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Industrial policy, techno-nationalism and Industry 4.0: China-USA technology war

Política industrial, tecnonacionalismo e Indústria 4.0: a guerra tecnológica entre China e EUA

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RESUMO: Este artigo analisa a evolução da guerra tecnológica entre China e EUA em um contexto de exacerbamento das estratégias tecnonacionalistas de desenvolvimento industrial e tecnológico. Esta análise concentra-se majoritariamente na estratégia chinesa de fomento à Indústria 4.0 e nas implicações das restrições impostas pelos EUA a sua busca pelo desenvolvimento autônomo de tecnologias centrais no paradigma em gestação. Parte-se da hipótese de que tais políticas, ao impulsionarem as tecnologias características da Indústria 4.0, têm como objetivo forjar um novo paradigma tecnoeconômico e reconfigurar as bases sobre as quais se assentam a dinâmica da concorrência intercapitalista e interestatal. A principal contribuição pretendida pelo trabalho é a análise das implicações da Guerra Tecnológica entre China e EUA a partir da segmentação do paradigma tecno-econômico da Indústria 4.0 em diferentes camadas, para além do debate tradicional acerca da transição para as redes 5G.
PALAVRAS-CHAVE: Guerra tecnológica; tecno-nacionalismo; Indústria 4.0; política industrial; economia chinesa.

ABSTRACT: This paper aims to analyze the evolution of the technology war between China and the USA in a context of exacerbation of techno-nationalist strategies for industrial and technological development. This analysis refers mainly to the Chinese strategy to deploy Industry 4.0 and the implications derived from US imposed restrictions on Chinese efforts to develop indigenous technologies that are central in the forthcoming paradigm. The hypothesis is that such policies, by boosting Industry 4.0, aim to create a new techno-economic paradigm and thus reconfigure the bases of inter-capitalist and

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interstate competition. The main contribution to the literature is providing an analysis of the implications of the technology war between China and the USA in different layers of the Industry 4.0 techno-economic paradigm, in addition to the mainstream debate about the transition to 5G communication networks.
KEYWORDS: Technology war; Techno-nationalism; Industry 4.0; Industrial Policy; Chinese economy.
JEL Classification: O53; O14; O25; O33; O38; L52.

INTRODUCTION

This article analyzes the evolution of the technology war between China and the USA according to three aspects: (i) the resumption of the post-2008 crisis debate on industrial policy and development, (ii) the rebirth of techno-nationalist development strategies in a context of reviewing the supporting elements of globalization since the last quarter of the 20th century, and (iii) the deliberate efforts by developed countries to push the technological frontier towards what is conventionally called Industry 4.0.[1]

The hypothesis is that the combination of these elements is part of a broader context aimed at creating a new techno-economic paradigm and thus reconfiguring the bases of inter-capitalist and interstate competition. This reconfiguration, in turn, is key to reaffirming the technological and economic leadership of the main national economies and, at the same time, imposing conditions on Chinese progress regarding those same elements.

Drawing on this framework, the article intends to make two contributions to the literature, both focused on the Chinese strategy to deploy Industry 4.0 and on the implications derived from USA imposed restrictions on Chinese efforts to develop indigenous technologies in the forthcoming paradigm.

The first is to describe Chinese efforts to systematize the country's industrial policy, considering the co-evolution of transformations in industrial policy and development strategy as well as the simultaneous coexistence of different stages of this development strategy. It is noteworthy that such coexistence combines, in different regions of the country, qualitatively distinct sectors, businesses, technologies and industrial policies. This is due to the economic, geographic and social specificities that make the Chinese development and catching-up process unique when

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[1] In order to provide a framework of industrial policy guidelines capable of dealing with the mentioned transformations, Diegues et al. (2022) proposes a normative typology based on the dialogue between the developmental and neo-Schumpeterian theoretical framework. This typology intends to suggest a set of heterogeneous policies that are conditioned by local productive and technological capabilities and by political and institutional characteristics. Based on these conditions, the typology suggests a diversified set of policies according to different levels of sectoral and technological development. As they are based on a dynamic analysis of conditions, these industrial policies co-evolve in parallel with the permanent transformations of the techno-productive paradigm.

compared to the flying geese pattern of growth. Contrary to the assumptions of the flying geese model, it is suggested that the advance of Chinese manufacturing towards areas of greater technological complexity does not necessarily imply the absolute reduction of domestic manufacturing in less complex and labor-intensive sectors. The reason is that, rather than moving abroad, those sectors would be gradually relocated to regions inside China with lower costs and lower levels of productive development.

The second and main contribution intended by the article concerns the analysis of the implications of the tech war between China and the USA in different layers of the Industry 4.0 techno-economic paradigm, in addition to the mainstream debate about the transition to 5G communication networks. Thus, it analyzes the potential consequences of this clash in different technologies or layers of cyber-physical systems in smart services and manufacturing, non-systemic equipment and processes enabled by 4.0 technologies (new generation robots, additive manufacturing, etc.), and enabling technology infrastructure (5G / telecommunications, cloud computing, internet of things, sensing and new generation semiconductors).

It is concluded that the sectors in which the potential of Chinese development seems to be more advanced are those related to smart services, artificial intelligence and big data. On the other hand, the enabling infrastructure layer related to state-of-the-art semiconductors is the main gap of China's strategy as laid out in the Made in China 2025 plan and in the goals outlined for the China Standards 2035 plan. Therefore, given the highly cross-sectoral and pervasive nature of those plans, overcoming this gap is key to enabling the deployment of other technologies in order to create a new techno-economic paradigm in which Chinese industry and technology play a leading role.[2]

In order to develop these contributions, the article is divided into two sections in addition to this introduction and the conclusion.

1. INDUSTRIAL POLICY AS THE VECTOR OF CHINA'S DEVELOPMENT STRATEGY TOWARDS INDUSTRY 4.0

In analyzing the relationship between China's industrial policy and development strategy since the last quarter of the 20th century, the first observation is its capacity for reconfiguration. In general, an important feature of this movement is the

[2] Diegues and Hiratuka (2021) and Hiratuka and Diegues (2021) stress this gap in analyzing the "New Generation Artificial Intelligence Development Plan" (AIDP): "It is important to highlight that the strategic assessment of the AIDP explicitly recognizes the gap between China and developed countries in relation to basic research, development of algorithms and key equipment, semiconductors, software, skilled labor and a structured ecosystem" (Hiratuka and Diegues, 2021, pp. 5).

co-evolution of transformations in industrial policy and the other aspects related to development strategy (Bresser-Pereira, Jabbour and De Paula, 2020).[3]

Besides this co-evolution, on a logical level there is the simultaneous existence of different stages of development strategy that combine qualitatively distinct sectors, technologies and industrial policies in different regions of the country. This is due to the economic, geographic and social specificities that impart a unique historical trait to the Chinese development and catching-up process when compared to the experiences of other countries.

Given the productive, technological, regional and social heterogeneity, added to China's size and population, this process cannot be understood as a strategy to emulate the historical experiences of countries like Japan and South Korea within the flying geese pattern of growth (Akamatsu, 1962; Palma, 2009). This is because structural transformation aimed at building an economy based on greater technological complexity, dispensing with manufacturing of medium and low technological intensity, faces obvious barriers in terms of incorporating and spreading the fruits of technical progress to the immense Chinese population. By way of illustration, it is worth noting that labor- and natural resources-intensive sectors accounted for 38% of Chinese manufacturing value added in 2017 (INDSTAT2, UNIDO). Regarding exports, the textile and clothing sectors alone accounted for a US$ 365 billion surplus in 2018, compared to US$ 383 billion of the electronics and electrical equipment sectors.[4]

Therefore, while one observes a quest for building an economy based on indigenous innovation – which dates back to at least the 10th Five-Year Plan (2001-2005) and is characterized by Developed by China (Wubbeke et al., 2016) – one also notes the coexistence between the industrial policy pillars that, since the last quarter of the last century, have sustained the strategy to promote the Made in China movement and a fairly solid presence up to recent times in sectors of low technological and high labor intensity, as argued by Nolan (2013).

In summary, contrary to what a linear step-by-step interpretation of Chinese development might suggest as an emulation of models from other Asian countries based on the flying geese pattern, there is permanent complementarity and mutual dependence among the different stages of development of domestic production.

On the one hand, such complementarity is necessary due to the geopolitical

[3] The authors argue that the co-evolution of institutional cycles and transformations in China's development strategy is a distinctive instrument of Chinese planning logic and key to understanding its dynamics of structural transformation.

[4] Araújo and Diegues (2022) offer a detailed qualitative analysis of the relationship between the Chinese technological catching-up process and the transformation of its export agenda based on domestic value added. By proposing an indicator of technological sophistication of exports, the authors show that in 2015, in sectors of high and medium-high technological intensity, more than 40% of value added is domestic. They also show that these sectors account for more than 50% of Chinese gross exports, besides being those in which China has the greatest forward participation in global value chains (i.e., in the generation of domestic value added that will be incorporated in exports made by other countries).

ambitions of Chinese civilization and the challenge of spreading the fruits of technical progress to the huge Chinese population, which cannot be done based on an export-led model with highly specialized insertion in global value chains. On the other hand, it is only possible due to industrial policy coordination centralized at the National Development and Reform Commission and SASAC (State-Owned Assets Administration Commission) and the consequent socialization of investment (Bresser-Pereira, Jabbour and De Paula, 2020).

It is understood that industrial policies to promote activities associated with the so-called Industry 4.0 and the digital economy in China are part of a broader context of permanent transformation of domestic production and the consequent pattern of international insertion.

In this context, since the 10th Five-Year Plan (2001-2005) there has been a quest to develop an economy oriented to indigenous innovation, which is gradually enhanced through initiatives such as the Medium and Long Term Plan for the Development of Science and Technology and its numerous mega-projects, as well as in the following Five-Year Plans, especially the 13th (2016-2020). This strategy results from the interpretation that technological complementarity with the USA and Japan based on instruments such as licensing and joint ventures would increasingly limit the development of Chinese indigenous innovation in key areas of the changing techno-productive paradigm. Therefore, strengthening industrial policy coordinated and executed by the state in its various features, both direct and indirect, aims at two major goals that coincide with China's two centenaries.

The initial aim is the consolidation of a moderately prosperous economy by 2021, on the centenary of the founding of the Chinese Communist Party. With the efforts to circumvent the middle-income trap, the goals for 2049 – on the celebration of the centenary of the Communist Revolution – are to establish the country as an industrial and internet superpower, a global leader in sectors of high technological intensity (Wubbeke et al., 2016).

The initiatives materialized in the Made in China 2025 plan (and in several subsequent plans such as Internet Plus and Next Generation Artificial Intelligence Development) are intended to meet a two-fold challenge. On the one hand, increasing competitive pressure caused by the initiatives of leading countries to push the technological frontier towards Industry 4.0 is seen as an attempt to reorganize the determinants of competitiveness and offset the competitive edge developed by Chinese industry. On the other, the search for cost reductions with the permanent relocation of industries to other countries in the East and Southeast Asia could also reduce China's relative competitiveness, especially in sectors of medium and low technological intensity.

Given these two challenges, promoting Industry 4.0 and the digital economy are important vectors to enable Chinese companies to obtain a greater share of global value chains, thus circumventing a hierarchically inferior position.

The set of industrial and technology policies guiding this broader strategy is part of a context of intensifying international inter-capitalist competition, accentuated after the 2008 crisis. Based on an interpretation that came to be called techno-nationalist, such policies are organized through a top-down approach and are materialized in various initiatives that feed back into each other to reinforce China's innovation system while strengthening its production structure (ZHOU and LIU, 2016; Chen and Naughton, 2016).

In this sense, as suggested by the seminal contributions of Reich (1987) and Samuels (1994), this paper understands techno-nationalism as the set of policies associated with the view that technological and scientific development must be understood as instruments for the creation of economic and military asymmetries in an international system characterized by instability and permanent inter-state competition. In the words of Samuels (1996 [1994]), "technology is a fundamental element in national security, that it must be indigenized, diffused, and nurtured in order to make a nation rich and strong" (SAMUELS, 1996, p. 33). Thus, "a domestic economy can be mature, and the nation secure, only if it exerts substantial control over the generation of knowledge and the standards by which design and manufacture are undertaken" (Zhou and Liu, 2016).

Generally speaking, such guidelines can be understood from the coexistence of three major vectors of materialization, combining efforts in R&D, innovation, funding and forms of state action in accordance with the strategies and current stages of productive and technological development of the domestic business framework. Within the limitations inherent in any effort to build a typology, Chart 1 seeks to break down schematically the important qualitative differences in the strategies of traditional state-owned companies, large companies initially and still mostly focused on the local market, and technology-based companies. The idea, therefore, is to systematize the main characteristics related to competition, innovation, and accumulation of three large groups of Chinese companies. This systematization involves a comparative analysis of the different technological strategies, the different forms of state participation in supporting companies and also the variations in instruments and institutionalism used to this end.

This systematization effort relates to the analyses by Pearson (2015), Nolan (2013 and 2014) and Naugthon and Tsai (2015) insofar as those authors seek to highlight important differences in the deployment of Chinese development strategy according to different sectors and companies. Based on quantitative evidence of national and international market share and technological efforts, Nolan (2013 and 2014) analyzes the Chinese catching-up process based on the hierarchy among multinational., state-owned companies and other non-state owned businesses of rapid growth. This attempt at hierarchization is also present in Tsai and Naugthon (2015) and more explicitly in Pearson (2015). The former emphasizes that the great capacity of the Chinese state to directly and indirectly coordinate the dynamics of accumulation in the different layers of the structure of production lies at the core of what they call State Capitalism. Such coordination leads to: (i) direct state control of strategic sectors, (ii) broad and vigorous industrial policy, and (iii) dominant state position in the banking system and stock markets. Also emphasizing coordination, Pearson (2015) provides qualitative evidence that makes it possible to divide the Chinese economy into three layers based on regulatory standards. The first consists of cross-input sectors or those based on natural monopolies, invariably owned by large state-owned companies, and directly coordinated by the central government through SASAC. In the middle layer, still according to Pearson (2015), are both state-owned regional and municipal companies and non-state owned companies in sectors where technological dynamism and relations with transnational companies are key to China's development strategy to build a technological superpower. Those sectors include electronics, machinery, vehicles, chemistry, and pharmaceuticals. Last, the third layer comprises smaller private companies operating in light industry, consumer goods and other sectors aimed at exporting low-cost products (Pearson, 2015).

This is precisely the backdrop of the typology described in Chart 1. It benefits from previous contributions and aims to complement them by detailing how industrial and technology policy is pursued in the different layers.

Chart 1: Systematization of Chinese industrial and technology policy according to different strategies, instruments and forms of state participation and internationalization

	Traditional SOEs	Large companies focused on local market	Technology-based companies
Main technology strategies	Modernization at productive, technological and organizational level	Consolidation of technological catching-up, strengthening of sophisticated engineering and innovation capabilities (design and brands)	Consolidation of innovative capacity in frontier areas, with high pervasiveness and technological standards not yet established
Main instruments of industrial and technology policy	Controlled market access to avoid excessive competition, local content requirement and use of public procurement	Controlled access to international capital, public procurement, diverse requirements for joint ventures with local companies and technology transfer to them, attraction of R&D centers	Consolidation of a solid national innovation system, strong incentive to establish local technology standards, public procurement mainly in new areas and substantial availability of resources for innovation and investment in "emerging industries"

Main means of state coordination	Directly, via SASAC	Public funding as an instrument for business concentration and investment targeting	Systemic, focused on indirect coordination via National Strategic Plans in specific areas
Main means of internationalization	Traditional / access to resources, to markets, etc.	Acquisition of brands, markets and indirectly of productive and technological capabilities	Traditional / access to resources, to markets, etc.

Source: Authors based on Nolan (2013 and 2014), Pearson (2015), Nolan (2013 e 2014), Tsai and Naugthon (2015), Bresser-Pereira et al. (2020), Lee (2018) and Burlamaqui (2020).

Regarding specifically the relationship between state-owned and private companies in China's National Innovation System, one also observes the coexistence of different institutionalizations of learning efforts according to the different stages proposed in Chart 1. Briefly, there is large state participation via laboratories and public research institutes to promote general purpose technologies and the development and application of technologies still in their gestation period (such as some linked to Industry 4.0). In areas where the technological standard is highly stable, SOEs generally carry out internal learning efforts aimed at incremental and process innovation. In disruptive areas, in turn, Naughton (2021) highlights the institutional innovation of allowing the main SOEs to operate as "State Capital Investment and Operations Companies" in order to sponsor the creation of "Industrial Guidance Funds," whose goal is to indirectly finance innovation in non-state companies, many of them highly promising start-ups, in technological areas with high disruptive power (such as China Venture Capital, created by Guoxin).

According to the proposed typology, the Chinese market is the main source of income of state-owned enterprises (SOEs). Despite their prominent presence in the economy, they are generally more relevant in typical Fordist sectors such as petrochemicals, core industry and metal mechanics. Such companies have mainly advanced in the internationalization strategy in traditional ways, seeking to exploit natural resources and gain access to markets to expand their potential for accumulation.[5] Among them are the oil giants (Sinopec – 5th largest global company in revenue in 2020 according to Fortune Global 500, China National Petroleum – 4th, CNOOC – 64th), power companies (State Grid – 2nd, Three Gorges), from the chemical sector (Chemical China – 164th and Sinochem – 109th), transport and engineering equipment (China State Construction Engineering – 18th), food and beverage (COFCO – 136th) among countless others.

[5] According to Fortune Global 500, in 2021, among the global top 100 earning companies, 30 were Chinese. Among the 500 largest this figure is 135, compared to 122 from the USA.

Among the main industrial policy guidelines for these companies is the need to advance in production and technology modernization (Nolan, 2013 and 2014). To this end, traditional instruments are used such as prior license requirements to operate in the Chinese market, market reserves and local content requirements. They are boosted by a comprehensive effort to coordinate targeted investment decisions at SASAC (Jabbour and De Paula, 2020).

It is worth noting, however, that although modernization and internationalization aimed at expanding the potential for accumulation are defining traits of this layer, strategies that are not necessarily restricted to the broader pattern of the aforementioned layer are also observed. Furthermore, it is noteworthy that, as is typical of Chinese development policies, there is a constant effort of experimentation, adaptation, and transformation – albeit gradual and cautious – of SOE strategies. Thus, contrary to what an interpretation of the typology might suggest based on rigid limits to defining the agents' strategies, there are cases of internationalization aimed at incorporating technologies (such as the purchase of Syngenta by Chemical China) and of SOEs strongly present in frontier technology areas (for instance, State Grid is the leading Chinese company in number of artificial intelligence patents, according to information from the CISTP of the University of Tsinghua), among other possible examples.

In the case of large companies basically focused on the local market in sectors that do not overlap with those of traditional SOEs, the goal of industrial and technology policy is to consolidate the catching-up strategy through business centralization, advance in R&D intensive activities and brand building (Nolan, 2013 and 2014). Prominent among such companies are those focused on the durable goods sector, such as Haier and Midea), the numerous automobile companies, state-owned or not, such as SAIC, DongFeng, BAIC and BYD, machinery and equipment manufacturers, also state-owned or not, such as XCMG, LiuGong and Sany, and those in the aeronautical sector, like COMAC, among others.[6]

For these companies, the main challenge seems to be catching up decisively with foreign counterparts, especially in activities with greater capacity to generate value. To this end, efforts to build up their technological and productive capabilities, and also their brands, are associated with a domestic strategy of simultaneously fostering Schumpeterian and Keynesian efficiency.[7] The industrial policy is supported by the huge and dynamic internal market to enable the generation of a virtuous circle combining high investment rates with the permanent search for technological learning.

As Burlamaqui (2020) argues, this trend benefits from a large amount of avail-

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[6] The three main Chinese automakers (SAIC, Changan and Dongfeng) sold in 2018 respectively 2.95, 1.5 and 1.2 million units. The recent launch of the C919 (which aims to compete with Airbus A320 and Boeing 737) is an example of catching-up strategy in relation to international competitors.

[7] These are concepts of efficiency that oppose the static perspective of Ricardian allocative efficiency by highlighting its structural dimension, either by diversifying towards sectors with greater appropriability and innovative dynamism (Schumpeterian efficiency) or with greater income elasticity and market dynamism (efficiency Keynesian). See Dosi et al. (1990).

able funding coordinated by China's Big Four banks (ICBC, CCB, ABC and Bank of China), as well as by the China Development Bank, the Export-Import Bank of China, and regional banks. The Big Four ranked 3rd and 5th among the largest global banks in terms of assets in 2019. According to Fortune 500 data, the total assets of these banks was 57% greater than the sum of the four largest USA banks in this same year.

In addition to cross-sectoral financial support, learning derived from the establishment of joint ventures with transnational companies is enhanced by an increasingly competent innovation system and, recently, by an aggressive internationalization strategy seeking to acquire brands and markets. Among the paradigmatic cases for this group of companies are the purchase of Swedish Volvo by Geely, of MG Rover by SAIC Motors, and of Pirelli and Syngenta by Chemical China, among others.

Lastly, for sectors in which a number of technology-based companies are close to the international frontier, state participation is systemic and pervasive, albeit in many cases indirect. Firstly, there are large and growing funds available for the national innovation system (Zhou and Liu, 2016). According to OECD data measured by purchasing power parity, R&D expenditures in relation to China's GDP increased from 0.89% in 2000 to 2.4% in 2018, with accelerated growth from the mid-2000s (275% between 2007 and 2018). This meant that in 2018 China's R&D spending was 95% greater than in the USA, four times greater than Germany's and 3.2 times greater than Japan's.

In addition, public procurement discretionally favors products with indigenous technology and once again the Chinese financial system – as well as the emergent and thriving venture capital market – has provided significant funds for domestic R&D activities, even when compared to global technology leaders such as the USA, Germany and Japan (Zenglein and Holzmann, 2019). The consequences of such vigor have been diverse. Regarding unicorn startups alone (companies valued at over US$ 1 billion), according to the Global Unicorn Club ranking of CB Insights, the influential market intelligence platform in high-tech areas, in July 2020 there were 476 unicorn startups in the world, of which 122 were Chinese and 229 were American. However, when analyzing market value, the Chinese companies were worth US$ 312 billion compared to US$ 316 billion for US companies.

According to Lee (2018), benefiting from this scenario are a myriad of companies mainly focused on the digital economy such as Baidu, Alibaba, Tencent, iFlytek, SenseTime, Megvii, Huawei, ZTE, DJI, Cambricon, Lenovo, Xiaomi, Vivo, Oppo, the semiconductor chip makers SMIC (Semiconductor Manufacturing International Corp.) and HiSilicon, among others.[8] Such advances are also evident from the rapid and

[8] In the second quarter of 2021, among the top five companies in number of cell phones sold, three were Chinese: Xiaomi (16.9% market share), OPPO (10.5%) and Vivo (10.1%). The others were Samsung (18.8%) and Apple (14.1%) (www.statista.com). In 2019, Tencent and Alibaba revenues amounted to US$ 56.59 billion and US$ 56.15, respectively. Alibaba's IPO in 2014 reached the highest value in history.

intense rise of some companies to prominent positions in international patent rankings, which is repeated among universities and R&D institutes (See Table 1).

Table 1: Chinese representatives among the largest patent applicants with WIPO (World Intellectual Patent Organization)

Type of Agent [a]	Rank in 2017	Name	Number of applications 2013	2014	2015	2016	2017
Companies (a)	1	HUAWEI TECHNOLOGIES CO., LTD.	2.110	3.442	3.898	3.692	4.024
	2	ZTE CORPORATION	2.309	2.179	2.155	4.123	2.965
	7	BOE TECHNOLOGY GROUP CO., LTD	353	553	1.227	1.673	1.818
	13	LE HOLDINGS (BEIJING) CO., LTD.	-	-	-	9	1.397
	18	SHENZHEN CHINA STAR OPTOELECTRONICS TECHNOLOGY CO., LTD	916	904	710	1.163	972
	28	ALIBABA GROUP HOLDING LIMITED	-	-	16	452	707
	32	TECENT TECNOLOGY (SHENZHEN) COMPANY LIMITED	359	1.086	981	172	560
	34	YULONG COMPUTER TELECOMMUNICATION SCIENTIFIC (SHENZHEN) CO., LTD	-	-	71	256	517
	40	GUANGDONG OPPO MOBILE TELECOMMUNICATIONS CORP., LTD	-	-	27	80	474
	49	XIAOMI INC.	-	-	126	298	354
Higher Educational Institutions (b)	222 (11)*	SHENZHEN UNIVERSITY	-	-	29	87	108
	244 (14)	CHINA UNIVERSITY OF MINING AND TECHNOLOGY	-	-	43	84	99
	272 (19)	TSINGHUA UNIVERSITY	-	-	120	84	90
	337 (27)	SOUTH CHINA UNIVERSITY OF TECHNOLOGY	-	-	49	50	70
	351 (28)	PEKING UNIVERSITY	-	-	81	54	67
	362 (30)	JIANGNAN UNIVERSITY	-	-	12	37	65
	427 (35)	ZHEJIANG UNIVERSITY	-	-	28	37	53
	444 (38)	ZHANGJIAGANG INSTITUTE OF INDUSTRIAL, TECHNOLOGIES SOOCHOW UNIVERSITY	-	-	18	18	51
	459 (41)	JIANGSU UNIVERSITY	-	-	9	30	50
	481 (45)	SHANGHAI JIAOTONG UNIVERSITY	-	-	32	30	48
State Research Instit. (c)	106 (3)**	CHINA ACADEMY OF TELECOMMUNICATIONS TECHNOLOGY	-	-	118	145	204
	320 (9)	SHENZHEN INSTITUTE OF ADVANCED TECHNOLOGY	-	-	18	31	75
	749 (27)	CHINA ELETRIC POWER RESEARCH INSTITUTE	-	-	1	6	32
Total in a			6.047	8.164	9.211	11.918	13.788
Total in b			-	-	421	511	701
Total in c			-	-	137	182	311

Source: SILVA (2019), based on WIPO (2015); WIPO (2018).

For these companies, which lie at the core of the construction of global technology leadership, business development strategy is often intertwined with techno-nationalist policy (Naughton, 2020; Majerowicz and Medeiros, 2018; Majerowicz, 2019). This fact can be observed in the efforts of the Chinese state to spread local technology standards globally, the most emblematic case of which is the fight over 5G telecommunications standards (Lee, 2018). Also as an example of this trend, in analyzing the internationalization of Alibaba in Asia, Naughton (2020) suggests the emergence of a "Digital Silk Road" as a vector of Chinese strategy in the region.

In these sectors, incentive to internationalization is also an instrument for in-

By way of comparison, Facebook and Amazon revenues for the same period were US$ 70.7 billion and US$ 280 billion (www.investopedia.com).

dustrial and technology policy to foster learning, as it combines efforts in search of new markets, acquisition of technological and innovative capabilities, and the attempt to internationalize national technologies. Thus, this internationalization tends to be directed primarily to countries where national innovation systems contribute to increasing local technological competitiveness.

The effort to combine the production and technology development strategies of the Chinese structure of production based on three large groups means that the effects of those strategies on the domestic and international structure of production will also be heterogeneous. In other words, they will be conditioned by the specific stages of development of each of the large blocks and actors involved. This is precisely the context in which a more detailed analysis should be made of the limits and possibilities of China's strategy to become an industrial and internet superpower by 2049, expounded more forcefully in Made in China 2025.

2. LIMITS TO THE CHINESE STRATEGY TO BECOME AN INDUSTRIAL AND INTERNET SUPERPOWER

The promotion of technologies associated with Industry 4.0 reinforces the systemic intertwining between the local structure of production and the geopolitical objectives of the Chinese state. Through a top-down approach to strengthen techno-nationalism, the main long-term goal of industrial policy is the construction of 40 national R&D centers in the core technologies of Industry 4.0.

Since many of those technologies are still in what Utterback (1996) calls fluid stages, initial efforts favor experimentation initiatives through the establishment of technology demonstration zones and the creation of pilot projects for smart cities and green smart factories. Both the laboratories and pilot initiatives will be spatially distributed to take advantage of different regional technology and production competences. According to Zenglein and Holzmann (2019), between 2015 and 2018, 1,646 pilot projects were launched in green manufacturing, 854 in smart manufacturing, and 388 in manufacturing & internet integration, among others.

In addition to the extensive network of public R&D institutes, the companies that make up what Nolan (2001) called the National Team play a key role in these efforts of experimentation. To them have been added a new generation of technology-based companies that are technologically and financially strong, especially the aforementioned Baidu, Alibaba and Tencent (which should compete internationally with the USA counterparts Google, Amazon and Facebook), as well as new prominent agents in artificial intelligence (iFlytek, SenseTime and Megvii) and in semiconductors (such as HiSilicon, a subsidiary of the giant Huawei and SMIC).

The technological development of these companies, in turn, aims to reduce Chinese dependence on technologies that are essential to the new techno-economic paradigm in the making. To this end, they would benefit from a substantial amount of funds from countless direct and indirect development programs, prominent among them the National Integrated Circuit Fund (with 19 billion euros) and the Emerging Industries Investment Funding (5.4 billion euros) (Hiratuka and Diegues, 2021).

Besides fostering R&D activities and the creation of domestic pilot projects, such funds also support local companies in making acquisitions of international competitors with the aim of incorporating technological capabilities, as well as establishing R&D centers abroad. A typical example of this strategy is the acquisition by the Chinese electrical equipment and household appliance company MIDEA – which had already acquired the air conditioner manufacturer Springer Carrier – of the German company KUKA, specialized in the development of industrial robots and strong in Industry 4.0 technological capability.

SMIC is another case worth noting, as it illustrates the main alternative to circumvent the growing limitations imposed on the sale of chips to Chinese companies. Despite not being able to produce more technologically advanced chips yet (SMIC is capable of producing 14nm units while TMSC produces 5nm units), it receives massive investments to advance technologically. In May 2020, US$ 2.25 billion were invested in its capital by funds linked to various spheres of the Chinese government. In July, in turn, the company received an additional US$ 6.55 billion through an initial public offering on the Shanghai Stock Exchange.[9]

Besides the incentive to domestic technological improvement and internationalization through the acquisition of strategic technologies, funding and the reduction of uncertainty are directly complemented by the powerful use of public procurement and the substantial amount of credit available from the domestic financial system.

Although these overall principles guide initiatives for the development of technologies associated with Industry 4.0, it is worth noting that a better understanding of China's strategy requires a more detailed analysis of the main technologies involved in the emergence of this new standard of technology and production. The evaluation proposed here divides these technologies into three distinct layers and also identifies the technologies that pervade and cut across those layers (Figura 1).

Among the components of this paradigm, those in which the Chinese economy seems to be better placed are the cross-sectional technologies of artificial intelligence and big data, with cyber-physical systems based on smart services, as suggested by Lee (2018), Naughton (2020), and Zenglein and Holzmann (2019).[10] That is because it benefits from advantages such as the huge protected domestic market, access to a gigantic volume of data, the power of public coordination to implement tech-

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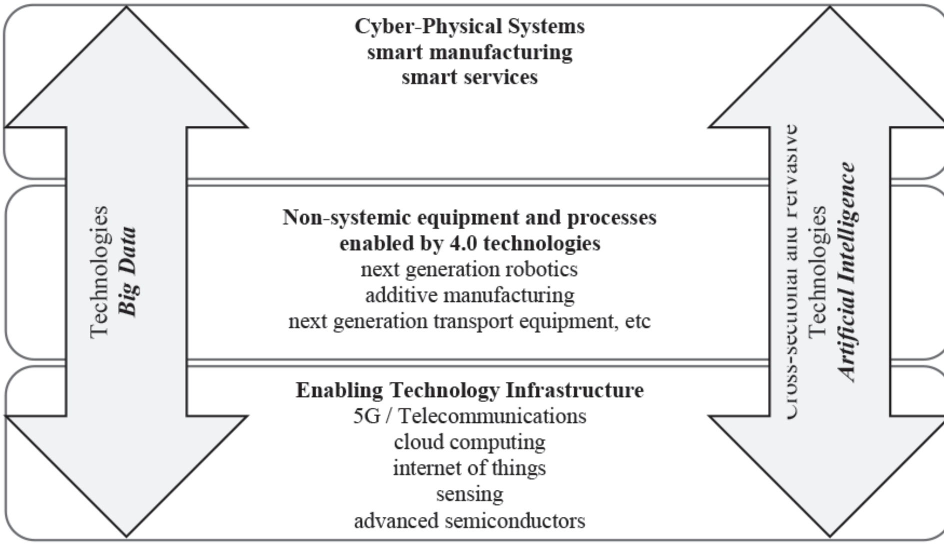
[9] As per https://www.icinsights.com/. According to reports from specialized consultants, SMIC ranks fourth in chip sales. The three leaders are TSMC (Taiwan), GlobalFoundries (USA) and United Microelectronics Corporation (Taiwan). The company is estimated to be about 5 years behind the level of technological development of the market leader TSMC and earn around 10% of its revenue (Wubbeke et al., 2016).

[10] Among the areas in which Chinese indigenous technology development is more consolidated Zenglein and Holzmann (2019) cite autonomous vehicles, smart cities and facial recognition. On the other hand, the areas with the greatest gaps and external dependence are enabling areas such as semiconductors, new materials and those related to basic research.

Figure 1: Technology layers associated with Industry 4.0:
an attempted systematization



Source: Author, based on Schwab (2016 and 2018) and Butollo (2020).

nologies in smart cities and the existence of internationally recognized local players with extensive knowledge of the specificities of the domestic market and who benefit from huge network externalities derived from the breadth of their technology platforms.

The main player of these platforms in the digital field – WeChat – had in 2017 more than 900 million users who daily use a variety of services integrated to the platform as a result of the growing blending of physical and virtual systems. Such blending, in turn, has enabled the explosion of payments handled by mobile devices. According to the consulting firms I-research and McKinsey, this volume reached US$ 15.4 trillion in 2017, or more than 40 times the amount handled in the USA. These are the segments in which most of the technology-based companies mentioned above are located, standing out internationally.

Two other important vehicles for the integration of these technologies into cyber-physical systems based on smart services are the City Brain initiative and the Taobao Villages, both mainly coordinated from technological platforms run by Alibaba. Drawing on pioneering efforts in its home city (Hangzhou), the group has aimed to integrate a large number of solutions capable of enabling the intelligent digitization of countless public services (in a broad, non-legal sense) through Alibaba Cloud. With the platform's improvement afforded by artificial intelligence, several potential policies are suggested in order to increase efficiency and the well-being of the population (from more traditional solutions such as traffic management to the use of complex systems to track diseases, fight their spread and provide solutions for later treatment through the health system).

With the technological consolidation of these solutions and following their packaging in a platform led by the Chinese technology giant, the company has benefited from Chinese influence in Asia to internationalize the offer of such solutions. Through domestically funded projects, such efforts led to the transnationalization of Chinese technology standards, via what has come to be called the Digital Silk Road (Naughton, 2020). Thus, coordinated by the City Brain initiative, spread across 23 cities in Asia, Chinese companies in related technologies are internationalizing and consolidating their technology solutions. Among them are the video surveillance equipment manufacturers Hikvision and Dahua and the data transmission equipment manufacturer New H3C Technologies, among others. It should also be noted that these initial efforts are at the core of a broader goal of Chinese technology development policy to encourage the establishment of local technology standards as a way to circumvent dependence on external technologies, through a supposed draft plan called China Standards 2035 (which is part of the discussions for the preparation of the 14th Five-Year Plan).

A similar effort has been observed in the support to the Taobao Villages, still mostly with national funding. Also led by the Alibaba group, this initiative integrates geographically dispersed villages into the company's global sales platform. The idea is to offer a number of smart services to local communities – such as in demand management, consumer behavior forecasting, supply chain management, marketing and finance, among countless others – in order to simultaneously facilitate mass production at low cost and with a high degree of customization. This revolution is enabled by cyber-physical integration based on smart services that, through artificial intelligence, makes it possible to identify consumer behavior patterns and predict certain demand trends.

Since access to the Chinese market by global service giants (such as Google and Facebook, among others) is restricted and given the high level of operational and technological development of local companies, cyber-physical systems based on smart services seem to be the Industry 4.0 area in which China most stands out in the tech war with the USA. This advantage is further enhanced by China's economic and political influence in Asia, which has been used to boost the internationalization of local technology standards.

However, USA pressure to prevent the internationalization of those standards from spreading to regions under its influence, such as Europe and Latin America, seems to be an important factor limiting the success of the China's internationalization strategy beyond Asia.

In turn, in sectors that are directly related to manufacturing activities, such as the consolidation of cyber-physical systems through integration technologies like robotics and additive manufacturing, China's position can benefit from the existence of a strong and diversified manufacturing sector. In addition, the existence of a complex local supply chain and the high capacity to coordinate investments by large state-owned companies can also contribute to joint development initiatives between private and state-owned companies and R&D centers.

Despite the potential of such partnerships (including some for pilot projects supervised by German research institutions, as recalled by Zenglein and Holzmann, 2019), it is worth noting that the domestic structure of production is still quite heterogeneous. Thus, despite the existence of global level companies in several sectors, the gaps in computerization and robotics in Chinese manufacturing pose challenges to the success of a supposed transition to a new paradigm.[11] In other words, there are numerous deficiencies in the universalization of 3rd Industrial Revolution technologies in local manufacturing, which could hinder the desired transition to the so-called 4th Revolution in the medium term.

Additionally, according to Butollo (2020), the widespread adoption of technologies associated with Industry 4.0 cannot be understood from a technical viewpoint. That is because factors such as implementation costs, available funding, development of complementary technological and managerial skills and economic profitability are decisive variables for technological migration, even though the machines, equipment and digital systems that enable smart manufacturing may be available. There are numerous elements that reinforce the lock-in (technical, managerial, of knowledge and financial) to production and marketing systems that are already integrated into dense networks of suppliers and buyers.

Since such technologies can be understood as dedicated to activities with less impact on politically and militarily sensitive issues, the potential for tension in the tech war between China and the USA seems to be relatively smaller. Although the importance of controlling standards in order to offer complete solutions is also a relevant competitive variable in these sectors, the impacts resulting from USA techno-nationalist policy are more indirect. Additionally, with a view to evading such impacts, Chinese industrial policy initiatives provided in Made in China 2025 have encouraged partnerships in the area of smart manufacturing between local agents (state-owned companies and R&D centers) and German research institutions and companies. The latter, aware of the relevance of the Chinese manufacturing sector as the largest potential consumer market in the world, try to position themselves – supported by national policies – as "factories of Industry 4.0 factories" (Butollo, 2020; Schwab, 2016 and 2018).

Finally, at the level of enabling technology infrastructure of factories and smarts services (5G/telecommunications, cloud computing, internet of things and sensing), once again telecommunication giants such as Huawei and ZTE and internet companies like Alibaba, Baidu and Tencent have drawn international attention to Chinese initiatives.[12] However, the strong technological dependence of companies such as ASML, TSMC, Qualcomm, Samsung and ARM on high-performance semicon-

[11] In South Korea, Japan, Germany and the USA, the number of industrial robots per 10 thousand workers in 2015 was, respectively, over 520, 300, 300 and around 180. In China it was around 25.

[12] In 2019, according to the telecommunications consultants Dell'Oro, Huawei was the global leader in telecom equipment, with a 29% share, followed by Nokia (16%), Ericsson (14%), the also Chinese ZTE (10%) and Cisco (7%).

ductor imports may be a major obstacle to the spread of enabling technologies such as artificial intelligence in the economy.

This seems precisely to be the weakest link in China's strategy in its quest for leadership in Industry 4.0 technology, as also highlighted by Zenglein and Holzmann (2019). Despite enormous efforts to promote capacity building in domestic semiconductor companies such as HiSilicon, HuaHong, Tsinghua Unigroup, SMIC, DJI and Cambricon, increasing restrictions imposed by the USA government on the sale of USA technology to Chinese companies may prove to be a hard hurdle for Chinese industrial policy to overcome.

The escalation of this trend has reverberated in geopolitical relations in a wide range of countries beyond the USA and has even led to growing restrictions on numerous attempts by Chinese companies to acquire European firms operating with strategic technologies. Such rejections are invariably justified by the risk posed by the Chinese advance to the security and national sovereignty of the host countries of these target companies. A case in point is the attempted acquisition in 2016 – barred by the German government – by a Chinese investment fund of the German company Aixtron, a manufacturer of machines used in the production of chips (Majerowicz and Medeiros, 2018; Majerowicz, 2019).

Also, with regard to dependence on the most basic layers of technology infrastructure that enables the pervasive technologies of Industry 4.0, the USA has stepped up pressure to force companies that supply machinery, equipment and technology for semiconductor foundries to restrict their sales to Chinese companies. The emblematic case, which reveals China's technological dependence on those layers, relates to pressure from the USA Department of State to prevent the Dutch company ASML from supplying equipment to the main Chinese manufacturer of semiconductor chips SMIC (Semiconductor Manufacturing International Corp).

ASML is the leading global manufacturer of advanced lithography equipment, deemed necessary for technological evolution in the miniaturization of integrated circuits. In other words, at the limit, ASML's technological capacity to develop increasingly precise machines conditions the evolution of the semiconductor production chain. Or, in the company's own words, the ability to change the entire global semiconductor industry "one nanometer at a time." Thus, any restrictions on the supply of ASML equipment to Chinese semiconductor manufacturers have important effects on the ability to develop Industry 4.0 enabling technologies.[13]

As noted by Majerowicz and Medeiros (2018) and Majerowicz (2019), the greatest limitation to the advancement of China's techno-nationalist industrial policy lies precisely in the semiconductor sector. This limitation, from mid-2020, seems to be virtually unavoidable in the very short term, given three sets of restrictions imposed directly and indirectly by the USA.

The first concerns the limitation imposed indirectly on any company – whether

[13] The main Chinese chip maker, SMIC, is capable of producing 14nm units while TMSC produces 5nm units, which means the Chinese company is technologically behind by around 5 years.

American or not – that uses USA technology, at any stage of its production process, to sell its products and services to the main Chinese companies dedicated to the development of Industry 4.0 technologies. Since USA technologies are virtually ubiquitous in the various segments of Industry 4.0, this restriction is difficult to evade.

The second set of restrictions concerns direct pressure for key companies in the semiconductor supply chain to break off partnerships with Chinese companies. The most emblematic cases include TSMC ending sales of its latest-generation integrated circuits and ASML being pressured to also restrict sales of its state-of-the-art equipment to Chinese companies. It is noteworthy that global chip supply is extremely concentrated and TSMC is the leader in the sector. Most technology companies that use state-of-the-art chips are fabless, that is, they only design the chips and then outsource their production, invariably to the Taiwanese TSMC when it comes to state-of-the-art chips. This arrangement includes both Chinese companies such as Huawei, ZTE, Xiaomi, Hi-Silicon, Cambricon, Vivo, Oppo, among others, and global giants like Apple, Qualcomm, etc. Partial exceptions are Samsung from Korea and Intel from the USA. It is precisely for these reasons that the USA government has also worked hard to convince TSMC to shift a significant part of its production to new factories to be built in the USA.

As detailed above, the main Chinese initiatives to circumvent these restrictions relate to strengthening the local production chain. The guiding logic of this process involves the effort to internalize practically all the key links in the production chain based on investments by the National Integrated Circuit Fund. Prominent initiatives include the provision of substantial funds for technological upgrading to SMIC (to manufacture microprocessors from 7nm to 5nm), Tsinghua Unigroup (and its subsidiaries YMTC – memory manufacturer – and Unisoc – chip design), Huahong Semiconductor (also for microprocessor manufacturing), and Hi-Silicon (chip design for mobile devices and artificial intelligence). Also noteworthy is increased research in disruptive technologies in the area by agents of the national innovation system and the attraction of highly qualified engineers and researchers, mainly from Taiwanese leading companies. There are also cross-sectional initiatives to encourage innovative companies in all niches of the segment by the state fund China Venture Capital and investments by local governments in new entrants in the segment of machinery, equipment and inputs for the production of semiconductors. Among the most promising companies in this area are NAURA (whose main shareholder is the municipality of Beijing), AMEC and AMC (both at least partially owned by the city of Shanghai).

The third set of restrictions concerns pressure on allied countries to restrict the access of Chinese companies and technologies to their markets, in which the battle over the definition of 5G telecommunication standards stands out. In this way, besides reducing the scope for appreciating Chinese capital, the internationalization of its technological standards would be prohibited, at least in these segments.

As a result of this circumstances and despite advances in all the other areas mentioned above, it is observed that the complex technology required for development and manufacture, especially of semiconductor chips (including those of artificial intelligence), is still the main gap of the Chinese strategy set forth in Made in China 2025 and in the goals outlined for China Standards 2035. Thus, given the highly cross-sectional and pervasive nature of those plans, bridging this gap is essential to enabling the spread of the other technologies in order to create a new techno-economic paradigm in which Chinese manufacturing and technologies play a leading role.

CONCLUSION

The intensification of inter-capitalist and interstate competition after the 2008 crisis is key to understanding the revival of industrial policy as an explicit instrument of national development strategies. Besides the potential impacts on building a growth trend that encourages Schumpeterian and Keynesian efficiency, the reorganization of these strategies aims mainly at transforming the techno-economic paradigm.

By encouraging technologies associated with what has come to be known as Industry 4.0, countries like the USA and Germany aim to deliberately push the technological frontier and thus reconfigure the determinants of competition, innovation, and accumulation. This reconfiguration is meant to reinforce their leadership positions and somehow counteract the Chinese advance.

Additionally, the ongoing tech war – especially in the case of the USA – is understood as a central element for the permanent reaffirmation of its international geopolitical dominance, given the deployment of Industry 4.0 technologies for military use and control and surveillance of global society. That is because there seems to be a growing perception among USA policy makers that the productive, technological, and financial connections between China and the USA in recent decades have created material conditions for the strengthening of China and its progressive affirmation as a nation with growing international geopolitical power. It is precisely in this context that recent USA reactions to the Chinese advance must be understood.

However, despite the growing signs of increasing Chinese influence in several areas, the limits of its strategy must be critically understood from a broader perspective. Albeit its relatively widespread technological advances, some considerations are key to delimiting its potential to challenge the international geopolitical leadership of the USA. First, China's structure of production is marked by a high degree of heterogeneity, which imposes important limits on the pervasive spread of Industry 4.0 technologies across the manufacturing sector in the medium term. Second, in the main enabling layers of these technologies – such as state-of-the-art semiconductor chips and especially the development of machinery and equipment necessary for the production of those chips – there is an almost ubiquitous direct and indirect control of technology by USA companies and research institutions, which often have historical links with the defense industry.

Finally, despite this evident asymmetry in favor of USA political and technological power, an influencing factor that cannot be overlooked in this tech war is the heterogeneity of internal political and economic interests in that country. Therefore, a point to be better evaluated as this strategic movement unfolds is the position of USA big business, which has been linked to the Chinese economy for decades and greatly benefits from the dynamism of that country to enable large-scale appreciation in the short term. In other words, the dependence of large USA technology companies on the dynamism of the Chinese market is also a relevant variable to understanding to what extent and by which means the tech war will escalate and the Chinese and USA economies will severe their links.

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