research Institute that is specialised in the design and fabrication of analogue ICs for military and commercial end use. Between 1986 and 1990, it pioneered China's military foundry projects, running military application-specific integrated circuits (ASIC) on experimental lines. In 1989, it fabricated military-grade analogue semiconductors for end use in the *Long March-2E* space launch vehicle. It also supplied semiconductors for the *Hangtian* project, which got underway in 1997, and for China's first manned spaceship, *Shenzhou V*, which debuted in 2003. As of 2002, the institute was housing two qualified manufacturing lines to provide the PLA with bipolar analogue ICs and high-frequency, wideband, low-noise amplifiers. In 2003, it established China's National Laboratory of Analogue Integrated Circuits.[67] However, it lagged behind its counterparts in leading semiconductor countries in military analogue ICs in terms of reliability and fabrication technology.

This gap began to narrow when SWID started using the TSMC fabrication service. As of 2005, it was using TSMC's 0.35-micron SiGe BiCMOS process technology to fabricate a radio frequency IC for Global Positioning System end uses.[68] Given SWID's military linkage, some of these TSMC-fabricated chips may have been inserted in PLA gadgets, with TSMC consequently contributing to the performance of at least two local fabless firms with defence links.

[66]Sara Sorcher and Karoun Demirjian, 'Top U.S. general calls China's hypersonic weapon test very close to a "Sputnik moment"', *Washington Post*, 27 Oct. 2021, https://www.washingtonpost.com/nation/2021/10/27/mark-milley-china-hypersonic-weapon-sputnik/> Ellen Nakashima and Gerry Shih, 'China builds advanced weapons systems using American chip technology', *Washington Post*, 9 April 2021, https://www.washingtonpost.com/national-security/china-hypersonic-missiles-american-technology/2021/04/07/37a6b9be-96fd-11eb-b28d-bfa7bb5cb2a5_story.html&gt.

[67]Xu, 'Junyong Weidianzi Jishu Fazhan Zhanlue'; Xiandong Wu, 'Junyong He Zhuanyong Jichengdianlu Shichang Gongyi Sheji Yaosu De Fenxi' [An Analysis of Market, Technology and Design Components in Military ICs and ASICs], *Weidianzixue* [Microelectronics] 21/2 (1991), 1–6; Lin Guo and Jianhua Liu, 'Jianli Junyong Foundry De Tansuo' [An Exploration for Establishment of the Military Foundry], *Weidianzixue* [Microelectronics] 22/3 (1992), 5–9.

[68]William Song, *Local Design House Analysis Report* (Shanghai: Global Advanced Packaging Technology 2003); Chuan Yang, Yong-sheng Wang, Tian-cai Wan and Lin Fan, 'GPS Weixing Daohang Jieshouji RF Dianlu De Sheji' [Design of a Radio Frequency Circuit for GPS Receivers], *Weidianzixue* [Microelectronics] 35/1 (2005), 21–4.

The third case is the link between Huajing, a member of the Chinese defence chip industrial base,[69] and the Central Semiconductor Manufacturing Corporation (CSMC), a company established by Taiwanese executives with hybrid sources of capital. Huajing conducted its military IC work at its Central Research Institute (CRI),[70] as it appeared in the 2002 version of the QPL.[71] In 1998, Huajing leased its Fab 1 to CSMC. The then Taiwanese-run company offered a two-year 'foundry management service' to the fab and improved the fab's production capacity and customer base for commercial end uses. As the project proceeded, the CRI concurrently provided the PLA with semiconductors. It is conceivable that the Taiwanese engineers running the fab nurtured the military IC work under Huajing's roof.

The fourth, fifth and sixth cases concern the Chinese Academy of Sciences (CAS) and three foundries with a Taiwanese connection. The CAS has supplied semiconductors to the PLA.[72] One hundred and nine Model III computers with CAS-fabricated semiconductors were inserted in atomic bombs between 1967 and the early 1980s.[73] The CAS's Shanghai-based Shanghai Institute of Metallurgy (SIM) fabricated transistors for atomic bombs in the 1960s, and in the 1980s and 1990s it developed military GaAs very high-speed ICs.[74]

The CAS has ties with three Taiwanese companies based in China. In our fourth case, the Electronic Design Automation (EDA) Center of the CAS has participated in the MPW services offered by HeJian, a foundry in which Taiwan's United Microelectronics Corporation has invested, to upgrade the IC design capabilities of MPW participants. Given the connections between the CAS and the PLA, these enhanced IC design capabilities can be exploited by the PLA.

As regards our fifth case, in 2005 the CAS's Institute of Microelectronics signed a pact with CSMC to build a six-inch wafer fab in Beijing. In June 2006, the fab started ramping up production. The CAS benefited from this joint venture because the CSMC's niche was six-inch wafer fabrication. Given the connections between the CAS and the PLA, the Chinese military or its spin-off companies probably used the fab to manufacture military chips. Although the technology at the fab lagged behind what was then considered state of the

[69]Huajing began to unsuccessfully build a 6-inch wafer fab in the early 1990s. See Hanting Fang and Fang Cao, 'Jichengdianlu Chanye Fazhan Zhong De Huahong Moshi Yu Xiangguan Jianyi' [The Huahong Model in the Development of the IC Industry and Related Suggestions], *Diaoyanbaogao* [Survey Report] 11 (2002), 1–10.

[70]Haoping Luo, Zongbing Li, Jinhua Cai, Chunbei Zhang and Jingkun Fan, 'Junyong ASIC Jiqi Duice' [Military ASIC and Its Strategy], *Bandaoti Jishu* [Semiconductor Technology] 6/3 (1992), 36–59.

[71]Yu, *Junyong Yuanqijian Shiyong Zhiliang Baozheng Zhinan*.

[72]Interview with a US department of commerce official, 1 Feb. 2005, Washington, D.C., USA.

[73]Jiuchun Zhang and Baichun Zhang, 'Founding of the Chinese Academy of Sciences' Institute of Computing Technology', *IEEE Annals of the History of Computing* 29/1 (2007), 29–30 & 33.

[74]Hua, *Zhongguo Junyun Dianzi Yuanqijian*.

art globally, it may have enabled the fabrication of chips better than those in existing Chinese defence systems.[75]

In the sixth case, graduate students at CAS's SIM underwent training at Grace Semiconductor Manufacturing Corporation (GSMC), another product of the migration, according to Zou Shichang, then chairman of GSMC.[76] At the commercial fab, these inexperienced local engineers had access to advanced equipment unavailable at SIM. They also absorbed the expertise of their senior counterparts, including those from Taiwan. Given SIM's history as a supplier of military semiconductors, these locally trained engineers may have used their enhanced know-how, refined at GSMC, a commercial fab, to advance Chinese defence microelectronics undertakings.

In the seventh case, the No. 771 Research Institute encouraged a Taiwanese company to provide it with a rad-hard IC design service for the *Hangtian* project. This institute supplied space-qualified and military-grade ICs and IC-based computers for end use in spacecraft and missiles. As a qualified QPL supplier, it used its four-inch complementary metal oxide semiconductor (CMOS) process technology to fabricate analogue and digital ICs for military and aerospace systems. As a QML supplier, it had run, as of 2002, two certified manufacturing lines to fabricate hybrid military ICs.[77] By 2005, its military-certified CMOS IC manufacturing line was producing an average of 5,000 to 10,000 wafers per month.[78] It also supplied China's second manned spacecraft, *Shenzhou VI*, with 22 IC-based space-qualified computers.[79]

In the mid-1990s, however, the institute had turned to Taiwan for IC design services. According to a senior executive at a Taiwanese firm at the time, the head of the institute contacted him seeking a rad-hard IC design service to support the *Hangtian* project. Although the company declined, the approach is a sign that the institute's semiconductor capability was such that it needed Taiwanese input to advance its military undertakings.

In the eighth case, a junior Chinese engineer at Shanghai Fudan Microelectronics absorbed the expertise of his senior Taiwanese counterpart on a PLA project. The Taiwanese engineer, head of a Chinese-based subsidiary of a leading Taiwanese design house, had become acquainted with the junior Chinese engineer through job interviews. When the local firm was

[75]For insiders' accounts of the backward semiconductors in Chinese military systems, see interview with Qinsheng Wang, Chair of Huada Electronic Design Co., 30 Aug. 2005, Beijing, China; interviews with veteran engineers of the 13th Research Institute, 17 March 2005, Shanghai, China; virtual interview with a seasoned industry executive.

[76]Interview, 27 Sept. 2005, Shanghai, China.

[77]Hua, *Zhongguo Junyun Dianzi Yuanqijian*; Yu, *Junyong Yuanqijian Shiyong Zhiliang Baozheng Zhinan*.

[78]No. 771 Research Institute, *Chanpin Zhinan* [Product Guide] (Xian: No. 771 Research Institute, China Aerospace Times Electronics Corporation n.d.).

[79]Junling Du, 'Shenliu Ershier Tai Jisuanji You Shanxi Zhizao Danji Zaojia Zuigao Guo Baiwan' [Twenty-Two Computers in Shenzhou Six Made in Shanxi with the Single Most Expensive Unit Costing More Than One Million Dollars], *Huashangbao* [Chinese Business View], 17 Oct. 2005.

engaged for a PLA-commissioned project to develop a 32-bit CPU around 2001, senior project members preferred to take a reverse engineering approach, whereas junior members embraced innovative solutions. The junior engineer contacted the Taiwanese engineer who had interviewed him for his input.[80] In 2002, the junior engineer's company debuted *Shenwei I*, which helped the firm to win a defence technology award. This case illustrates how, through interpersonal exchanges, junior Chinese engineers were able to engage in military projects and absorb the expertise of their senior Taiwanese colleagues following the latter's migration across the Taiwan Strait.

In the final case, Shenzhen I-Lacs Technology Co., Ltd. purchased ICs from Taiwan's VIA Technologies Inc. (VIA) for its military personal computer (PC) products. In 2006, the company became China's first civilian qualified supplier of military-grade PCs to the PLA. It used Taiwanese semiconductors, primarily from VIA, in some of its military products.[81] One such military PC product is equipped with a VIA Eden CPU.[82] When asked if VIA had supplied chips to this Chinese firm, an executive at VIA replied, 'I am not sure … I don't think the military business is that important because it comprised a small percentage of the revenue'.[83] Nevertheless, this case demonstrates that a qualified supplier to the PLA purchased Taiwanese chips for military end use.

In sum, these cases show that members of the Chinese defence semiconductor industrial base have absorbed resources from Taiwan. Given the continuing trend of globalisation in the cross-strait context, China's future defence chip capability will not be de-coupled from Taiwan.

Security implications

Several security implications of this sectoral globalisation emerge from these cases in respect of modernising the PLA and the ensuing shift in the regional balance of power.

Firstly, such globalisation has nurtured the Chinese commercial chip subsector and helped facilitate the CMI process. The IC design capabilities of local firms, developed partly by way of Taiwanese contributions, and the training received by inexperienced Chinese engineers in Taiwanese-run firms are assets for the Chinese military chip operations through the CMI process. Secondly, as globalisation has improved the Chinese defence chip industrial base, as these cases illustrate, it is probable that PLA gadgets equipped with

80Interview, 19 Aug.2005, Hsinchu, Taiwan.

81Gongkong.com, 'Pathway to Military Industry: Interview with Zhang Shengrong, President of Shenzhen I-Lacs Technology Co.,Ltd'., http://www.gongkong.com/news/detail.asp?id=6644&gt.

82Shenzhen I-Lacs Technology Co., Ltd., 'I-LACS Motherboard Family Has Got a New Member', 21 April 2004.

83Interview, 12 July 2005, Taipei, Taiwan.

semiconductors of Taiwanese design or fabrication may become part of the PLA's war-fighting systems in a strait contingency.

Crucially, the Taiwanese expertise transferred has been a greater asset to the PLA than the Taiwanese supply of hardware. Given the gap in semiconductor technology between Taiwan and China, with the former enjoying the upper hand in IC design and fabrication,[84] the diffused Taiwanese knowledge, once in the hands of the Chinese defence sector, supports the PLA's modernisation. Taiwanese hardware is less important to the PLA than knowledge transfer;[85] it constitutes to a larger supply pool, including government-owned defence entities, local commercial firms engaged in military production activities and the international market by way of diversion, espionage[86] or legal channels of dual-use acquisition with the support of national funds.[87]

Notably, the level of process technologies used by Taiwanese chipmakers (e.g., the TSMC) in their Chinese subsidiaries as of 2007 was comparable to that used to make chips for the US military. As the technologies at these Chinese-based Taiwanese operations advance over time, they will be assets to the PLA should it choose to not regard these firms' Taiwanese background as a security threat and to rely on them as internal sources of supply.

Although it remains unclear whether Taiwan-related semiconductor players in China could be eligible for CMI partnership with the PLA in Chinese military projects, insiders argue that national security considerations mean that wholly Taiwanese-owned firms would be the least likely partners for the design or fabrication of chips for mission-critical Chinese military systems, despite their technological edge. The PLA would view Taiwan as a 'foreign adversary' rather than 'part of China' in this instance and would prefer indigenous firms as partners.[88]

[84] As of early 2022, Taiwan was the world's second largest IC design hub, and it accounted for 92% of the world's most advanced (below 10 nm) semiconductor manufacturing capacity and more than half of global semiconductor manufacturing capacity. See Becca Wasser, Martijn Rasser, and Hannah Kelley, *When the Chips Are Down: Gaming the Global Semiconductor Competition*, 4 (Washington: Center for a New American Security 2022), https://www.cnas.org/publications/reports/when-the-chips-are-down.&gt.

[85] Interview with James Mulvenon of Defense Group Inc., 21 Jan. 2005, Alexandria, VA, USA; interview with Roger Cliff of Rand Corporation, 31 Jan. 2005, Arlington, VA, USA.

[86] Tai Ming Cheung, 'Innovation in China's Defense Technology Base: Foreign Technology and Military Capabilities', *Journal of Strategic Studies* 39/5–6 (2016), 744–5; William Hannas, James Mulvenon and Anna Puglisi, *Chinese Industrial Espionage: Technology Acquisition and Military Modernization* (New York: Routledge 2013); Nicholas Eftimiades, 'On the Question of Chinese Espionage', *Brown Journal of World Affairs* 26/1 (2019), 125–42.

[87] Anja Manuel and Kathleen Hicks, 'Can China's Military Win the Tech War?' *Foreign Affairs*, 29 July 2020. https://www.foreignaffairs.com/articles/united-states/2020-07-29/can-chinas-military-win-tech-war> Mathieu Duchâtel, *The Weak Links in China's Drive for Semiconductors* (Paris: Institut Montaigne 2021), https://www.institutmontaigne.org/en/publications/weak-links-chinas-drive-semiconductors&gt.

[88] Interview with a senior Taiwanese IC designer, 19 Aug. 2005, Hsinchu, Taiwan; interview with the chairman of CSMC, 25 Sept. 2005, Shanghai, China; interview with the chairman of Ningbo Sinomos Semiconductor Incorporation, 14 Sept. 2005, Ningbo, China.

Furthermore, senior executives have varied opinions on whether Taiwanese-owned or run foundries in China have fabricated chips for military end use. Interviewees at SMIC, GSMC, HeJian, TSMC Shanghai and CSMC claim that their firms had no PLA customers,[89] although the above analysis of SMIC and TSMC links to the Chinese defence industrial base contradicts some of these claims. One TSMC executive has asserted that TSMC's subsidiaries would not knowingly have made chips for the PLA because the company was aware of the cross-strait antagonism.[90] Other industry interviewees[91] concede three reasons why the Taiwanese foundries might have fabricated chips for PLA end use: because the foundries did not have prior knowledge of the end use of the chips, due either to the difficulty of distinguishing a military IC from a commercial one or to the PLA's use of third-party private firms to make the order; because the low level of demand in the commercial market led to their engagement with PLA-related businesses; or because the parties involved kept the deals confidential.

As Taiwan has helped China acquire an increasingly integrated semiconductor capability, what will the security externalities be of a solid Chinese chip industrial base? The answer to this question is fourfold.

Firstly, such a domestic production base would mitigate the vulnerabilities of foreign dependency and alleviate any negative impact on China's security from export controls on militarily sensitive semiconductors and equipment to China. According to Zou Shichang, China's IC industry would attempt to manufacture security-related ICs unavailable in the international market due to such export controls.[92] This would contribute to China's security given its lack of trustworthy allies to guarantee a supply of militarily sensitive semiconductors.

Secondly, an improved commercial semiconductor industry in China would increase Chinese security by removing an obstacle to the PLA's pursuit of digitalisation, namely, the limited ability of its defence production system to supply advanced semiconductors to the PLA. This would accelerate the formation of a digitalised Chinese military force. While China has historically depended on state-run entities to manufacture low-end semiconductors for the PLA, the president of a Taiwanese fabless firm envisages that a rapidly improved commercial chip sub-sector would be able to produce higher-

[89]Interview with the CEO of SMIC; interview with a former president of GSMC, 14 Sept. 2005, Ningbo, China; interview with the president of HeJian, 21 Sept. 2005, Suzhou, China; interview with the president of TSMC Shanghai, 26 Sept. 2005, Shanghai, China; interview with the chairman of CSMC.

[90]Interview, 30 June 2005, Hsinchu, Taiwan.

[91]Interview with a sales manager at HeJian, 21 March 2005, Shanghai, China; interview with a vice-president of a Taiwanese IC design house, 7 Dec. 2004, San Jose, CA, USA; virtual interview with a veteran industry player with decades of experience in the industry development in China and Taiwan; virtual interview with a seasoned industry executive; virtual interview with a seasoned industry insider.

[92]Interview with Zou.

quality semiconductors for military end use and thus accelerate the take-off of the PLA.[93]

Walden C. Rhine, CEO of Mentor Graphics Inc., the world's third-largest EDA firm in 2004, has argued that having advanced commercial ICs would help China increase its military capability.[94] The president of a Taiwanese foundry based in China has contended that Beijing's 'obvious military ambition' would drive the PLA to exploit the domestic commercial IC industry to modernise its forces, as sectoral globalisation continues to nurture the sector.[95] A Pentagon official has stated that it is 'important to have a reliable and vibrant industry domestically' to produce home-grown semiconductors for American weapons systems, as evidenced by the broadened scope of the Trusted Foundry programme,[96] and this observation would also apply to China.[97]

These two security ramifications of a solid chip industrial base in China lead to a third security outcome: an improved PLA capability to wage war by conventional and non-conventional means.

Improved Chinese semiconductor capability would provide the PLA with cutting-edge semiconductors with strong computational capabilities, enabling it to build its precision-guided weapons systems, its command, control, communications, computer, intelligence, surveillance and reconnaissance operations,[98] and its artificial intelligence (AI) gadgets, including next-generation stealth drones.[99] This would help the PLA pursue information superiority over its enemies and contribute to the performance of these military systems, improving the PLA's traditional war-fighting capabilities.

Furthermore, China's upgraded IC industrial base would increase the PLA's unconventional war-fighting capabilities in defensive and offensive terms. Semiconductor-dependent electronic systems are susceptible to IW operations, such as chipping and EMP strikes. Chipping, referred to as the 'Trojan horse of microelectronics', involves malicious acts at the hardware and/or software level.[100] These attacks may involve the modification, alteration,

[93]Interview, 20 Oct. 2005, Hsinchu, Taiwan.

[94]Interview, 7 Dec. 2004, San Jose, CA, USA.

[95]Interview, 21 Sept. 2005, Suzhou, China; virtual follow-up interview with the same industry player, 23 May 2022.

[96]Chu, *The East Asian Computer Chip War*, 106–7; Brandon Eames, 'On Trust Analysis for Microelectronics Based Systems', (Albuquerque, NM: Sandia National Laboratories 2017), https://www.osti.gov/servlets/purl/1456554]&gt.

[97]Interview, 2 Feb. 2005, Alexandria, VA, USA.

[98]James C. Mulvenon, 'The Digital Triangle: A New Defense-Industrial Paradigm', in Evan S. Medeiros, Roger Cliff, Keith Crane and James C. Mulvenon (eds.) *A New Direction for China's Defense Industry* (Santa Monica, CA: RAND 2005), 205–51.

[99]Wenxing Fu, Guo Hang, and Yan Jie,'Zhi neng wu ren fei hang qi ji shu fa zhan qu shi zong shu' [Overview on the Technology Development Trend of Intelligent Unmanned Aerial Vehicle], *Unmanned Systems Technology*, 4 (2019), 31–37.

[100]Winn Schwartau, *Information Warfare: Chaos on the Electronic Superhighway* (New York: Thunder's Mouth Press 1994), 164.

design or use of ICs for purposes beyond what they were designed for; they can be launched during peacetime when the semiconductors are made on an adversary's soil and activated during wartime.[101] A strong chip industry helps a country accumulate in-depth semiconductor knowledge and technology in support of its IW capabilities. It can also provide a sufficient onshore supply of ICs to meet any critical national infrastructure needs,[102] thus minimising the likelihood of chipping occurring at offshore production sites. The above observation is true of China, given the PLA's stated objective of a strong domestic IC industry to strengthen its IW capabilities. PLA strategists have further aspired to launch asymmetrical warfare operations to destroy the technological edge of its adversaries.[103] Such unconventional warfare tactics could take the form of chipping or EMP strikes to paralyse the networked electronic devices underpinning the US and Taiwanese economies and militaries. As China's IC industry becomes stronger, Beijing will get closer to achieving these objectives and improving its capabilities in unconventional warfare.

The fourth and final security implication relates to changes in the regional balance of power in Beijing's favour relative to Taiwan as China increases its capacity for warfare. The globalisation of IT manufacturing and R&D could also lead to a change in the relative capacity of the PLA vis-à-vis other powers.[104] Taiwan's sectoral migration has nurtured China's indigenous capacity, which means that the PLA can remove a bottleneck in the development of its weapons systems, which would create a further shift in the regional balance of power in question.[105]

However, the PLA will not catch up with its American counterpart and develop weapons systems as sophisticated as those produced by the US any time soon on the basis of Beijing's acquisition of advanced IC technology. The former president and CEO of International SEMATECH C. Mark Melliar-Smith observed that there was 'a big gap' between having access to ICs and being able to build weapons systems.[106] Others, however, express greater concern. As one American defence

[101]Defense Science Board Task Force, *High Performance Microchip Supply* (Washington: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics 2005); Mohammad Tehranipoor and Koushanfar Farinaz, 'A Survey of Hardware Trojan Taxonomy and Detection', *IEEE Design & Test of Computers* 27/1 (2010), 10–25; S. Bhunia, M.S. Hsiao, M. Banga and S. Narasimhan, 'Hardware Trojan Attacks: Threat Analysis and Countermeasures', *Proceedings of the IEEE* 102/8 (2014), 1229–47; DSB Task Force on Cyber Supply Chain, *Final Report of the DSB Task Force on Cyber Supply Chain* (Washington: Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics 2017), 8–9.

[102]Luyan Fu and Yong Li, '"Xinpianzhan" Qiaoran Zoulai' ['Chip War' Quietly Creeps In], *Jiefangjun Bao* [PLA Daily], 26 May 2004.

[103]Mulvenon, 'The Digital Triangle', 250–1; Liang Qiao and Xiangsui Wang, *Unrestricted Warfare: China's Master Plan to Destroy America* (Panama City, Panama: Pan American Publishing Company 2002).

[104]Adam Segal, 'Globalization is a Double-Edged Sword: Globalization and Chinese National Security', in Jonathan Kirshner (ed.) *Globalization and National Security* (London: Routledge 2006), 305–10.

[105]Interview with Matthew S. Borman, deputy assistant secretary at the US Department of Commerce, 1 Feb. 2005, Washington, D.C., USA.

[106]Interview, 4 Jan. 2005, Austin, TX, USA.

industry player contends, the improved chip capability of the Chinese may 'help them improve their military capabilities rather significantly by having electronic systems comparatively competitive to the West'.[107] As Roger Cliff of the Rand Corporation notes, if Beijing had acquired an electronics capability comparable to that of Washington, 'that would have enabled Chinese defense manufacturers to produce weapons systems comparable in capability to those produced by the US … [I]f we were to enter into conflict with China, then the risk to US forces would increase significantly'.[108] The aforementioned case of China's hypersonic missiles supports this further. Thus, China's upgraded chip capability would result in a downward spiral of compromised security for Taipei and Washington. Conversely, should China fail to build a solid chip industry[109] despite Taiwanese input and other enabling factors, the aforementioned security threats might occur to a lesser degree.

Conclusion

This paper shows that sectoral globalisation across the Taiwan Strait has nurtured the relevant industrial base in China and could help the PLA to improve its capacity and change the relative capacity of the PLA vis-à-vis other powers. These findings challenge the viability of the de-coupling narrative that has recently gained traction among policy influencers.

China's pursuit of semiconductor supremacy is integral to its pursuit of becoming a 'world-class' military by 2049. It urgently needs to make more advanced chips to satisfy rising demand given its rapid advances in AI, a growing supercomputer programme and rapid military build-up. However, its ambitions have been dampened by growing US pressure to further control pertinent technology transfer to China. As analysed in this paper, Taiwan's contribution to China's growing semiconductor capacity demonstrates the significance of globalisation to the PLA's modernisation. If, despite US-led efforts to

[107]Interview with Stephen D. Bryen, President of Finmeccanica North America, Inc., 31 Jan. 2005, Washington, D.C., USA.

[108]Interview with Cliff.

[109]Existing studies and industry interviewees have mixed assessments of China's semiconductor capability. Hurdles include the lack of highly skilled labour, the reliance on global giants for EDA tools and advanced semiconductor manufacturing equipment, inefficient investments in company R&D, and export controls. Opportunities include the magnet of the enormous Chinese market, western firms' incentives to sell to the Chinese market, the Chinese returnees, and the continuous forces of globalisation in terms of venture-capital investments and talent flows. See John VerWey, 'Chinese Semiconductor Industrial Policy: Prospects for Future Success', *United States International Trade Commission Journal of International Commerce and Economics*, Aug. 2019, 16, https://ssrn.com/abstract=3441959> Duchâtel, *The Weak Links in China's Drive for Semiconductors*;John Lee and Jan-Peter Kleinhans, *Mapping China's Semiconductor Ecosystem in Global Context: Strategic Dimensions and Conclusions* (Berlin:MERICS and Stiftung Neue Verantwortung 2021), https://merics.org/sites/default/files/2021-06/China%E2%80%99s%20Semiconductor%20Ecosystem_0.pdf> Khan and Flynn, *Maintaining China's Dependence on Democracies for Advanced Computer Chips*; virtual interview with a veteran industry player with decades of experience in the industry development in China and Taiwan; virtual interview with a seasoned industry executive; virtual interview with a seasoned industry insider.

disrupt them through various policy measures, these forces of globalisation intensify over time, they will continue helping the PLA to thrive.

In the circumstances, two policy lessons can be formulated. Firstly, Washington should coordinate policy more closely with Taipei through the newly inaugurated IC supply chain cooperation forum[110] and thus more effectively control transfers of semiconductor technology, investment and human resources across the Taiwan Strait by involving pertinent Taiwanese firm executives who have in-depth knowledge of Chinese semiconductor capabilities. Secondly, Washington and Taipei should both recognise that firm-led globalising actions may have undesirable security externalities that do not align with state interests and which indicate the limitations of government-led control measures designed to curb the PLA's modernisation by constraining globalisation. The challenge is to strike a balance between these two lessons at the nexus of globalisation and security.

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[110] Eric Lee, 'How Taiwan Underwrites the US Defense Industrial Complex', *The Diplomat*, 9 Nov. 2021, https://thediplomat.com/2021/11/how-taiwan-underwrites-the-us-defense-industrial-complex/&gt.

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