Sino-US Competition in Global Information Infrastructure, Critical Technologies and Its Implications

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Abstract

The competition over technologies is becoming central to the rivalry between China and the United States (US). The US achieved superpower status as a result of its unmatched political influence, economic strength, and military technological leadership. But China has recently made great strides in building its information infrastructure, which is essential for both the nation's military might and economic growth. China currently has the second-largest economy in the world. This paper examines how China is emerging as a competitor to the US in major critical technologies such as cyberspace, 5G, Artificial Intelligence (AI), quantum computers, and space. The US is taking preventative actions against China in order to protect its superiority and both countries are working to establish independent capabilities in these technologies which have major implications. Power transition theory and neorealism provide an explanation for the Sino-US drive for technological superiority and how it is influencing the global power structure. Techno-nationalism stemming from competition for semiconductors and microchips, techno-politics through technology-driven political interests and alliances, economic gains, market control, automation of weapons, and challenges to governance of these technologies and cyber-security are some of the implications of this ongoing competition. This article proposes a global agreement on governance and regulation of these technologies.

Keywords: *China, US, strategic competition, global information infrastructure, critical technologies, semiconductors, cyber security*

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Introduction

In the era of innovations, the development and spread of cutting-edge information-based technologies in unprecedented ways has made great power competition more complicated and consequential. Following the disintegration of the Soviet Union, the United States gained the status of superpower due to its unmatched technological leadership, economic might, military supremacy, and political influence. The US upheld its dominance and safeguarded the liberal order it had established with its fellow western powers based on democracy, human rights, freedom of speech, capitalism, and open trade. To preserve this order, the US also did not hesitate to implement regime change policies in many places. This also led the US to involve in various military and armed conflicts. Until China became the second-largest economy, there was no other country to challenge the US hegemony.

Following Sino-US diplomatic relations in 1978, the US made significant investments in China, making them major trading and business partners in the coming decades. Ever since joining the World Trade Organization (WTO) and obtaining Foreign Direct Investment (FDI), China has remained a significant actor and partner in the promotion of US-led global order. China maintained a pragmatic and rational approach toward relations with other countries. The primary reason for the US apprehension about China was rooted in China's emergence as the biggest manufacturer in the world in 2010 and 2011,[1] which also gave an unchallenged legitimacy to a one-party governance system of 'socialism with Chinese characteristics' under the leadership of Communist Party of China (CPC).

Initially, the driver for China's focus on developing its information infrastructure was its fear of the US regime-change policy after the 2010–2011 Arab Spring, in which US–led digital platforms and information campaigns played a crucial part in the movement against autocratic rulers. In addition to China's economic boom, there

were also other factors which pitched it as a rising challenge to the US primacy such as its incremental claims and assertiveness in the South China Sea, and the announcement of the Belt and Road Initiative (BRI) in 2013, i.e., a mega infrastructural, industrial, digital, and trade corridor connecting Asia with the rest of the world. To counter China, the US broadened its Asia rebalancing strategy to Indo-Pacific Strategy.

It was China's extraordinary economic rise and distinct political system that prompted the US to designate it as a strategic rival to its global power in the National Security Strategy (NSS) 2017. In terms of commerce, the two countries' imbalance was reported to be $53 billion in 1997 and increased to $367.4 billion in 2022. The US increased its propaganda against China in 2019 by focusing on its political system, which was seen in its criticism of the 2019 protests in Hong Kong, human rights in the autonomous regions of Xinjiang and Tibet and China being the origin of the COVID-19 pandemic. Additionally, the US increased its arms trade with Taiwan, which agitated China. Thus, the US implemented a comprehensive containment strategy against China.

The integration of information technology in all sectors of the modern world makes it a major tool to influence economic, military, and political domains, globally. The domination, control, and destabilisation of other countries can be achieved through information rather than by material means alone. The major reason for the US to classify China as the most "comprehensive and serious challenge" to US security in its NSS 2022 has been its rapid advancement in scientific and innovative capabilities, especially in information infrastructure and critical technologies.[2] As per the document, China is the only rival that possesses the capability to alter the global order and the intention to do so, along with growing economic, diplomatic, military, and technological might. To maintain its technological superiority, the US Senate earlier in 2021 passed the

United States Innovation and Competition Act 2021. This law recognised China as a rising science and technology power.[3] The US not only announced new strategies to regain its leadership in technology but also raised preventive and protectionist policies against high-tech cooperation with China.[4]

There are a wide range of cutting-edge technologies in which China is increasing its capabilities. However, this paper attempts to measure China's emerging competence vis-à-vis the US in cyberspace, 5G, Artificial Intelligence (AI), quantum computers, and space which bear the potential to seriously undermine US dominance and have significant implications. This paper uses the qualitative method for the research and focuses on Global Information Infrastructure (GII) as a broader term for the new domain of power that is the strategic use of information manifested in critical technologies. The problem under focus in this study is the tendency of both China and the US to develop independent capabilities in critical technologies aimed at achieving superiority. To address why Sino-US competition is escalating in critical technologies, and how this factor is significant in altering the global power dynamics, the explanations provided reflect the underpinnings of offensive realism and power transition theory.

China now leads in strategically important industries, according to Information Technology and Information Foundation (ITIF) Hamilton Index 2023. It is "producing more than any other nation in absolute terms and more than all but a few others in relative terms."[5] According to Robert Atkinson, the president of ITIF, the US and Soviet Union were mainly competitive in military strength during the Cold War, while present day competition between China and the US is in economic strength based on technological leadership.[6] The impact of critical technologies is more comprehensive to alter global power dynamics. The countries which lead in global information infrastructure, critical technologies, and employing successful

strategies for adoption of these technologies will have comparative advantage in both economic and military power.

Global Information Infrastructure and its Significance for Global Power Dominance

Among all sorts of technologies, the Global Information Infrastructure (GII) is a comprehensive term used for technologies related to the strategic use of information with a wider range of its integration in the industrial innovation and its conversion to critical technologies and weapons.[7] Therefore, the strategic competition is compounding in this domain between China and the US with far-reaching consequences in the 4th industrial revolution period for global power dynamics and a shift in economic centres. Considering that GII is a system of applications, activities, data storage, data surveillance, and relationships as well as hardware and software, whichever country leads its production and control will have sway in the global power struggle. Now its advancement has led to critical technologies such space, cyberspace, Artificial Intelligence (AI), Quantum Computers, and 5G technology. The global chains of Information and Communication Technology (ICT) and its applications have become increasingly intertwined with the global trade, financial and commercial activities, defence and interests of the countries worldwide.

The US still maintains a competitive edge in the world due to its leadership in technology and innovation. Due to its robust institutional foundations, financial options, and dynamic innovation ecosystem, the US topped the 2018 Global Competitive Index and is among the top three countries in the Global Talent Competitiveness Index 2023 of the World Economic Forum.[8] It was the technological superiority and innovation that increased competitiveness of the US vis-à-vis other countries and led to its global domination.

China since its economic modernisation has remained dependent on Western technology. It embarked on the initiative for

independent innovation in science and technology in the 2006 plan and 'Thousand Talents Plan in 2008' to develop research programmes in China by using the scientific knowledge acquired from the developed world.[9] Indigenous innovation became more important for China in the new era of digitalisation under the fourth and upcoming fifth industrial revolutions which are largely dependent on microchips and semiconductors.[10] The most important initiative was in its 14th Five Year Plan (FYP) in 2015, 'Made in China 2025', aimed at reducing dependence on foreign technology. Under this strategy, China focused on the production of 10 high-tech technologies including sophisticated Robots, AI, Electric Vehicles (EVs), as well as other new energy vehicles, and the next generation of ICT, which have the power to further stimulate China's economic growth.[11] This initiative is enabling China to shift its industry from low-end manufacturing to high-end manufacturing. China's Research and Development (R&D) spending also increased to 7 per cent with the focus on leading the 'Next Industrial Revolution'. The Internet Plus initiative is aimed to digitalise major sectors of the economy by integration of industrialisation and information for smart and intelligent manufacturing aimed at improving quality, competitiveness, and productivity.[12] Despite the high contribution of the agriculture sector to China's GDP, the economic production from telecommunications, software, and information technology totalled $587.4 billion in 2020, according to the Chinese Ministry of Statistics,[13] making China a peer to the US.

Sino-US Competition in Theoretical Perspective

One of the elements surfacing in Sino-US strategic rivalry is the quest for power. In the given global structure, from a neorealist perspective, countries either attempt to rebalance 'power' in their favour or to overtake the contender. The two theories of offensive and defensive realism have some relevance to the current strategic

rivalry, particularly in the context of gaining superiority in key technologies. Kenneth Waltz's defensive realism is accurate in that, as it explains the actions of both established and developing powers. Nonetheless, the phenomenon cannot be sufficiently explained by defensive realism. Given that defensive realism places a strong emphasis on the balance of power, a particular degree of strength is thought to be sufficient to feel comfortable. However, China is growing its autonomous skills in critical technologies, which the US fears may eventually overtake it. The US, which is leading in many technologies, is taking action to stop China.

John Mearsheimer's offensive realism can serve as a prism to view the trends in the race of critical technologies that the powerful states are using to gain domination. These technologies have the potential to change power distribution in ways not seen before. These technologies can not only increase the material capabilities but their interconnected abilities through information technology can have far-reaching consequences on distribution of power through its impact on the economic growth, military capabilities, global supply chains and also on controlling ideas, knowledge, and narratives. Although AFK Organski's 1958 power transition theory is also used to predict wars when a rising and dissatisfied power tries to overtake or reach parity with the dominant power, the theory can also explain Sino-US competition. As this paper will explain in detail, the preventive measures of the US against China resulted in boosting China’s independent capabilities in these technologies which have many implications. Since the US views China as an unsatisfied power with aspirations to reshape the world order in its favour, it sees China as having merely profited from the current economic order without contributing to its creation.

Power transition becomes even more complex in the new age as it cannot be only altered in material terms. Due to the

abilities of these technologies in power diffusion, countries need to increase strength in both these technologies and their associated policies. As explained by Joseph S Nye, Jr, the elements of power transitions are different in the world of the 21st century because of the "burgeoning revolution of information technology." The composition in the form of economic, military, and transnational linkages has different impact on power distribution at the global level. "Power diffusion may be a greater threat than power transfer in an information-based world."[14] Therefore, the increasing prowess in information technology and its infrastructure can change the power equation between China and the US, not only through their own capabilities but also by expanding influence globally for achieving their respective interests. They will not only compete for acquiring these technologies but also to adopt policies for their strategic use to maximise power. On this preposition, James Andrew Lewis, Director of the Strategic Technologies Programme at the Centre for Strategic and International Studies (CSIS) points out that "fostering national power requires creating an environment that promotes innovation in both technology and strategy and allows its adoption."[15] China is clearly not just creating critical technologies but also having a strategy, given its centralised one-party system, policy continuity, desire of rejuvenation by 2049, and a reformative outlook on the world order. This is another reason why the US has decided to take preventative action. The announcement of a $250 billion package under the United States Innovation and Competition Act 2021 was the first significant action taken by the US to restructure federal science, innovation, technology, and research in the country and to produce incredibly small computer chips in an effort to challenge China's rising dominance in high technology.[16]

The growing trade deficit with China has also been the reason for the US decoupling with the former. Nevertheless, China's rapid success in technologies is central to this measure. As decoupling would be a slow process, a new strategy of de-risking has been implemented in which the US curbs China's access to key strategic innovation partnerships and investments with China. The US banned sale and imports of five types of "made in China" communication equipment from five companies including Huawei and ZTE (a leading 5G company in China) as well as sanctions on the export of microchips and semiconductors.[17] In addition, the US also barred Chinese students from research and study in the advanced science and technology research centres and universities.[18] Following the recurring US sanctions, China launched an internal chip industry with state funds amounting to $40 billion in 2023.[19] The US still tops the Global Innovation Index (GII) in 2022, however, China for the first time in 2023 topped in 24 Science and Technology (S&T) clusters among the top 100 surpassing the US with 21 clusters.[20] Given China's population size, industrial capacity, R&D spending and successful strategic policies, it has much larger potential to excel in critical technologies.

China as Competitor to the US in Critical Technologies

To understand the relevance of Sino-US strategic competition to global power dynamics, it is important to measure China's potential in critical technologies. The rapidly evolving technologies such as space technology, cyberspace, AI, information infrastructure 5G technology, and quantum computers are essential for change in power redistribution because of their broader scope of applications in economy, military and political domains as explained earlier.

Space Technology

In recent years China has demonstrated major breakthroughs in space technologies. It is rapidly increasing its capabilities in space

exploration and independent internet or information capabilities by launching advanced satellites. China set a national record by launching dozens of satellite missions to outer space in 2023 alone.[21] According to a report, in 2020 China sent more satellites into space than the US and Russia.[22] China's Zhurong rover successfully landed on Mars on 15 May 2021, which makes it a peer to the US and Russia. China did in a single experiment what took the US space agency National Aeronautics and Space Administration (NASA) decades, as put by planetary scientist Roberto Orosei.[23] Its touch on Mars also marks China's participation in planetary exploration. The Chinese Manned Space Agency (CMSA) launched a low orbit space station Tiangong at a distance of 217 and 280 miles over the planet in 2021 with its first module Shezhou 12 to send images of earth. This space station will enable China to conduct experiments in the exploration of space.[24] Tiangong expanded to second and third modules Wentian and Mengtian in 2022 and 2023, respectively. Efforts by China are in line with its policy of becoming a world-leading country in space equipment and technology by 2045.[25]

Additionally, in June 2020, China built its own international satellite navigation system, known as 'BeiDou'. This satellite serves as a substitute for the Global Positioning System (GPS), which is owned by the US government. Experts believe that in case of a crisis, this will aid China's military systems in remaining operational. Chinese spacecraft made its first-ever return to Earth in December 2020 carrying moon rock samples. The US is still leading in overall space capabilities, but China is rapidly achieving parallels with the US, said Scott Pace, Director of the Space Policy Institute, Elliott School of International Affairs.[26] China is ahead in its mission to develop a Digital Silk Road to rewire the global network which shows its quest to achieve maximum political leverage.[27] In this regard, BeiDou will aid in providing navigation data to its domestic market and will also lead it to the global market.[28]

Cyberspace

Cyberspace as a 'network of interaction between human users and information systems' is an important medium to transmit and store data through signalling between processors and devices.[29] Cyberspace is increasingly becoming the fifth domain of warfare between rivals after the four domains of traditional warfare such as land, air, maritime, and space.[30] This domain influences policy areas including elections, trade, defence, and transparency when it comes to the bilateral relationship between the US and China.

With rapid expansion in the digital industry, the world is moving towards the next generation of the internet. Currently, IPv4 internet is prevailing and innovation is taking place to move to another internet protocol which is IPv6, most likely in the next decade. The Chinese and the US military have already expressed the "desire to move to IPv6 to support the modernisation of their large networks."[31] The Mandiant Report exposed China's extensive economic espionage programme, and Edward Snowden revealed the US PRISM Project in 2013, making cyber-enabled espionage activities the next big problem.[32] It is concerning that these operations result in hundreds of billions of dollars in annual costs for the US due to cyber theft. Despite facing new challenges, the US is still leading the world in terms of offensive as well as defensive cyber capabilities.[33] In order to safeguard its interests and raise its capabilities to the level of the US, China is building its own independent information infrastructure. In 2014, China launched the De-IOE programme, to uninstall software made by American suppliers such as IBM, Oracle, and EMC from its e-commerce companies and banks.

5G Technology

High-speed Fifth Generation (5G) wireless internet is revolutionising mobile telecommunication and real-time data transfer abilities. Coupling with other reinforcing technologies, 5G is emerging as a driver of the global infosphere. In the near future, around 6 billion

people will be interacting through 5G capabilities distributed in everyday appliances such as the Internet of Things (IoT) at an average rate of once every 18 seconds.[34] Keeping in view the amount of data produced daily, 2.5 quintillion bytes (2.5 quintillion is 2.5 x 1018),[35] 5G will enhance data-collecting capabilities by enabling universal internet connectivity of things and devices. 5G will be instrumental in enhancing China's dominance in the science of AI and other means such as deep learning mechanisms, data science techniques, and the fields of machine learning.

China is achieving excellence in 5G technology. Former Google CEO Eric Schmidt and Harvard University Professor Graham Allison admitted that China is far ahead in 5G technology than the US. China will own a 5G future if the US does not make it a national priority, Schmidt and Allison urged Biden Administration in a Wall Street Journal article.[36] China's target has been to hit 5G coverage to 90 per cent by increasing numbers of base stations in 2023.[37] By September of 2023, China claimed to have the world's largest 5G network reaching the target of around 3.19 million 5G base stations. This policy is in line with increasing 5G in China's industrial production and management. The data from the Ministry of Industry and Information Technology of China shows that "the market scale of the industrial internet industry has exceeded 1.2 trillion yuan ($167 billion) in the country, with more than 8,000 5G-plus industrial internet projects and over 89 million connected industrial devices."[38] 5G has been integrated into 70 per cent of China's economic sector within three years.[39]

Additionally, 5G has another significant potential role for tracking data. Since China has developed its satellite BeiDou combined with a 5G telecommunication system, it can enable its government to monitor, store, track, and evaluate the cell phone data of the users.[40] The geolocation system through the BeiDou satellite is extended to China's BRI partner countries. Hence, 5G will be critical for industrial and market transformation through geo-targeted advertisements.

China will not only be able to control the networks on which the data is transported, but its 5G will also enable it to access that critical data.[41] This is the domain in which these technologies have interconnected abilities which further increases China's strategic and economic leverages.

Quantum Computers

Quantum computers are advanced forms of computers based on quantum physics with larger data storage capacity and greater computational power than classical computers.[42] Since quantum computers can solve highly complex computations that cannot be solved by the world's supercomputers, this invention is another critical technology. The breakthrough in the quantum computer was first announced by scientists at Google in the US in 2019.[43] They developed the Sycamore computer which solved a numeric computation in 200 seconds that would have taken 10,000 years to solve by the world's most powerful supercomputer. After the invention by Google, the International Business Machines Corporation (IBM) also announced a classical bit-based technology that could solve the same problem in 2.5 days. Soon after that a team of Chinese physicists at the University of Science and Technology at Hefei also announced a photon computer with the ability to solve the mathematical computation called the 'boson sampling problem' in 200 seconds, an operation that would have taken a classical supercomputer 2.5 billion years to solve.[44]

In August 2022, the world's largest search engine, Baidu Inc. of China, announced the development of a 36-qubit quantum chip in addition to its first quantum computer with a 10-qubit processor, named Qianshi. Joining the global competition, China aspired to launch this technology to outside users in real-world applications. Similarly, the US tech-giant IBM and Alphabet Inc's Google also plan to launch more advanced forms of quantum computers by 2030.[45] In 2023, Chinese scientists developed Jiuzhang 3.0 quantum computer

prototype that puts China again in a leading position in the field of quantum computer research and development.[46]

Quantum computers can have multiple uses including macroeconomic and global financial markets for complex computations. Quantum computers can also be used in astronomy to enable scientists to understand the large universe. Most importantly, these advanced computers can be instrumental to the safety of critical data, but at the same time, they can endanger the IT security of other systems. For now, an encryption system is applied to safeguard the 'browsing, email, and banking data'. Quantum computers can break encryptions which depend on the complex algorithms for which classical computers can take years.[47]

Due to the unique properties of this invention, particularly its requirement for data security and also cyber vulnerability, China has joined the race with the US and the European Union (EU) by investing heavily in this field, leading them to develop independent capabilities yet in another field of critical technology. It is anticipated that a $16.4 billion investment would be made by global governments in quantum development by 2027.[48] Keeping in view the importance of this technology, the competition in the domain seems very intense. China would strive to overtake the US in this technology to safeguard its national security interests. According to experts, advancement in this field can even determine future global dominance among powers.

Artificial Intelligence (AI)

Artificial Intelligence (AI) with its super intelligent and advanced functions has broad applications including strategic information, economy, in various services, and in the military.[49] China is rapidly maximising its potential in AI. Around $150 billion are allocated by China to develop the 'innovation centre for AI' by 2030.[50] According to the *Harvard Business Review*, China is becoming a leader not only in AI publications and patents but also in AI-powered businesses of applications, i.e., recognition of speech and image.[51]

During the presidency of Donald Trump, around $1 billion was dedicated by the US to AI and quantum computing.[52] This was not enough to ensure the US primacy in this domain. A report by the National Security Commission on Artificial Intelligence in March 2021 warned the US of its lack of preparedness to compete in and defend the era of AI. It further warned that China can soon surpass the US in AI supremacy which will have serious military and economic consequences for the US. Since then, President Joe Biden has accelerated efforts in these domains,[53] leading to the creation of the National Artificial Intelligence Research Resource Task Force in June 2021 for AI innovations.[54]

In 2021, China's spending on AI innovation was $10.38 billion, which increased to $14.45 billion in 2023 and it is expected that China's market value of AI will go up to $26 billion in 2026.[55]More breakthrough inventions in AI are underway. Despite China's big spending on AI, it is facing challenges in emerging as a leader in AI by 2030. The US is using its advantage in key technologies, especially microchips, required for AI advancement. The US is preventing China access to advanced microchips through sanctions. Despite challenges, ChatGPT prompted China to create its own ChatGPT-like tools in response to the US launching of ChatGPT on 30 November 2022. China's Baidu developed its own AI chat bot in March 2023 named Ernie Bot 4.0.[56] The US's desire to prevent China from becoming the leader in AI demonstrates the technology's enormous potential for power redistribution on global scale.

Besides China and the US, some other powers including Germany and Russia, are also racing for increasing spending on AI development.[57] It brings along great potential as well as unpredictable threats. According to Russian President Vladimir Putin, "Whoever leads in this area will lead the world."[58] These tendencies reflect both competition and techno-nationalist efforts, especially among

countries that are politically and ideologically at odds with China and Russia.

Implications

Rising Techno-Nationalism and the Race for Semiconductors

The rapid advancement in technology and its vitality in increasing national power are giving rise to techno-nationalism. The way the scientific superiority of a nation, especially in the hi-tech domain, is linked to its prosperity, and national security, can be termed 'techno-nationalism'.[59] As a response to intensifying technological competition and keeping in view the technological leadership for national security, many countries around the world announced budgets and set goals to achieve national capabilities instead of dependence on other powers. The EU and the US set targets for securing maximum production of semiconductors by 2030.[60] In the spirit of national capacity and in response to the US curbs on exports of microchips, in 2023 alone China imported microchip production tools worth $40 billion to boost its indigenous production.[61]

Techno-nationalism is more prominent between China and the US. It is not only the strategic rivalry; the ideological differences are fostering 'competitive techno-nationalist policies' between them.[62] Both countries have varied standards for the regulation and governance of these technologies. Techno-nationalism shows a normative divide. Democratic and state-centred governments can employ technologically-enabled methods to empower drastically diverse norms on data privacy, censorship, surveillance, digital currency, transparency, and intellectual property. Internally, China maintains its independent information and communication system. Its technology diffusion to the world can give it leverage for controlling information outside of its country. This has been considered a threat by the US. This is one of the reasons for the US to prevent China's

leadership in these technologies. The techno-nationalist diverse ideologies can destabilise the international order in unprecedented ways.[63] As quantum computers and specialised chips further power AI applications, comparative competitiveness and comparative advantage in these technologies will be central to the US and China's competition.[64] The special characteristics of quantum computers and AI will make them indispensable for other technologies in the coming years. And so, the production of these technologies in large quantities will also require a larger supply of microchips and semiconductors. This scenario determines the future competition for rare-earth resources and semiconductor production which is causing strategic decoupling in key supply chains between China and the US.[65] This will prompt diversions or protections of markets and services, the key components, raw material and technical knowledge. The EU and Japan are also concerned and willing to raise protections against China.

This tendency of techno-nationalism will keep on interfering in the trade of high-tech infrastructure among countries leading to alliances and distribution of power. The US is pushing its close allies for anti-China tech alliances. The alliances will also be defined by interests of countries and their ideological inclinations. This development poses challenges and also opportunities to other countries for economic, strategic and diplomatic benefits. Some countries with advanced infrastructure for production of these technologies will play neutral between the two countries. Malaysia is one such example which is taking advantage of the Sino-US tech competition.[66] Malaysia is becoming a new hotspot for high-tech firms because of its well-established infrastructure for the production of microchip and semiconductors.

Private Sector and Control over IT Governing Standards

In the debate over the governing standards of emerging technologies, there is also the aspect of the private sector which is heavily involved in developing and controlling advanced

technologies. In the US, mostly private sector big enterprises control advanced technologies. The private sector ownership of many high-tech companies and also their globalised chain of production and utilisation can scarcely give leverage to the governments to make policies and regulations. Alibaba, Alphabet (Google), Amazon, Apple, ByteDance, Meta (Facebook), Microsoft, and Tencent are some of the examples of big private high-tech companies with potential leverage in shaping the governing standards of the emerging technologies.[67] This is especially true when technologies are created solely for financial gains and their development paths are completely determined by market forces. These companies contribute to the revenues of the host countries. In case the US and China impose restrictions on these private firms due to their techno-nationalist tendencies, it will also result in the financial losses and reduction in further investments.

High-tech enterprises work in the market ecosystem of the US, China, and other countries. Mostly these enterprises in the US work independently. Even though Chinese State-Owned Enterprises (SOEs) are heavily involved in the infrastructural projects of BRI, the private companies have a greater share of GDP at around 60 per cent. Moreover, China's private companies contribute to innovation in the range of 70 per cent, urban employment at 80 per cent, and new jobs at around 90 per cent. Similarly, private wealth is also responsible in China for 70 per cent of investments and 90 per cent of exports.[68] The global 5G revolution is being led by Huawei, which is eager to export its innovation. Despite the remarkable success of China's private technology sector, Chinese government enjoys a certain level of governance control over these companies. There is a stark difference in the government systems of the US and China. China maintains a centralised system. Therefore, the regularisation of its private sector is also different. However, as compared to China, the US may have less control over the policies of its private high-tech vis-a-vis its responses

to China. This may give the US less leverage to undertake protective measures by prohibiting China-led technology in its economic ecosystem. The consequences of this potential misuse of these technologies can be globalised due to the integration of economies and growing connectivity.[69] This is the reason that governing standards of these technologies prompted US sanctions against China's 5G.

Cyber Security Concerns

The mutually reinforcing capabilities of the critical technologies, their proliferation across all fields, their infosphere in which data is transferred or received, and different governing standards of data privacy have potential consequences for cybersecurity. Cyber threat is not limited to one sector or a single country. It is now more overarching due to the dependence on the cyber infosphere worldwide. The information access through Chinese 5G because of its intelligence value is seen from a national security perspective in the US. The interconnectedness of information-based technologies, communication, and data privacy remains vulnerable to breaches and cyberattacks.[70]

Some of the critical technologies as explained in this paper can give leverage to one country over another in cyber protection. For instance, quantum computers may be used to protect as well as attack other computers for data theft. Data encryption relies on the ability of computers to generate random secret numbers. Cyberattacks can take place in case of the random numbers of classical computers. While quantum computers can generate such random numbers, which may not be vulnerable to cyber-attacks, quantum computation bears the potential to threaten the operations of the cryptographic protocol. According to estimates, a quantum computer will be in existence by 2035 with the ability to crack the crucial RSA2048 cryptographic scheme which is so far considered as a reliable encryption for the safety of data.[71] The block-chain technologies including the five major

crypto currencies, "Bitcoin, Ethereum, Litecoin, Monero, and ZCash are considered to be vulnerable to attacks from upcoming quantum technologies."[72] There is a private key for storage of crypto currencies which can be accessed by hackers.

The conflicting governing standards for these technologies and their role in increasing the country's overall capabilities will also have consequences for regulating the proliferation of these technologies. Big power politics and division can undermine the effectiveness of many multilateral organisations. Dividing the world into two camps of techno-political spheres of influence can also have consequences for future dialogue-related global risks for cybersecurity. The non-state actors can benefit from this polarisation and threaten cyber safety in the world.

From Geopolitical to Techno-Political Rivalry

The development and use of information-based critical technologies underpinned by ideological, nationalist, and political motives can create a techno-political sphere of influence. The term 'techno-political' can be used for the politics in the digital age. It implies the policies of countries in response to the technology-led influences on the country's overall power configuration, political system and social norms and relations across borders. Given the broader impact of critical technologies, countries will not only be involved in geopolitical contentions but the technologically-advanced countries will be subject to techno-political disputes. As these technologies are now central to economic, security, and narrative-building, setting their governing standards for the use of these technologies is aimed at a greater advantage over the contender. Since China and the US follow different political systems and values, they will steer different political objectives to shape the global politics in favour of their respective objectives. Both the operation of these technologies and commerce in these technologies will shape political influence. This techno-political competition is rising between China

and the US.[73]As mentioned earlier, both countries are developing independent capabilities in critical technologies. The impact and influence of these technologies will also vary with their different governing standards. China and the US, both have their fears and concerns about each other. The way the US is threatened by China's data surveillance or espionage through its 5G capability, China is also concerned about the US information war and its liberal agenda. Countries like Germany and the EU are also concerned about data privacy due to large-scale Chinese ingress in technology investments.

Apart from cybersecurity concerns of economic losses or breaching of military and defence-related data, there are also fears of political manipulations, election results and leveraging these technologies for geopolitical gains. Transferring these technologies to allies and like-minded partners can create contending groups and alliances. Moreover, western countries are also concerned about increasing authoritarian tendencies. Additionally, European counties are concerned about how the data surveillance capabilities will have implications for the democracies. According to them, "Chinese high-tech businesses not only support authoritarian and oppressive regimes, but they also encourage the spread of anti-liberal ideas about government and society."[74] So far, the world has been dominated by the US-led infosphere. However, China as an emerging leader in the production of these critical technologies will also be enabled to control information, big data, eventually creating political influence. This will create divided governing standards of critical technologies. Mainly the defence policies of countries are made in response to geopolitical conditions. Contemporary big power politics will be more about the techno-political interplay.

China's Technology-Enabled Economic Gains

The power of technology is more encompassing than military superiority. In the past, military superiority would give the country a central place. In the contemporary world, the development,

production, sale, and, application of critical technologies can increase all kinds of capabilities. Technology will continue to grow and it will become a concern for national and economic security. The world's economy is now digitalised and the networking of all commercial activities is dependent on IT. The demand for these technologies is increasing. The production houses of these technologies have a never-ending scope for making wealth. Both the hardware and software and its application industries are the biggest beneficiaries. Furthermore, according to research conducted by the World Bank, by 2030 China will economically further pull ahead of the technologically developed countries because its economy will be further strengthened through innovations in areas of comparative advantage.[75] The scale and potential of China's enlarging digital economy is the result leveraging the empowerment of expanding 5G in the industrial and financial sectors of China.[76]

AI alone is now considered a new frontier in China-US competition for comparative economic gains. China focused on AI in the last decade and now this high-tech is supporting China's economy. China is the leading country in research, development, and economy linked to AI. According to Stanford University, China is among the top two countries in AI vibrancy in the world. One-third of all scholarly publications and citations in the discipline were produced in China, which also drew $17 billion in private-sector investment. The analysis by McKinsey projects indicate that AI may add over $600 billion to China's GDP by 2030, with $335 billion of that amount coming from autonomous vehicles alone. This is due to the way that China has connected AI-driven consumer apps like Alibaba, ByteDance and Taobao. The integration of AI with Taobao, the largest e-commerce app in China, can give it one billion customers[77] by smart searching or suggestions with increased efficiency for transactions. The e-commerce platform or the extensive availability of products on social apps has further increased China's advantage in digital economy.

Race for Autonomous Arms in Military Domain

The automation of arms is more relevant to the domain of robots and AI functions. Autonomous weapons, automated armed vehicles, and super intelligent decision-making against the adversary during wartime; robots, automated precision drones, and espionage capabilities, are only a few perceived functions of AI in its military application.

For some experts, AI is just an extension of human intelligence supported by machines. But for others, the application of this technology in various domains of modern defence systems such as nuclear weapons would have consequences. AI's military applications, such as Intelligence, Surveillance, and Reconnaissance (ISR) operations, sensor data processing and interpretation, or geospatial imaging analysis, will reduce the role of humans in warfare and ultimately alter the nature of the conflict.[78]

As both China and the US have interest in advancing their defence capabilities by employing critical technologies, it will be hard to determine whether it would be China to develop superior AI arms or the US will come out as a victor in this AI arms race. However, it is a fact that the US and China are locked in competition for automation and AI hegemony. Approximately, a 45 per cent increase is noticed in the US investment in AI projects between 2016 to 2022.[79]About 685 active AI projects are on the agenda of the US Department of Defence (DOD) under the project Maven to integrate AI into military structures. The US has already used these AI algorithms to determine targets in military operations in Syria and Iraq.[80]

China wants to rival the US's military prowess by dominating the technologies related to the fourth industrial revolution.[81] China also decided in 2020 to integrate AI into the military structures by 2025. It anticipates itself as a global leader in AI by 2030[82] and also seeks the integration of civil and military AI forces to make its armed forces more intelligentised, meaning to equip them with disruptive

technologies of new era warfare.[83] The discovery of nuclear weapons technology was different from the development of these critical technologies. There were limitations on its production and expansion. However, these technologies are already well integrated into the systems on a large scale with continuous evolution creating security vulnerabilities in many unprecedented ways.

Conclusion

The competition among great powers is traditionally analysed in the domains of diplomatic, military, and hard power. However, global information infrastructure is a more comprehensive domain for great power competition in the new era. This study found that critical technologies are vital for acquisition of power because of their interlinked, interconnected abilities, wider applications and strategic use of information. The emerging technologies discussed in this paper are related to the rapid advancement in ICT. The innovations in the listed technologies are bringing changes in the global economy, politics, and security in unprecedented ways. The strategic use of information complemented by advanced technologies can strengthen the comparative advantage and relative gains of one country while weakening the other country. The struggle for oil and advanced nuclear weapons was central to power competition between powerful countries which is still true. Now the biggest domain for achieving greater power against a rival lies in increasing potential in critical technologies. These technologies can substantially shift the military and economic balance.

Since China announced its 'Made in China 2025' strategy in 2015 and increased R&D, it has achieved much ground to close the gap with US in critical technologies. Keeping in view, China's growing potential in AI, quantum computers, space, cyberspace and 5G as studied in this paper, qualifies China as a global competitor to the US. It was technology and innovation that gave the US superpower status.

Therefore, China's prowess in this domain has threatened the US position and has prompted it to contain China. Secondly, the developments in these domains also suggest that both countries are not seeking parity and instead strive to achieve superiority in these technologies because of the huge potential that they bear to give a powerful position to the country that would lead in these technologies. Since the US is the largest economy and the most powerful country, and China is the second largest and a qualified contender to the US primacy, the strategic competition between the two are linked to the global power dynamics because of their huge impact.

Growing techno-nationalism is leading the world to new dynamics in the global power structure and security landscape. The race for microchips, semiconductors, essential resources for these advanced chips, division on regulation of these technologies, as well as their impact on global supply chain and trade have a massive impact in redistribution of power and influence globally. China's efforts to excel in critical technologies and US's preventive measures will also lead to a new conflict. This struggle also hinders them from agreement on governance of critical technologies and rules for their proliferation. As studied, these phenomena, in view of offensive realism and power transition theory, is driving them for continuation of independently developing capabilities for their desire for power and domination. Techno-nationalism will also adversely impact scientific knowledge as a global public good.

As in power transition theory, creating parity or overtaking an established power can cause war. The way the US critically views China-led technologies and considers it a challenge to the western-led normative order in the world is leading the conflict to ideological competition. The divide over governance of these technologies between the two largest producers of the same, and the nationalist tendencies and strategic rivalry between them for power acquisition

also increases risk for cybersecurity and lack of cooperation in this domain against security risks posed by non-state actors or cyber terrorism. Since the domain of competition is much broader due to the wider scope of the applications of these technologies, countries will have more leverage for political gains through technology. As previously the contestation between countries was more driven by geopolitical interests, in the current scenario it will be more driven by politics of technologies. The country leading in technology will have more political influence globally with propensity of shift in power.

The technology enabled economic gains for China because the size of its population and production capacity is another indicator for the role of these technologies in changing the power equation in the world. China's growing prowess in space technology and the integration of AI in defence systems is also making China a serious contender in military might with the US.

These findings show that the domain of critical technologies have scope and potential for changing the power equation between China and the US. Even if achieving global hegemony is not desired by China, the intense competition in these technologies as proved by this research has prospects for conflict with far-reaching consequences for the global economic future, peace, and security. Therefore, there must be limitations through regulations and a global consensus on the proliferation and governance of these critical technologies in the same way that nuclear technology has been regulated.

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