CHINA'S RACE TO GLOBAL TECHNOLOGY LEADERSHIP

edited by **Alessia Amighini**
introduction by **Paolo Magri**

ISPI

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Introduction

Last December the Chief Financial Officer of the leading Chinese telecommunication company Huawei was travelling from Hong Kong to Mexico when she was arrested while changing flights at Vancouver Airport by the Canadian authorities acting on an extradition request from the United States. Meng's arrest and detention are a significant development in China-US relations, marking a dramatic change in the relationship between Beijing and Washington.

The current trade war between the US and China looks like a small element in a much larger contest over world leadership in which China plays the part of the ascending challenger that seeks to upset the existing balance of power. China's weapons of choice are technology and innovation: it is making a frontal assault on the US in a sector that has traditionally been America's *forte*.

Imperial China was recognised as an inventor of advanced technology, and its best-known inventions (the magnetic compass, gunpowder) were essential factors in the country's rising influence, giving it a significant advantage over other regional powers. Despite this technological background, however, Communist China has so far primarily opted for a different path: its preferred approach has been to acquire Western technology as a way of boosting its own innovation and growth. The means China employs to this end have often been denounced as barely legal: the rules imposed on access to the Chinese market, for instance, forced American multinationals to set up joint ventures with Chinese enterprises, which then demanded technology transfers as a part of the deal. Although those rules are set to become less stringent in January 2020, they were in place for decades and China will undoubtedly continue to feel the benefit. The "Thousand Talents Plan" unveiled in 2008 was another blatant example of the same strategy: targeting Chinese academics outside the country, it offered them state subsidies and tenured positions in China's top universities if they would set up research programmes in China on the basis of the scientific knowledge they had acquired in their work abroad.

Acquisitions of technology became more prominent as China turned out to be the second biggest global economy. Chinese investments in the West have targeted high-tech companies: in 2016, Chinese foreign investments in the technology sector reached US$24.13 billion, and included the acquisition of Kuka Robotics, a German pioneer of Industry 4.0, by Guangdong Midea Consumer Electric. Such investments are perfectly in line with Premier Li Keqiang's plan entitled "Made in China 2025", which subsidises mergers and acquisitions of Western companies with the objective of strengthening China's chains of production.

Whatever the preferred strategy, Beijing's efforts are paying off. China's top telecommunication providers Huawei and ZTE, for instance, were the first to develop the technology needed for the commercial application of 5G.

Against this backdrop, the US is keen to point out that China has been unfair in its path towards technological leadership while not moving towards democracy – as expected – even after forty years of engagement with Western powers. Yet despite President Trump's tariffs, the extensive linkage between China and the US has created such highly intertwined strategic and economic benefits for both countries that disastrous results would inevitably ensue for each of them if they were forced apart.

China is not only acquiring technology; it now also has ambitions concerning the regulation of international trade and global governance generally. In other words, China is challenging the liberal order out of which it emerged as a global player. Just what a China-led global order would look like is still unclear, and the uncertainties are even more significant since the technology sector has rules of its own. The inherent dangers of technology need to be meticulously assessed, as they have the potential to alter the core values of modern societies, with which they are inextricably entwined.

This need is becoming more pressing as China's technological rise is no longer a thing of the future, but a present reality: there are other pointers to it besides leadership in the commercial application of 5G technology. The biggest of all start-ups, for instance, is the financial arm of Alibaba (Ant Financial), with an estimated value of over US$150 billion; and of the top fifty unicorn companies (start-ups valued at US$1 billion or more), 26 are Chinese and 16 American. Europe does not make the list at all. In terms of growth, moreover, while top US tech companies grew 26% between 2017 and 2018, their Chinese counterparts grew at 33%. This gap between East and West is growing wider and wider, and it would be unwise to ignore it. Most recently, Google has taken action to fill this gap by precluding Huawei's access to Android, the system on which most Huawei smartphones operate. Google acted upon a ban from the US government that demands American telecommunication companies not to install foreign equipment that may threaten national security. Less than a day later, the US granted a temporary general licence to the Chinese telecom provider, so as to reduce the damage that an abrupt halt would inflict to US companies and organisations that run their operations on Huawei's products and to limit repercussions from China.

Last year's ISPI report was entitled "China, Champion of (Which) Globalisation?". It focused on the kind of globalisation that China's growing influence would bring to the world, examining the changes, rules and standards implied by a China-led economic system. This year it is time to investigate what part technology will play in China's rise.

The present ISPI report tackles the question by looking at various practical aspects of China's challenge to US technological leadership and by considering its implications for the US, Europe and – last but not least – the entire global liberal order. While the trade war is a weapon in a wider technological contest, the two powers' race for world leadership in technology is a battle between two different approaches to economic growth. In China the Communist Party remains the main provider of innovation: it sets the standards for businesses to follow, and the objectives. In the West, on the other hand, governments have a more peripheral role since they are only in charge of providing public goods; businesses are free to follow the direction indicated by markets. China's state-oriented economic model is rooted in a practical protectionism that challenges the Western principle of free trade and the multilateral global economy championed by the World Trade Organization.

In her first chapter, Alessia Amighini attempts to answer the baseline question of whether China has what it takes to strip the US of the title of global technology leader. Amighini stresses that despite the long series of investments towards innovation enacted by the Chinese leadership since the 1970s, the country has not yet found a way to advance disruptive technologies to the same extent of incremental technologies. This inability is a substantial loss, as it is disruptive technologies that have the potential to reform the global economy, thus offering a considerable advantage to their proponents. The challenges that Amighini identifies as the sources of China's struggle over technology advancements mainly point to three domains of China's economic system: institutional, organisational and social barriers. The reform of these domain is, according to Amighini, key for the country to assume full control of the global technology sector.

Jie Yu's chapter analyses the implications of China's global technological leadership in terms of a reshaping of global alliances. Specifically, Yu focuses on the implications for the European Union, whose internal crises are making it unable to perform its traditional role as mediator between China and the US. In addition, President Xi Jinping might well grow increasingly confrontational as China's economy loses momentum: according to IMF data, GDP growth fell from 6.9% in 2017 to 6.6% in 2018, and the IMF forecasts a further slowing to 6.2% in 2019. Yu points out that President Xi Jinping has promised both a stronger party and a freer market. Technological progress will be the key to China's success.

The precise degree of interconnection between China and the US is the subject of the chapter by James A. Lewis, who argues that a disengagement of the two economic superpowers would lead to a series of shocks that are bound to have a severe impact on advanced economies and on major emerging markets such as India. According to Lewis, the more nationalistic the stance taken by the US the greater the distinctive advantage to China. The danger is that this opposition between China and the US could become an all-out "technological Cold War", with effects on the global economy which cannot yet be predicted.

Given the practical applications of the topic, this ISPI report focuses on two sectors mostly affected by China's technological rise: energy and fintech (financial technology). On the energy sector, Fabio Indeo presents the geopolitical implications of China's leadership in terms of sustainable energy. Beijing's increased reliance on renewable sources is building a reputation for China among its trading partners as a reliable energy superpower, for China supports the development of its partners' own energy production capacity, also by reducing their dependence on oil and gas. The energy sector is not unaffected by the present US-China confrontation, as President Trump's 30% tariff on imports of solar cells and panels is intended to protect US manufacturing.

Another study focuses on fintech, or the retail distribution of financial goods and services using information and communication technology (ICT) such as online banking, smartphone applications and cryptocurrencies. Although fintech platforms significantly reduce costs, they have a drawback in the inaccurate measurement of risk, and that in turn endangers the stability of the financial system. Paolo Giudici presents a comparative study of fintech platforms in China and Italy, and concludes that more accurate assessment of credit risk by P2P platforms would be a viable solution and would make fintech more sustainable.

As the US-China trade war reaches new levels of complexity, speculation abounds. The global liberal order has already been weakened by repeated systemic shocks. Losing the race for world leadership in technology could be the final nail in the coffin for US hegemony, and an ideal opportunity for China to take the lead. It is for this reason that the unfolding of the US-China confrontation shows that President Trump is conscious of the extent of the trade war – that is, a global technological leadership that, in the not too distant future, is bound to transform into an all-out battle for global leadership *tout court*.

Paolo Magri
ISPI Executive Vice President and Director

1. Beijing: Ready for Global Technology Leadership?

Alessia Amighini

The rapid growth of China's economy over the last 40 years has relied upon very high rates of physical capital accumulation on a scale that is unique and unprecedented in economic history. This pattern of economic growth has been more successful in expanding production capacities than in "building a widespread and robust indigenous innovation capability in Chinese firms"[1]. Very rapid accumulation of production capital allowed China to grow as the world's factory, but at a very high cost of depletion of natural capital, which now requires a lot of resources to clean up and therefore poses a limit to further growth.

However, the more challenging limitations to the possibility of China's having the potential for sustainable growth in the future are more likely to depend on its ability to accumulate a further type of capital, i.e. intellectual capital, the kind of capital that is fundamental for economic growth in mature economies, as it is the most important factor that fosters science, technology, and innovation. New growth theories and new trade theories emphasise a strong link between an increase in the knowledge base and the rate of productivity growth, and

[1] S. Gu and B.Lundvall, "China's Innovation System and The Move Towards Harmonious Growth and Endogenous Innovation", in B.-Å. Lundvall (ed.), *The Learning Economy and the Economics of Hope, Anthem Studies in Innovation and Development*, Anthem Press, 2016, pp. 281-282.

therefore knowledge and learning play a pivotal role in economic development[2].

The need to shift to a growth path that relies more on innovation to achieve sustainable economic growth has been very high on the agenda of Chinese authorities since 1978, when the first National Science Conference was organised where Deng Xiaoping acknowledged that science and technology are a productive force, the key to China's "Four Modernisations" drive, and that intellectuals are part of the working class[3]. The policy attention and space given to innovation have progressively increased over time, so that now China's innovation policies have evolved into something much more ambitious, to the point that they are now considered a challenge to the rest of the world. China has outperformed its growth record with an exceptionally high rate of investment in knowledge since 2000, with investment in R&D, the annual number of PhD graduates and the number of scientific publications all growing at double the rate of GDP growth per year (20%).

This chapter will venture into the issue of China's position in the global technology landscape, by asking the somewhat naive question of how likely it is for China to become a global technology leader. Of course, China has developed a wide range of specific technical capabilities to innovate in a number of sectors, sometimes leapfrogging industrialised economies (as in the well-known case of electric cars). However, the huge economic literature on the history and mechanics of technological innovation suggests that **global technology leadership** entails a lot more than the individual ability to innovate in some sectors. Indeed, it **requires a series of changes within the domestic environment that go far beyond the scientific and technological skills, and also include institutional, organisational**

[2] B.-Å. Lundvall, "The Economics of Knowledge and Learning", in J.L. Christensen and B.-Å. Lundvall (eds.) *Product Inovation, Interactive Learning and Economic Performance (Research on Technological Innovation*, *Management and Policy*, Emerald Group Publishing Limited, 2004, pp. 21-42.

[3] OECD, *OECD Reviews of Innovation Policy*, "China", 2008, OECD, Paris.

and social changes. This is the perspective I will follow when asking what the likelihood is of China managing to upgrade from its latecomer and follower position to a more prominent role on the global scene; what internal constraints China faces that might jeopardise its plans, and which direction the country should take to become a credible contender for the global technology leadership role.

Innovation is among the least tangible of the growth factors. In most of economic history, societies that have reached the highest degree of technological innovation and economic growth are countries with a more individualistic culture[4], that rewards personal achievements with social status and monetary incentives, while countries with a more collectivist culture have invariably enjoyed lower long-run growth[5]. Asian industrialised economies (Japan, Taiwan, Singapore and South Korea) are a notable exception to that pattern, as they have consistently outperformed (in terms of growth, patenting activity and innovation) countries with higher levels of individualism (measured by Hofstede's index of individualism)[6].

China today also poses a theoretical and empirical challenge to the extant knowledge on the role of culture and institutions in growth, to the extent that it requires a better understanding of which factors underpin the relation between innovation and growth in societies with low levels of individualism. **China** is **today** at the forefront of a global transformation of the geography of world innovation and **aims at establishing itself as a major hub for both the generation of knowledge and the production of innovation**[7]. However, according to Lundvall,

[4] Y. Gorodnichenko and G. Roland, "Culture, Institutions, and the Wealth of Nations", *The Review of Economics and Statistics*, vol. 99, no. 3, July 2017, pp. 402-416.

[5] Y. Gorodnichenko and G. Roland, "Individualism, innovation, and long-run growth", PNAS, 27 December 2011, vol. 108 (Supplement 4).

[6] Ibid.

[7] A. Rodríguez-Pose and C. Wilkie, "Putting China in perspective: a comparative exploration of the ascent of the Chinese knowledge economy", *Cambridge Journal of Regions, Economy and Society, no.* 2016, pp. 479-497.

in China **"this massive investment in knowledge has not [yet] been accompanied by a corresponding effort to build a learning economy"**[8]. A learning economy is one where workers, consumers and citizens interact together in many complex ways and participate in the economy and society, one "where the success of individuals, firms, regions and countries will reflect, more than anything else, their ability to learn"[9]. According to the wide body of research that investigated the nature and the mechanics of innovation[10], the enhancement of innovation from imported or marginal innovation to endogenous innovation requires building a learning economy, the basis of which is social capital, the highest, less tangible and less reproducible form of capital in a society. Although there is growing attention to the evolution of social capital in contemporary China, there is still very scant research on how it affects innovation activities.

It goes far beyond the scope of this chapter to either review or summarise the results of the extant research on the evolution, features and impact of China's national innovation system. What we will do in Section 1 is to start from the main highlights and takeaways from the growing body of economic literature that explores innovation in China from a range of perspectives[11] to understand the position of China in the international knowledge landscape and the major challenges that China is facing today to succeed in becoming a learning economy. The section will draw on the growing body of evidence on the innovation performance of Chinese firms to highlight some of the institutional and organisational factors China is currently facing as major obstacles to further improvement in its innovative capacities.

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[8], p. 382. B.-Å. Lundvall (2016), p. 382.

[9] B.-Å. Lundvall, "Economics of Knowledge to the Learning Economy", in *Knowledge management in the learning economy*, Paris, OECD, 2000.

[10] See among others B.-Å. Lundvall (ed.), *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*, London, Pinter, 1992.

[11] A. Rodríguez-Pose and C. Wilkie (2016).

Knowledge, Technology and Innovation: Where Does China Stand?

China is a latecomer country in the global technology landscape. Today some Chinese firms are developing their own innovative capabilities, they are introducing their own global brands, but most Chinese firms are far from being innovation leaders and the country is still overall dependent on the supply of foreign technology. However, China has been committed, since the Open-door policy (1978), to enhancing human capital formation and increasing capabilities in science, technology and innovation by boosting investment in knowledge and R&D, and by building a more efficient innovation system.

The history of China's innovation policies is complex, dates back to the late 1970s, and has been a chief factor in its current innovation trajectory[12]. Innovation policies in China have become even more prominent in recent years, following the need to implement new sources of growth. As Chinese labour costs have increased, firms are relocating their manufacturing activities to countries with lower labour costs, so China's competitive advantage as a global manufacturer is eroding. **A 30-year strategy to strengthen China's position in the global economy was launched in 2015 with a series of national ten-year plans to enhance innovation, product quality and environmental sustainability, optimising the industrial structure and developing human resources in Chinese manufacturing. The first of these plans has been called "Made in China 2025"** and includes ten key sectors of intervention (ICT, robotics, agriculture, aerospace, marine, railway equipment, clean energy, new materials, biological medicine and medical devices). In parallel, the "Internet Plus" initiative was launched in 2015, with a view to digitalising major sectors of the economy and building

[12] See Liu Feng-chao, Denis Fred Simon, Sun Yu-tao, Cao Cong, *China's innovation policies: Evolution, institutional structure, and trajectory*, Research Policy 40, 2011, pp. 917-931; B.-Å. Lundvall (2016); OECD (2008); OECD, *G20 Innovation Report 2016*, 2016, OECD, Paris; A. Rodriguez-Pose and C. Wilkie (2016).

a service-oriented, interconnected intelligent industrial ecosystem by 2025[13].

Today China is a rapidly emerging player in the Science, Technology and Innovation (STI) landscape. According to a number of selected innovation indicators collected and discussed in the G20 Innovation Report 2016, China has achieved a record performance in many dimensions[14]. Compared to the world's largest R&D performer, the United States, China ranks second, and is broadly similar to the combined EU28 area. China has a similar percentage of gross expenditure on R&D financed by industry (between 75 and 80%) as Japan and South Korea, all of them much higher than the OECD average of 60.9% (update). Unlike Japan and South Korea, where the overall gross expenditure on R&D is much higher than the OECD average of 2.4%, China spent around 2% of GDP on R&D. China has set a national R&D target of 2.5% of GDP, like many other OECD countries, and now ranks fifth in the international ranking after Japan, Germany, the United States and France, before the combined EU28.

China has therefore gained significant ground in enabling itself to lead the Next Industrial Revolution, which refers to a range of technologies including the so-called Internet of Things (advance robotics, 3D printing) as well as big data analysis and quantum computing technologies, which are among the currently most disruptive technologies. Taken together, Japan, South Korea, and China have contributed about 36% of such inventions, compared to a declining share by both the United States and the EU.

Public support for business R&D in China has been provided by both direct public R&D support for business (such

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[13] This paragraph mainly draws from "China Manufacturing 2025: Putting Industrial Policies Ahead of Market Forces" European Union Chamber of Commerce in China, 2017.

[14] These indicators are taken from the OECD Science, *Technology and Industry Scoreboard 2015*. The data reported in this Section are taken from a more recent release of the same Scoreboard published in 2017.

as grants or contracts), and tax relief measures. In 2015, 28 OECD countries gave preferential tax treatment to business R&D expenditures. Korea, the Russian Federation and France provided the most combined support for business R&D as a percentage of GDP in 2013, while the United States, France and China provided the largest volumes of tax support. The relative importance of tax incentives has increased across a majority of OECD countries and G20 economies, but many hightly innovative countries do not provide R&D tax incentives, such as Germany and Mexico[15].

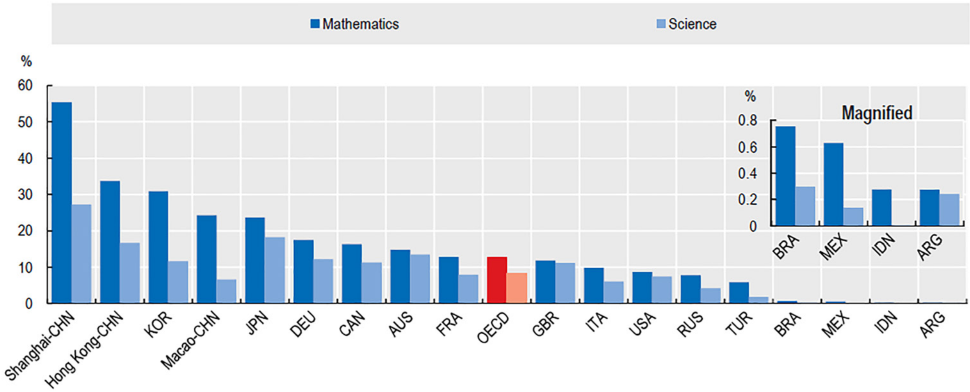
Besides general policy attention and effort devoted to an overall increase in national R&D investment, a series of specific policies were introduced with the aim of fostering the creation of new knowledge and technologies through an increase in high-level competences. There are two different sets of indicators one should examine when trying to assess the relative strength of a socio-economic system in terms of innovative capacities over time. One such set refers to the number and share of top-performing students among 15-year-olds, to the extent that the acquisition of high-level talents and skills starts at a very early age. According to data on proficiency patterns from the OECD's Programme for International Student Assessment (PISA)[16], there is high variability among the G20 economies in the proportion of top performers across countries, both in matematics and in science. In all G20 economies, the share of top performers was higher in mathematics than in science[17], and the first two positions are for Shanghai and Hong Kong, followed by South Korea, Macao (China) and Japan.

[15] Ibid.

[16] Ibid.

[17] Ibid.

Fig. 1.1 - Top performers in mathematics and science, selected G20 economies, 2012



Notes: The OECD PISA programme assessed in 2012 the skills of 15-year-olds in 65 economies. Around 510,000 students participated, representing 28 million 15-year-olds globally. "Students" assessed by PISA are between the ages of 15 years 3 months and 16 years 2 months. They must be enrolled in school and have completed at least 6 years of formal schooling, regardless of the type of institution, the programme followed, or whether the education is full-time or part-time. "Top performers in science" are students proficient at Levels 5 and 6 in the PISA 2012 science assessment (i.e. they have obtained scores higher than 633.3 points). "Top performers in mathematics" are students proficient at Levels 5 and 6 in the PISA 2012 mathematics assessment (i.e. with scores higher than 607.0). These students are expected to be at the forefront of a competitive, knowledge-based global economy. They are able to draw on and use information from multiple and indirect sources to solve complex problems.

Source: OECD (2014), "PISA 2012 Results: What Students Know and Can Do – Student Performance" in *Mathematics, Reading and Science*, vol. I, Revised edition, February 2014, OECD Publishing, Paris.

A second set of indicators of a country's capacity to sustain the human capital education that is required to enable innovation activities include the level of investment in science and engineering. Data on the supply of graduates in the natural sciences and engineering show that the proportion of those highly educated individuals is still low in China compared to other G20 countries. In particular, Germany and South Korea supply the largest percentage of tertiary education graduates in natural sciences and engineering, while the proportion of graduates in natural sciences and engineering among doctorates is higher than for other tertiary levels, reaching an average of approximately 40% for a sample of G20 economies. The natural sciences account for almost 50% of new doctoral degrees awarded in France. Engineering accounts for more than 50% of new doctoral degrees in South Korea and Japan[18].

Although high-level competences and skills are required to increase the potential supply of innovation in a society, one should not forget that the diffusion of innovation depends on both supply and demand factors. High demand for innovation in a society depends on the diffusion of basic level skills that enables a large proportion of the population to develop the abilities to adopt and therefore to demand innovation (the so-called absortive capacity). The demand for innovation also depends on the overall perception of the impact of science and technology on people's lives. A comparison of results from household surveys carried out in different countries indicates that the public in China has a mainly positive view of the societal impact of science and technology, with over 80% of respondents having a more positive view than the percentage in Germany, France and Italy[19].

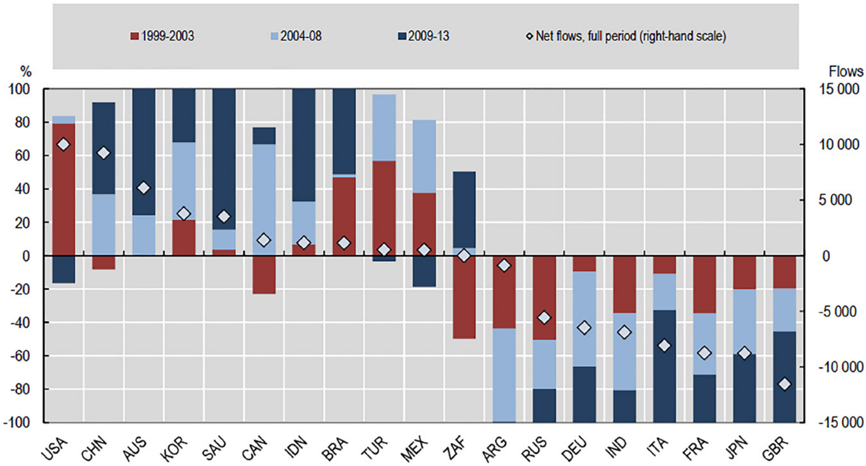
Besides innovation policy, **a further chief channel through which China has pursued upgrading its innovation score is the set of policies that have favored inflows of knowledge into the country.** Acknowledging that access to foreign knowledge is one important vehicle for improving one's own capabilities not just to adopt but also to develop innovation, **China has facilitated the acquisition of two types of knowledge, one embedded in people, the other embedded in goods**. The former has been achieved by facilitating researcher mobility from abroad. Formally, since 2008, there has been a national policy aimed at benefitting from scientific knowledge produced

[18] Ibid.

[19] OECD (2016).

abroad by inviting talented scholars and researchers to take tenured positions in China, the so-called "Thousand Talent Plan". China reversed what were net outflows experienced in the late 1990s into a significant net inflow of authors in the last few years and today has the world's second largest (positive) percentage of net inflows of scientific authors, after the United States. This is a very important channel for the diffusion of scientific knowledge, and shows that while some countries are net receivers, some others (e.g. major European economies) are net providers of scientific authors to the rest of the world[20].

Fig 1.2 - International net flows of scientific authors, G20 economies, 1999-2013



Note: This figure decomposes the overall net flow of scientific authors across different years for G20 economies over the period 1999-2013, expressed in relative terms. This helps to identify the timing and intensity of different phases of net entry and net exit from the perspective of a given country. For example, the United States and China experienced similar net inflows over the entire period (see the diamond) but the timing and trends are rather different. In the case of the United States, the net flows turn from being positive in the early 2000s to negative in more recent years, while for China the pattern is exactly the opposite. It is difficult to capture consistently the movement of scientists through statistical

[20] OECD (2015).

surveys, which are national in scope. Monitoring changes in scientist affiliations in global repositories of publications provides a complementary source of detailed information but these are limited to authors who publish, and moreover who publish regularly: otherwise their affiliations cannot be detected and timed in a sufficiently accurate way. Mobility can only be computed among authors with at least two publications. These indicators are likely to understate flows involving moves to industry or organisations within which scholarly publication is not the norm.

Source: OECD calculations based on Scopus Custom Data, Elsevier, version 4.2015, http://oe.cd/scientometrics, June 2015.

Knowledge acquisition also happened through acquisition of stakes in foreign firms (so-called knowledge-seeking FDI)[21]. This is the case of strategic asset-seeking motives that inspire Chinese acquisitions in developed economies[22]. Chinese multinational enterprises (MNEs) use acquisitions as a vehicle to access advanced knowledge and to initiate a reverse-knowledge transfer to the Chinese parent company. Chinese investors are interested in both technological know-how and managerial knowledge such as brand or sales expertise. In this way, Chinese MNEs aim to overcome their competitive disadvantages and to catch up to their Western MNE competitor[23]. A study shows that outward FDI has a positive effect on the innovation performance of Chinese emerging market enterprises' subsidiaries (EMEs) and that this effect is stronger when the outward FDI is directed towards developed rather than emerging countries. These findings advance the notion that EMEs can use outward FDI as a strategy to globalise R&D and enhance their innovation performance[24].

[21] See among others H. Berry, "Leaders, laggards, and the pursuit of foreign knowledge", *Strategic Management Journal*, vol. 27, no. 2, 2005, pp. 101-129.

[22] N. Zheng, Y. Wei, Y. Zhang, and J. Yang, "In search of strategic assets through cross- border merger and acquisitions: Evidence from Chinese multinational enterprises in developed economies", *International Business Review*, vol. 25, no. 1, 2016, pp. 177-186.

[23] Ibid.

[24] P. Piperopoulos, Jie Wu, Chengqi Wang, "Outward FDI, location choices and innovation performance of emerging market enterprises", *Research Policy*, vol. 47, no. 1, 2018, pp. 232-240.

Last but not least, the type of knowledge acquired from abroad is embedded in the inflow of goods imported into China. This inflow of technology into China's industry is closely linked to its participation in global value chains. It is widely acknowledged that China's foreign trade pattern results from the leading role China plays in international processing activities. For instance, the processing of imported inputs into goods for re-export, most notably in electronics and electrical machinery, and also in a number of other manufacturing sectors. The international specialisation of China in intermediate or final processing and assembly was intentionally pursued through trade policy regulations that exempted from tariffs those imports used for processing and re-export, especially by foreign affiliates, in order to increase domestic production (although initially not domestic value added) and develop successful export industries. Since the 1980s and 1990s, China's imports were much more technology intensive than its exports[25], and to a certain extent this is still true nowadays.

China's imports of high-technology parts and components are heavily concentrated in the sector of electrical machinery and show China's technological dependence on the more advanced industrial economies. China's dependence on advanced economies' technology (mainly US) has been brought to the general attention during the current tensions between the United States and China over the state and course of their bilateral economic relations. Due to the many interlinkages in production processes within global supply chains, in many sectors, production of core components by US firms relies on sourcing inputs (e.g. steel, rare earths) from China, while at the same time Chinese producers import a number of individual parts (not only chips, but also a wide range of electronics, including passive components and optical parts)[26] from the United States.

[25] F. Lemoine and D. Unal, China in the international segmentation of production processes, CEPII Working paper no. 2, 2012.

[26] Cheng Ting-Fang, Lauly Li and Coco Liu, Nikkei staff writers "Exclusive: Huawei stockpiles 12 months of parts ahead of US ban", *NIKKEI Asian Review*,

The current developments of the trade war – from import tariffs to export bans – show that the real motive behind the trade war is not only or mainly the bilateral trade deficit the United States runs *vis-à-vis* China, but rather the technology transfers that China has achieved through its peculiar specialisation pattern, i.e. the processing of high-tech imported inputs into exports. The same issue is also at the heart of the developments in the way a Chinese firm, Huawei Technologies, has been formally targeted by the US administration on issues related to national security. Huawei, the world's leading telecom equipment maker, accounts for a global procurement of around $67 billion a year, from a vast range of suppliers around the world. Huawei started towards the end of 2018 to build up stocks of crucial components for the year ahead, in order to face the uncertainties of the coming trade war between the United States and China. Those uncertainties became harsh reality when the US Department of Commerce announced, around mid-May this year, that it was placing the company on an export control list (meaning that all of Huawei's American suppliers will require US government approval to sell to the Chinese company)[27].

The Huawei case has increased awareness of at least two facts, the importance of which seems to have been largely underestimated before. Firstly, the recent US ban on business with key suppliers was anticipated by Huawei, which had prepared for a worst-case scenario, and in fact has contributed to further accelerating innovation within the company, which had already set a goal of developing its own versions of semiconductor devices (including high-end radio frequency and optical chips, for which it still relies heavily on US suppliers) and now is in greater need of becoming more independent from all US suppliers[28].

17 May 2019.

[27] A. Kharpal, "Shares of Huawei's American suppliers slide, but the Chinese giant says it can survive US blacklist", CNBC, 17 May 2019.

[28] According to the *South China Morning Post*, the CEO of Huawei, Ren Zhengfei, said the US ban would have no impact on Huawei's 5G plans and that its rivals

Secondly, the US-China trade war is likely to jeoparidise supply chains all over the world, as they are networked with firms from other countries (Huawei sources from many big suppliers in the region, including Sony and Taiwan Semiconductor Manufacturing Co., the world's largest contract chipmaker[29]).

Institutional and Organisational Challenges to Future Technology Upgrading

The previous section summarised the documented increase of China's *investment* in knowledge (science, technology and innovation), but how really has it increased knowledge *production*? Have the vast number of science and technology research, incentive and funding programmes played a significant role in enhancing the country's scientific and technological strength? Competence and innovation are the two main outcomes of knowledge production (not just investment), and both work effectively in organisations that learn interactively. The 13th Five-Year Plan, launched in March 2016, and the 13th Five-Year Plan on Scientific and Technological Innovation, released in August 2016, established a set of targets and policies for S&T development for 2016-2020[30]. But how far have they gone in supplying or facilitating the kind of institutional changes that are needed to further improve the efficiency of the Chinese system of national innovation?

First of all, it is worth remembering that technology and innovation policy in China shifted dramatically in 2003, returning to "techno-industrial policy" that involves direct government interventions to shape specific industrial sectors[31]. This policy

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cannot catch up with the company for at least two to three years, adding that US politicians have underestimated the company. https://amp.scmp.com/tech/article/3011048/huawei-founder-ren-zhengfei-says-clash-us-was-inevitable?__twitter_impression=true

[29] A. Kharpal (2019).

[30] OECD (2015).

[31] L. Chen and B. Naughton, "An institutionalized policy-making mechanism:

shift was formulated through a policy process that, like others in China, has become increasingly institutionalised. In the case of innovation policy, this structured policy process facilitated a shift to a substantially more interventionist policy[32]. However, a significant share of China's public research is funded by firms, which suggests that there is sound industry-science cooperation, but China's universities and Public Reasearch Institutes (PRIs) are not yet very engaged in patenting activities (see panels O and P in the next graph)[33]. There has been a surge in patenting activity by Chinese firms and organisations since 2001[34], with large evidence of a strong role played by universities in the building of China's national innovative capacity over the last 15 years, and a puzzling apparent lack of contributions from the public sector in reinforcing China's national innovative capacity[35]. Under the Law on the Promotion and Transformation of Scientific and Technological Achievements (revised in 2015), the government encourages R&D institutions and higher education institutions to transfer S&T achievements to enterprises or other organisations by assignment, license, investment as a trade-in, and other means. A study examining how collaborations with universities and research institutes influence the ability of Chinese EMEs to develop innovation, has shown that institutions evolve in different ways across sub-national Chinese regions[36]. This uneven institutional evolution affects the enforcement of intellectual property rights, the level of

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China's return to techno-industrial policy", *Research Policy*, vol. 45, no. 10, 2016, pp. 2138-2152.

[32] Ibid.

[33] OECD (2015).

[34] Mei-Chih Hu and J.A. Mathews, "China's national innovative capacity", *Research Policy*, vol. 37, no. 9, 2008, pp. 1465-1479.

[35] Fu Xiaolan and Hongru Xiong, "Open Innovation in China: Policies and Practices", *Journal of Science and Technology Policy in China*, vol. 2, no. 3, 2011, 196–218. https://doi.org/10.1108/17585521111167243.

[36] M. Kafouros, Chengqi Wang, P.s Piperopoulos, Mingshen Zhang, "Academic collaborations and firm innovation performance in China: The role of region-specific institutions", *Research Policy*, vol. 44, no. 3, 2015, pp. 803-817.

international openness, the quality of universities and research institutes across regions and thus the degree to which Chinese EMEs benefit from academic collaborations[37].

Despite the dramatic rise of national innovation capacity, China still performs rather badly by some international standards. One of these is the quality of science. Although the quality of science is a complex and multifaceted dimension, it can be easily measured by the level of scientific impact of publications (as a higher citation impact should be related to higher quality of scientific production). Among the factors that help raise the quality of science is cooperation among research institutions, more specifically international collaboration. Data from the OECD show that there is a strong relationship between measures of scientific research collaboration and citation impact. Collaboration with higher education or public research institutions constitutes an important source of knowledge transfer for large firms, both for firms that use R&D (either internally developed or externally acquired) and for those that are not R&D-active[38]. China, like several other larger G20 economies, shows low quality of science and low international collaboration, and it still ranks much lower than any other of the G20 countries in both dimensions. Moreover, one of the main reasons why the social and economic returns to R&D investment are still lower in China compared to other advanced countries is that the composition of R&D is much more oriented towards experimental development (D) rather than research (R), which leads to higher patentable knowledge[39].

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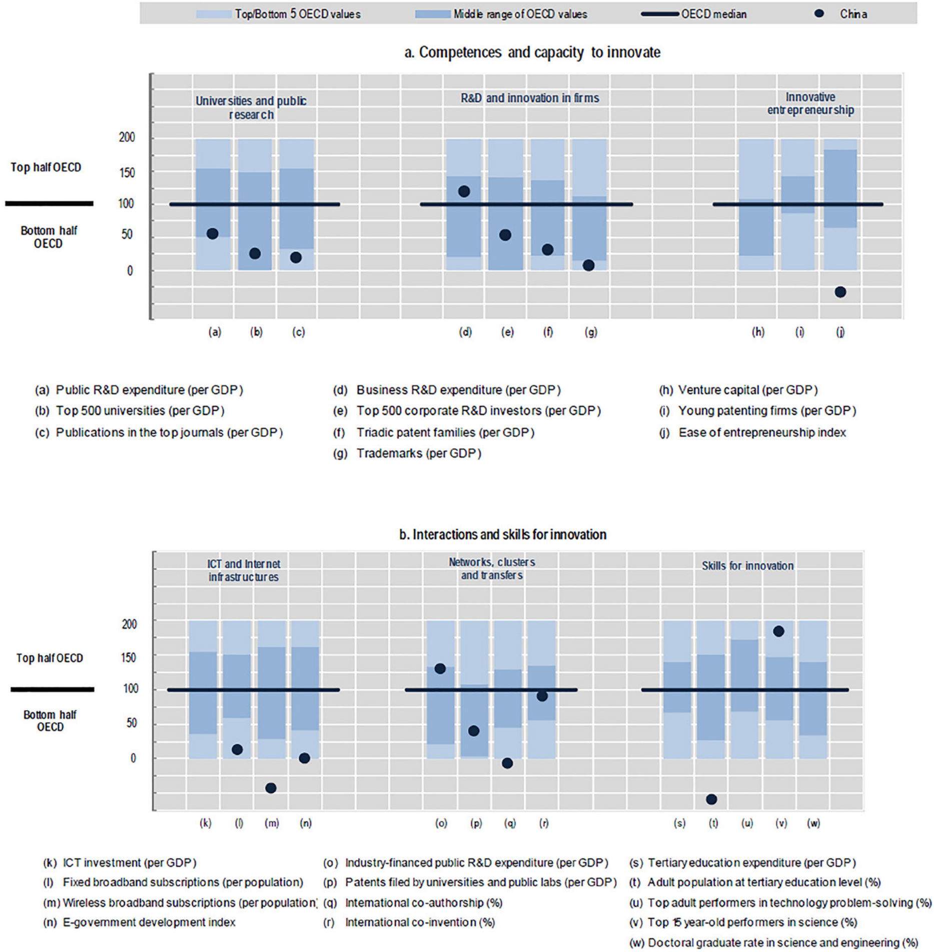
[37] Ibid.

[38] OECD (2016).

[39] OECD (2008).

Fig. 1.3 - Science and Innovation in China



Notes: Normalised index of performance relative to the median values in the OECD area (Index median=100). For China, 2012 values were used for the indicator (m) Wireless broadband subscriptions (per population). It is compared to values of December 2015 for OECD countries.

Although business expenditure on R&D as a share of gross expenditure on R&D has risen significantly, with firm self-funded

R&D reaching 94% of BERD in 2012, the review of the implementation of the Medium- and Long-Term National Plan for S&T Development (2006-20), carried out in 2010, noted that there was a need for greater vitality and business participation in technological innovation[40].

One of the most important instruments in the policy mix adopted by China's innovation policy over time is equity funding. A national SME development fund has been set up and focuses on support for the development of seed, start-up and growth-oriented SMEs. In April 2015, China launched a national strategy for mass entrepreneurship and innovation, which aims to enable more people to start their own business[41]. This follows the experience of one of the largest government R&D programs that support R&D activities of small and medium-sized enterprises in China, the Innovation Fund for Small and Medium Technology-based Firms (Innofund). Data on Chinese manufacturing firms from 1998 to 2007 show that Innofund-backed firms generate significantly higher technological and commercialised innovation outputs compared with their non-Innofund-backed counterparts and the same firms before winning the grant. Moreover, the changes in the governance of Innofund in 2005 from centralised to decentralised made the effects of Innofund on technological innovation outputs become significantly stronger[42]. Research has also investigated whether firms leverage public entrepreneurship investments to improve innovation and financial performance and found that firms possessing observable merits and political connections are more likely to receive Innofund grants.[43] However, firms receiving high project evaluation scores and Innofund grants perform better than those that do not receive grants and have lower scores[44].

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[40] OECD (2015).

[41] Ibid.

[42] Ibid.

[43] Yanbo Wang, Jizhen Li, J.L. Furman, "Firm performance and state innovation funding: Evidence from China's Innofund program", *Research Policy*, vol. 46, no. 6, 2017, pp. 1142-1161.

[44] Ibid.

Many of the challenges China is facing in its ascent to becoming a hub for innovation production are related to the institutional structure and governance of its national system of innovation. Although national innovation systems differ widely from country to country, China has a very peculiar geography of innovation that does not resemble either any system in advanced economies or any in emerging economies[45]. First of all, in China there is a much greater concentration of innovative activity than witnessed elsewhere. The diffusion of knowledge occurs within the boundaries of regions – and, more often than not, in highly dense and agglomerated metropolitan areas – rather than across regions. Innovation results mainly from collocating and agglomerating externalities, which facilitate the absorption of innovative potential from other regions rather than from R&D investments, human capital endowments and knowledge spillovers. "The concentration of innovative activity in Guangdong is in many ways the result of a national strategy designed to turn China into the workshop of the world"[46].

Major institutional innovation has been progressively applied to the national system of S&T policy and governance. China has established an open and unified national S&T management platform, which consists of a new evaluation and inspection mechanism. A programme to evaluate National Engineering Technology Centres has been designed using a new set of indicators. China has also started making use of the results of STI evaluation exercises to improve S&T management and enhance the national innovation policy design. In 2014, the China Publishing and Distribution Trading Cloud Platform was established, serving the publishing industry chain, based on cloud computing technology. The Ministry of Science and Technology (MOST) also established the National S&T Information System, a public information service platform to

[45] A. Rodríguez-Pose and C. Wilkie (2016).

[46] R. Crescenzi and A. Rodríguez-Pose "An 'integrated' framework for the comparative analysis of the territorial innovation dynamics of developed and emerging countries", *Journal of Economic Surveys*, vol. 26, no. 3, 2012, pp. 517–533.

access reports and information, including on resources and data about publicly financed R&D projects[47].

One of the most fascinating research questions about the factors that foster or hinder the supply of innovation refers to the influence of corporate ownership on innovation activity. The ownership perspective has inspired a lot of research. Among the most interesting results, one study has shown the interplay of foreign owners and domestic owners in generating the "indigenous" capabilities for innovation. Data from 548 Chinese firms show that firm innovation performance is associated with the presence of foreign owners in the firm, as well as with the firm's affiliation with a business group. The influence of state and institutional ownership on innovation performance is positive but lagged. Contrary to expectations, insider ownership leads to lower innovation performance and concentrated ownership has no significant impact[48].

In recent years, Chinese firms increased their spending on R&D substantially and worked on achieving a higher quality level of R&D[49]. Privately owned enterprises (POEs) not only obtain higher returns from their own R&D than majority and minority state-owned enterprises (SOEs), they are also able to increase their leading position. POEs not only produce R&D of the highest quality but are also the only ownership type profiting from higher quality. This analysis depicts the strengths but also the weaknesses of the corporate sector in China[50].

Research on the patenting behaviour of publically listed Chinese firms between 2002 and 2011 shows that the presence of institutional investors enhances firm innovation, and that

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[47] OECD (2016).

[48] Suk Bong Choi, Soo Hee Lee, and C. Williams, "Ownership and firm innovation in a transition economy: Evidence from China", *Research Policy*, vol. 40, no. 3, 2011, pp. 441-452.

[49] P. Boeing, E. Mueller, and P. Sandner, "China's R&D explosion - Analyzing productivity effects across ownership types and over time", *Research Policy*, vol 45, no. 1, 2016, pp. 159-176.

[50] Ibid.

the effect of institutional investors on firm patenting mainly comes from mutual funds. The effect is more pronounced when product market competition is more intense: while the effect exists among private and minority state-owned enterprises, it does not appear among majority state-owned enterprises[51].

Moreover, to spur technology transfer, emerging market policymakers often require foreign firms to form joint ventures (JVs) with domestic firms. Through knowledge spillovers, JVs may reduce technology acquisition costs for domestic firms. Yet domestic firm revenues from JVs could discourage innovation because of the "cannibalisation effect", i.e. the tendency by foreign partners to benefit from the innovation output of JVs. In China's auto sector, in response to fuel economy standards requiring firms to upgrade technology or sacrifice quality, firms with JVs reduced quality and price relative to their counterparts[52].

A number of sector studies have been designed to test the importance of institutional factors in the innovation trajectories of individual Chinese industries, among those that have been more successful innovators by international standards. Among these sectors, China's mobile communications industry once again deserves special attention as it is now at the centre of the current trade and technology dispute between China and United States, as presented in previous sections. The catching-up process of latecomer Chinese firms, most notably Huawei[53], depends on a combination of market and technological regimes. Segmented markets and generational technological change allowed domestic firms to leverage their initial

[51] Zhao Rong, Xiaokai Wu, P. Boeing, "The effect of institutional ownership on firm innovation: Evidence from Chinese listed firms", *Research Policy*, vol. 46, no. 9, 2017, pp. 1533-1551.

[52] S.T. Howell, "Joint ventures and technology adoption: A Chinese industrial policy that backfired", *Research Policy*, vol. 47, no. 8, 2018, pp. 1448-1462.

[53] For a simple and short story of Huawei, you can read Zen Soo and Li Tao, "How Huawei went from small-time trader in Shenzhen to world's biggest telecoms equipment supplier", *South China Morning Post*, 18 February 2019.

advantages on peripheral markets to catch up in core markets and therefore facilitated the catching-up of domestic firms with respect to foreign multinationals.

Generational technological change opened windows of opportunity for domestic firms to catch up with foreign multinationals in new product segments.[54] One interesting implication of this study is that latecomer firms may find it difficult to catch up if technological changes are fully competence-destroying[55]. Therefore, the current efforts to build innovation in high-tech sectors dominated by disruptive technologies may raise the issue of the extent to which the competences required are similar or different from the traditional ones held by investing firms.

A vast literature on technology transitions within industries suggests that the early phases of new technologies are marked by periods of intense experimentation. This literature has inspired a study of what prompts firms to experiment across one emerging technology platform—plug-in electric vehicles (PEVs) – in China[56]. The study shows that in contrast to the innovation trajectories of multinational and Chinese arms of joint venture (JV) firms, independent domestic Chinese firms are undertaking significant experimentation across multiple levels – infrastructure, core system, subsystem, and component – of the emerging PEV technology platform. This research proposes the concept of "institutional complementarities" to describe how interactions among institutions – here the national JV regulation and local market support and subsidies—may have turned regional markets into protected laboratories, extending the incubation periods for independent domestic firm experimentation. This suggests that, in order to scale beyond regional

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[54] Daitian Li, G. Capone, and F. Malerba, "The long march to catch-up: A history-friendly model of China's mobile communications industry", *Research Policy*, vol. 48, no. 3, 2019, pp. 649-664.

[55] Ibid.

[56] J.P. Helveston, Y. Wang, V.J. Karplus, and E.R.H. Fuchs, "Institutional complementarities: The origins of experimentation in China's plug-in electric vehicle industry", *Research Policy*, vol. 48, no. 1, 2019, pp. 206-222.

markets, consolidation induced by national policy standardisation may be required for PEV innovations[57].

Some research has also explored the impact of innovation on future firm performance and in particular how heterogenous risk drives the firm innovation–survival relationship using a large sample of new entrepreneurial firms in China[58]. Results show that innovation increases the probability of survival. Cautious innovators are found to survive longer and contribute to higher social welfare via gains in firm efficiency. In contrast, risky innovators are less likely to survive, are less efficient, and are only sometimes compensated for their risk in terms of higher profits[59].

Besides the role of institutions, there is one further dimension to the innovation process, i.e. the organisational structure of firms. According to Lundvall, "most Chinese firms operate with hierarchical forms of organisation, and there is little room for creative contributions from employees"[60] and therefore little room for individual and organisational learning. As China is now a society with a rapidly increasing number of highly educated people, the higher individual learning reward (besides the monetary reward) in foreign firms compared to domestic firms might imply a divergence in the ability of domestic firms to achieve organisational learning compared to foreign invested firms. Corporate governance has been considered one of the major factors impacting the development of technological capability within firms, explaining the limited catching-up in high technology sectors – and to a lesser extent in medium-high technology.[61] One of the major challenges for China's innova-

[57] Ibid.

[58] A. Howell, "'Indigenous' innovation with heterogeneous risk and new firm survival in a transitioning Chinese economy", *Research Policy*, vol. 44, no. 10, 2015, pp. 1866-1876.

[59] Ibid.

[60] B.-Å. Lundvall (2016), p. 382.

[61] Yangao Xiao, A. Tylecote, and J. Liu, "Why not greater catch-up by Chinese firms? The impact of IPR, corporate governance and technology intensity on late-comer strategies", *Research Policy*, vol. 42, no. 3, 2013, pp. 749-764.

tion policies is to "realise the potential of combining this major effort to promote STI-mode of learning with a stronger emphasis on the Doing, Using and Interacting mode (DUI-mode)"[62]. Organisational space is also at the heart of the technological catching-up in leading automotive groups, where it helped the building of technological capabilities by encouraging the mobilisation and integration of internal resources and promotes group-wide synergy for an effective internalisation of acquired assets[63].

Five fundamental activities are involved in the national innovation process – R&D, implementation, end-use, education, linkage – whose overall performance implications depend, rather than simply on the role and performance of particular actors, institutions and policies, on system-level characteristics, including the distribution of these activities within the system, the organisational boundaries around them, coordination mechanisms, evolutionary processes, and the effectiveness of the system in introducing, diffusing and exploiting technological innovations[64]. Some research has emphasised the presence of inconsistencies and perverse incentives that policymakers must address to achieve their development goals[65].

There has been growing attention in recent research to the similarities of socio-technical transitions in various parts of the world, which suggests that too much emphasis might have been given to the specificities of national innovation systems, and proposes an alternative "global" regime perspective[66]. One such study shows the case of an unsuccessful transition in the

[62] B.-Å. Lundvall (2016), p. 382.

[63] Kyung-Min Nam, "Compact organizational space and technological catch-up: Comparison of China's three leading automotive groups", *Research Policy*, vol. 44, no. 1, 2015, pp. 258-272.

[64] Xielin Liu and S. White, "Comparing innovation systems: a framework and application to China's transitional context", *Research Policy*, vol. 30, no. 7, 2001, pp. 1091-1114.

[65] Ibid.

[66] L. Fuenfschilling and C. Binz, "Global socio-technical regimes", *Research Policy*, vol. 47, no. 4, 2018, pp. 735-749.

Chinese wastewater sector. Key decisions on wastewater infrastructure expansion were not only influenced by path-dependencies stemming from China's national context, but equally (or even more critically) by the dominant rationality of the water sector's global socio-technical regime[67].

Contemporary research on entrepreneurship has showed that social capital can improve firm activities such as technological innovation. In a study on the impact of social capital on firms' technological innovation performance in China, with the data from 249 publically listed Chinese firms that have received venture capital investment, results show that both venture capitalists' social ties and entrepreneurs' social ties negatively affect these firms' technological innovation performance, including total patents granted, R&D expenditure, and total factor productivity. In other words, venture capitalists' social ties as well as entrepreneurs' social ties actually impede, rather than facilitate their firms' technological innovation[68]. This study suggests there are many different dimensions that need to be analysed in future research on the role of ties in the ascent of China to a knowledge economy.

The history of innovation policy and performance in China shows that the country has adopted a quite well-developed policy mix that covers all areas relevant to innovation and includes many instruments that have been adopted in many OECD countries. The transition of China to a more innovation-driven growth model will require further improvement of the framework conditions for innovation. From the guiding principles suggested by the OECD back in 2007 in their Review of Innovation Policy written jointly with the Chinese Ministry of Science and Technology[69], some recommendations on the

[67] Ibid.

[68] Zhenzhong Ma, Lei Wang and Keith Cheung, "The paradox of social capital in China: venture capitalists and entrepreneurs' social ties and public listed firms' technological innovation performance", *Asian Journal of Technology Innovation*, vol. 26, no. 3, 2018, pp. 306-324.

[69] OECD (2016).

need to improve governance of science and innovation policy were followed, but not those pointing to the need to promote more market-based innovative clusters beyond the fences of science and technology parks, to move to a more open innovation model. The current trends suggest the Chinese government has somehow centralised the structure of the Chinese innovation system, has not avoided high-technology myopia and is more fascinated than ever by the ambition to become a world technology leader.

2. China's Technological Prowess: Implications for Global Alliances

Yu Jie

Many discussions of power shifts and the Thucydides Trap revolve around the rivalry for economic and military supremacy between Beijing and Washington. While President Trump's erratic tactics to attack the Chinese technologies sector has changed the frontier of a clash of two titans.

The fear that China will dominate crucial technologies is now more widespread than ever in the West. The US political elites, along with leaders from the so-called Five Eyes countries, believe that China's strident "Made in China 2025" industrial upgrade strategy introduced by Beijing in 2015 poses an existential threat to the US monopoly over high-tech sectors. China's technological prowess, together with its distinctive political system at home, is now reshaping the global technological and economic order.

In today's highly integrated global economy, it is simply not feasible for the US to single-handedly mount what would effectively be a technological blockade against China. It would need help from elsewhere. However, President Trump's willingness to tear up agreements with long-standing allies, in Europe as well as in Asia, makes it unlikely that help would be forthcoming.

That is a particular concern for the EU and Washington's East Asian alliances. Many are suspicious of Beijing's intentions and would instinctively prefer to entrust their national security to the US. But they are also acutely aware that their economies' prosperity depends increasingly heavily on staying on good terms with China. If they no longer trust the US' ability to provide stable global leadership and a regional security umbrella, they will find China's gravitational pull even harder to resist.

Technological collaboration between China and the West is not an emerging phenomena and greatly helped China to accelerate its economic success after Deng Xiaoping's landmark reforms and opening-up since 1978. After forty years, China has gradually transformed itself from a mere pupil of the West into a formidable competitor in some key technological sectors.

China's technology prowess has posed some fundamental challenges to the conventional understanding of the relationship between technology and governance and the roles the market and the government play in facilitating innovation. And these challenges will inevitably redefine how domestic politics and international affairs are shaped by technology innovation. In particular, it will require states to consider with whom they want to collaborate or compete; and how the collaboration or the competition will pan out.

This essay seeks to explore a key question – will China's emerging technological prowess become a convenient vehicle for Beijing to forge diplomatic partnerships? Or, quite the reverse, will China put its potential partners in jeopardy precisely because of an unusual combination of an authoritarian regime and technology expertise? It will also investigate what the existing technological collaboration has been; and what the main drivers are for current controversies about China's technological advancement; and to what extent this technological cooperation and competition will co-exist in years to come, in particular, what would Europe's role be in placing itself between the two titans?

The Good Old Days

Technology developments have always been positioned at the heart of the Chinese government; the 1979 economic reforms and opening-up also opened the doors for China to acquire advanced technologies from many developed countries. As a China watcher observed, this pursuit of self-reliance regarding technologies came well before the latest "Made In China 2025" Industrial Strategy[1].

Chinese leaders realise that technological leadership is one of the bases of power, something first captured in China by the idea of "two bombs and one satellite," which showed the Soviets and the Americans that China was a peer in strategic technology and did not need them[2]. The focus now is on surpassing the United States in a broad range of technologies while again asserting that China does not need the United States' help to do this.

Nearly thirty years ago, China emerged from the tumultuous year of 1989. The Chinese government had an industrial strategy of acquiring and domesticating foreign technologies. It had very little expertise in terms of what kind of technologies the Chinese government and companies had in their minds. Instead, both foreign governments and companies played a major role in shaping the nascent developments of Chinese technological acquisitions.

From the author's initial findings back to 2016, central government institutions in Beijing played a decisive role in shaping China's industrial and technology development policies as well as in determining broader international collaborations[3].

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[1] N. Thomas, "Mao Redux: The Enduring Relevance of Self-Reliance in China", *Macro Polo*, 25 April 2019.

[2] M. Chan, "The day China entered the nuclear age", *South China Morning Post*, 17 October 2014.

[3] Y. Jie, *Partnership or Partnerships? An Assessment of China-EU Relations between 2001 and 2013 with Cases Studies on Their Collaborations on Climate Change and Renewable Energy*, London School of Economics and Political Science, London, September

Foreign companies that intended to secure a lion's share of the Chinese market were fully aware of the enormous power that the central ministries have to shape policy outcomes.

As a result, foreign conglomerates often treated the Chinese government's ministries as the first choice for collaborative partners when they initially entered the Chinese market. Successful alliances between the central ministries and the foreign companies mostly took place at the very early stage of developments for any leading technological sector inside China.

This was largely because formulating and executing policies in those particular industries were daunting challenges to the government agencies due to their lack of industrial expertise in both sectors. The European enterprises played the role of "information provider" by introducing technological standards and industrial practices to the central ministries. By providing information, the European companies enabled their preferred policies to be introduced; and their products were adopted by the Chinese authorities.

For example[4], the Danish wind energy giant, VESTAS, set an exemplary case for technological alliance building between the Chinese government and foreign companies. As demonstrated by other scholars and industrial reports, VESTAS' influence on China's renewable energy policy between 2009 and 2010 was not just a rare case in the early stages of China's renewables development – the impact of foreign companies on China's industrial upgrade also extended into other sectors such as the high-speed railway and automotive industries[5].

VESTAS managed to act as an insightful information provider, which was similar to the way in which some Chinese SOEs

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2014.

[4] Ibid.

[5] R. Lema, A. Berger, H. Schmitz, *China's Impact on the Global Wind Power Industry,* German Development Institute, Discussion Paper, 16/2012; International Renewable Energy Agency (IRENA), "Regional Report on Wind Energy: China", accessed at: https://www.irena.org/DocumentDownloads/Publications/GWEC_China.pdf

did with their corresponding governmental departments. As a Chinese media outlet asserted, "the main reason for VESTAS' success in collaborating with the Chinese government was China's nascent development of renewable energy"[6].

New Era, New Challenges

The foreign conglomerates' technological collaborations with their Chinese counterparts were not free from difficulties and bureaucratic predicaments. Collaborations with Chinese counterparts had not been insulated from the usual difficulties that foreign companies encountered in China, such as the increasingly protectionist approach taken by the Chinese authorities, the lack of transparency in policy implementation and IPR violations.

Things became far more difficult for foreign companies when the Chinese government began to launch its "Indigenous innovation" campaign. There was a sea change due to the rapid progress that China's domestic technology manufacturers made in a relatively short space of time. The "Indigenous Innovation" campaign was a turning point for China's technology collaborations with foreign partners.

The Chinese government commenced for foreign companies when the Chinese government began to launch its "Indigenous innovat国家中长期科技发展规划 (2006-2020) in 2006, intending to advocate for indigenous innovation and create an egnnovative society (创新型社会)新型社会6-2020) y 2020.

Central to this program, Beijing took a much stronger protectionist approach to ensure that domestic manufacturers were treated favourably. It dismissed foreign conglomerates' claims that that they were undermining foreign companies' commercial interests, and their futile efforts to protest against their

[6] "维斯塔斯牵手中国电科院风电研究" ("VESTAS advices wind energy to NDRC's Institute to China's Electricity Research"), *China Energy Daily*, 13 June 2011.

decisions. Such discrimination against foreign enterprises also largely exists in all technology sectors in which the Chinese government would like to give priority for development.

There is nothing wrong with China developing "indigenous innovation", but the centrally planned programme includes measures, incentives and other forms of market protection to support domestic enterprises, which erode free market norms and possibly WTO rules. For instance, under the initiative, the Semiconductor Manufacturing International Corps, one of China's handful of domestic semiconductor manufacturers, received a subsidy worth over US$100 million in 2017 alone[7].

"Made In China 2025" aims to achieve China's gradual economic transformation from low-cost manufacturing to great innovation power, which remains the top priority of President Xi Jinping and his comrades for the years to come. However, such prowess has caused more fear than appreciation across advanced economies in the US and Europe. As an industrial development guideline, Beijing has its eyes on 10 strategically and technologically important sectors, including information technology, biotech, robotics, aerospace and clean-energy vehicles.

Beijing is tailoring the initiative to produce national champions that can lead China's dominance in the above 10 sectors, with the aim of eventually replacing foreign technology with domestic suppliers. The key message here is a strong sense of self-reliance.

In recent months, China found itself fighting an economic slowdown coupled with an unexpected and enduring trade war with the US. President Xi began to offer an approach to revive the economy – a more pro-market rhetoric combined with a package of RMB 2 trillion (US$294 billion) in tax cuts for private enterprises[8]. And those companies specialised in technological sectors are given priorities. However, the state will still

[7] Y. Xie, "China's top chip maker SMIC sees revenue grow as state subsidies surge amid trade war", *South China Morning Post*, 10 August 2018.

[8] "China to cut taxes to support private sector: Xinhua", *Reuters*, 9 November 2018.

direct where private companies can invest and how much they can borrow. Instead of following the market, entrepreneurs must be led by the Party.

The Party is also explicitly moving beyond just regulating private enterprises to mapping out their future. The Chinese leadership is prescribing industrial policies that actively manage private enterprises by channelling capital and manipulating cash flows into innovation-driven industries, notably information technology, AI and robotics.

Interestingly, the phrase "Made in China 2025" was conspicuously missing from all of Beijing's propaganda campaign due to pressure from Washington, which has jumped on China's tech ambitions as a target in the trade conflict. But Beijing's commitment to focusing on private companies entering innovation industries has demonstrated that Made In China 2025 will continue without its formal name.

Political elites in Beijing stress that a party-led and state-dominated economy is fundamental both to the future growth of the world's second-largest economy and consolidation of Communist Party's legitimacy to rule the country. China has decisively ignored backlash against its policies from its major trading partners and competitors.

Beijing's protectionist approach has paid off to some extent, in particular when it comes to collaborating with Southeast Asia and many developing countries on technologies. For example, the contentious debate about 5G and Huawei has taken a totally opposite direction from what the US expected in some parts of the world. In Southeast Asia, where Huawei estimates there will be 80 million customers within the next year and US$1.2 trillion in business opportunities over the next five years, Washington's fears have had little impact[9].

So when picking technologies, it's tempting for governments to choose the cheapest option, especially when the deal

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[9] M. Tobin, "My way or the Huawei: how US ultimatum over China's 5G giant fell flat in Southeast Asia", *South China Morning Post*, 20 April 2019.

is sweetened by the promise of local employment opportunities – in Malaysia, for example, Huawei has already created more than 2,500 jobs[10]. For many, the choice between Chinese or Western technology is a matter of economics, not geopolitics.

It's not just that countries in Southeast Asia are less suspicious of China's motives. Many have been seduced by its technological prowess. Huawei claims a 12 to 18 month advantage over its competitors, promising those who sign up for its technology the fastest and most advanced 5G networks in the world[11].

Thailand hopes to roll out a Huawei-led 5G service by 2020 and is already carrying out joint research with the firm in its hi-tech Sriracha district[12]; Singapore's M1 service, Malaysia's Maxis and Indonesia's Telkomsel have all signed up for trial services with the company[13]; and in the Philippines, a Huawei-backed service is to be introduced by the leading wireless provider Globe Telecom as early as the second quarter of this year[14].

And not only is its technology more advanced than its Western competitors, it comes at a fraction of the cost – especially for those nations already using Chinese technology in their existing communications infrastructure. Beijing also intends to add the Digital Silk Road as a key attraction to existing customers in developing countries[15].

However, inherent tensions in Chinese policy and China's unique political system make Beijing's desire for a leading role in international technology alliances more complicated and problematic.

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[10] T. Sukumaran, Malaysia welcomes Chinese tech giant Huawei despite Western concerns, *South China Morning Post*, 15 April 2019.

[11] Zen Soon, "With the power to change the world, here's why the US and China are fighting over our 5G future", *South China Morning Post*, 17 April 2019.

[12] M. Kishimoto, "Huawei joins Thailand's first 5G trial", *Nikkei Asian Review*, 9 February 2019.

[13] Huawei, "Indonesia's Telkomsel Signs MOU with Huawei to Cooperate on Building a Fully Connected Digital Indonesia", 25 February 2019.

[14] C. Venzon, Philippines' wireless leader pushes on with Huawei 5G launch, *Nikkei Asian Review*, 12 February 2019.

[15] B. Harding, *China's Digital Silk Road and Southeast Asia*, Washington DC, Center for Strategic and International Studies (CSIS), 15 February 2019.

Beijing's underlying position is considerably weaker. In the minds of many Beijing represents an autocratic political regime, so different from the more democratic forms of governance that have prevailed in other countries associated with technological innovation power in the modern era. In terms of the political and legal features that might reasonably be expected of a country aspiring to play a central role in driving global technology alliances, China does not inspire a high level of confidence[16].

To date, Beijing has shown scarcely any respect for intellectual property rights or imposing stringent enforcement of business contract obligations. The country's governance structure is not known for transparency or accountability. Quite the reverse, the ruling Communist Party has always been dictatorial in nature and often opaque in policy implementation.

A World Bank survey of global governance indicators recently ranked China in just the 46th percentile for the rule of law[17], while Transparency International places China 77th out of 180 nations in its corruption perceptions index[18]. Indeed, over the medium term, it is not even clear whether political stability in China can be assured.

China's rulers do not deny the issue. Indeed, at the annual meeting of the Communist Party's Central Committee on 23 October 2014, under the leadership of President Xi Jinping, the governance problem was noted and a formal commitment made to firmly establish "rule of law" by 2020[19].

In practice, however, deeds matter more than words. The Party clearly did not have Western-style democracy in mind. "We absolutely cannot indiscriminately copy foreign rule-of-law

[16] Y. Jie, *Party Versus Market: Xi Fails to Resolve China's Contradictions*, London, Chatham House, 16 March 2019.

[17] The World Bank, Doing Business. Measuring Business Regulations, China.

[18] E. Morton, "Transparency International: China climbs two places in global corruption perception ranking as President Xi Jinping wages war on graft", *South China Morning Post*, 22 February 2018.

[19] Communique of the 4th Plenary Session of the 18th Central Committee of CPC, China.org.cn, 2 December 2014.

concepts and models", declared the Central Committee[20]. The goal, it seemed, was to refine Party control, not dilute it. As The Economist commented: "Official English translations refer to the importance of the 'rule of law'. But Mr Xi's tactics appear better suited to a different translation of the Chinese term, Yi Fa Zhi Guo (依法治国): 'Rule by law'. His aim is to strengthen law to make the Party more powerful, not to constrain it"[21].

In this light, only the most audacious technology entrepreneurs or innovators would see today's China as fertile ground for their talents and money.

If Beijing is to become a fully-fledged innovative power, it must implement reforms that go to the heart of the Communist Party's distinctive model of political and economic management[22]. It would have to make the country's governance structure more transparent and accountable, with more emphasis on genuine respect for intellectual property rights.

It would have to tone down elements of economic nationalism in its "Made in China 2025" Industrial Strategy, to reassure apprehensive neighbours in order to build aspired-to technology alliances. It would also need to commit more funding to original research and development in all technology sectors, but without the bravado and the boastful rhetoric. The current leadership should heed the words of wisdom from Deng Xiaoping, when it comes to developing its indigenous technologies. "Hide your strength, bide your time" will not do much harm.

And above all it would have to put more effort into cultivating a truly efficient and open domestic market environment to permit real competition, in order to enhance China's appeal as an innovative power. All these steps would risk eroding the Party's grasp on power and data control at home.

More rule of law would mean less rule by law. And more market liberalisation in the technology sector would weaken a

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[20] Ibid.

[21] "China with legal characteristics", *The Economist*, 1 December 2014.

[22] Y. Jie, *China Can No Longer Afford an Indecisive Approach to Economic Reform*, London, Chatham House, 2 January 2019.

critical tool of leadership control – the government's long-standing ability to manage market conditions and the use of data.

Domestically, data-use control has meant direct authority over what kind of technology sector Beijing would be in favour of developing and which tech companies the political elites are happy to incorporate into the Party machine. This enables the state to allocate resources to favoured entrepreneurs and to minimise its governance costs.

Internationally, control means an insulated market where only the Party's favoured technology enterprises dominate. A sense of technological repression is an emerging snag in Beijing's machinery of political autocracy. It is not at all clear how much political authority the ruling class is prepared to sacrifice for the sake of true technological innovation without strict oversight from the Party.

Beijing's technology statecraft thus operates under some deeply rooted domestic constraints. The hope, plainly, is to encourage wider alliances in the use of Chinese technologies or Chinese tech companies abroad without seriously threatening Party control at home. To say the least, the Party is now walking on eggs.

In effect, the Chinese government has been trying to make as few concessions as possible in terms of economic or political reform, hoping that the nation's economic size alone will support international technology alliances with Chinese characteristics. Whether a compromise like that can work effectively over the longer term remains an open question.

The Long-Lasting Impacts

Innovation has now become an indispensable element in expanding a country's global influence. In the case of China, it intends to shift itself from a manufacturing hub to an innovation powerhouse. Beijing's intentions and deeds will surely bring long-lasting effects in the global race to technological premiership. Yet, it is far too early to conclude that China's actions do more harm than good. Instead, it brings a whole set of new issues that have to be dealt with in both developed and developing countries.

The first implication is a re-assessment of the relationship between personal freedom and innovation. As conventional wisdom holds, there is a positive causal relationship between individual freedoms – the greater the personal freedoms a society enjoys, the greater innovation derives from that society.

However, China has taken every possible step to challenge this established convention. Mr Xi's decision to abolish presidential term limits has dashed Western elites' hopes of China experiencing a democratic transition with greater personal political freedoms. The lack of institutional constraints and differing opinions create the danger that hubris may infect governance. Leadership by control has not had an illustrious history.

China's ample supply of innovation talents builds a solid foundation in its quest for global technology supremacy, yet its tightened control over personal freedoms could undermine other global partners' desires to collaborate with China over both the short and longer terms. It seems that both innovation and control are flourishing simultaneously in China. As pointed out by an expert, "the unanswered question for China is whether it is possible to have scientific innovation without personal rights"[23].

The second implication comes from the relationship between the market and the government. China and the West have essentially taken two different paths in terms of investments in innovation. Beijing runs a nationalist and heavily government-led approach in driving innovation. It prescribes industrial policies that actively manage Chinese private enterprises in the technology sectors by channelling capital and manipulating cash flows into innovation-driven industries.

[23] J. Lewis, "Technological Competition and China", Washington DC, Center for Strategic and International Studies (CSIS), 30 November 2018.

The Chinese government has moved explicitly beyond regulating innovation enterprises, which remain the most dynamic elements of its economy. It continues to direct where those companies can invest and how much they can borrow. Instead of following the market, the technology entrepreneurs must be led by the state, hence the Party.

Whereas the West in general still believes that government remains merely a provider of public goods, not an investor in innovation. There is a strong preference to cut government spending and wholly rely on the private sector to generate cash flows and innovation. It is futile to whine about China's misdeeds regarding innovation. Instead, for China's competitors, it is perhaps time to reassess the role the market and the government have played and offer tangible solutions.

The third implication comes in the form of global alliances. As China moves into a central place to challenge the existing international order, it is inevitable that many of the partners and alliances of the West will have to re-think their relationships with a technologically brilliant but more politically assertive China. A Middle Kingdom that does not share the same values ably exploits the flaws of a rule-based international order. A China determined to create its own indigenous industry therefore undermines the technological dominance of the United States.

Some global alliances might likely be determined by economic viability rather than by shared political ideologies. As discussed earlier, a partnership with China on innovation collaboration is about economics as much as about geopolitics, as in some of the Southeast Asian countries.

Implications for Europe

To date, Europe has shown little interest in involving itself in the global power struggle between Beijing and Washington as the author pointed out in her recent piece[24]. The majority

[24] Y Jie, "EU-China relations require a cautious reset", *European Leadership*

of European governments take a nuanced view of the China challenge; many share the US' concerns over the direction the Middle Kingdom is taking under President Xi Jinping, including on domestic market access and unfair competition from state-owned and state-backed Chinese companies. Yet internal divisions over China have long since troubled Europeans.

Given their limited security interests in the Asia-Pacific, and large economic interest in China, many Europeans have feared the impact of China's rise on international democratic governance norms and on the rule of law.

In recent months, the EU has also found itself under increased pressure to comply with American demands to treat the Huawei 5G network with caution. Ongoing controversies over other Chinese investments have added even more uncertainty to the Sino-European relationship.

This emerging shift in global alliances will prove to be immensely challenging for the EU and for the EU's already fragile unity. The European single market remains extremely attractive to Chinese companies and the government. In the eyes of many Chinese investors, the EU represents a secure home for their investments. In particular, a preferred partner for China's ever-growing appetite for technology acquisitions.

Beijing is eager to be recognised by established economies and has high hopes for European endorsement of its global ambitions on every front, such as the Belt and Road Initiative, as recently demonstrated by Italy – a decision raising eyebrows in European capitals, as well as in Washington.

The EU has every reason to view China's technological ambitions with anxiety. It harbours deep suspicions about China's broader strategic calculation beyond its commercial gains. Many Europeans perceive Beijing's "Made in China 2025" industrial upgrade initiative as posing a direct challenge to the EU's own "Fourth Industrial Revolution".

Network, 8 April 2019.

Judging by the increasingly strong rhetoric coming from Brussels and other European capitals, China's might and money has spread more fear than it has admiration. This all too easily feeds into the narrative that many challenges faced by the EU are a direct result of China's economic and innovation ambitions – and a threat to the liberal democratic values that Europeans uphold.

The EU's engagement with China stems from its neighbourhood policy, in which the democratisation process, through political reform, re-integrated the formerly Communist East European states. This approach generates great suspicion in the Chinese public and political elites where it is viewed as a fundamental challenge to state stability, which is based on the Chinese Communist Party's absolute legitimacy and governmental role. Europeans cannot afford to ignore the omnipresence of the Party, nor pretend that significant conceptual differences on democracy and political freedom do not exist.

Brussels' hand will be strengthened if it can agree on the planned Transatlantic Trade and Investment Partnership with the US. That is still far from certain – but it would command Beijing's attention and respect by enabling Brussels and Washington to join forces in setting the global technological agenda. Conversely, failure would signal weakened Western commitment and resolve, from which Beijing would be quick to draw the consequences.

Conclusion

As China's military, economic, and financial power have grown, it has been obvious that Beijing would not accept all global institutions and standards exactly as they are configured today. And importantly, this would be true even without Xi Jinping in power. China's sheer size, weight, and self-perception of its own interests will inevitably lead the Middle Kingdom to expect changes in the governance of international institutions and, in other words, the rules of the game. These changes, in particular on the technology front, have come much earlier than the rest of the world expected.

And a more ambitious China cannot be a "status quo" or static power. Beijing seems to believe that a recipe for quick success will come out of the technology race with the established powers while building partnerships with a select number of developing economies.

The conventional thinking about the relationship between personal freedoms and innovation are profoundly changed by an authoritarian regime like China and by the populations who use the technology dimension to challenge incumbents in the liberal democratic West.

China's words and deeds in the quest for technological supremacy also disrupt the established understanding about the ties between the market and the government regarding technological innovation. The perennial debate between Keynes and Hayek is now being extended into the realm of technological innovation.

And lastly, China's allure in rapid technological progress has also re-set the tent of global partnerships. Many of the middle powers will inevitably re-think with whom they would like to set up partnerships. They will have to balance ideological divisions with realism about how much they can change the Chinese government's outlook and political choices while enjoying the economical and efficient technologies offered by China's domestic talents.

Whether the EU can realistically aspire to go further and develop a more comprehensive and coherent strategy for engaging with China on the technological front is less clear. The EU today is stumbling from crisis to crisis – over mass migration, probable UK withdrawal and the rise of political populism. All this is draining political energy and confidence, causing the EU to increasingly turn inwards and even calling into question its future institutional survival.

Nor do recent trends in China inspire optimism. Under President Xi, China has adopted a stridently nationalistic stance, which may intensify if its economic performance deteriorates further. Faced with the paradox between the centrality of the Party and market forces, Xi promises both a stronger Party and a freer market. Life as a great power with publicly stated leadership aims and reform ambitions is not comfortable. Its technological advancements may well bring the additional means to govern, yet simultaneously more controversies on how to handle those technologies with care.

3. Competing Over Leadership: China *vs* the US

James A. Lewis

How to deal with China is the central strategic problem of the next decade, perhaps even longer. China seeks to reorder the world to serve its interests. The issue is not whether China will be powerful (that is a given), but how China's leaders will exercise that power, and whether Western nations can shape China's behaviour.

China is a challenger and opponent for the US. This in itself is not objectionable. What is objectionable is how China competes, and how unscrupulous its rulers are in the actions they take to maintain power. China's human rights record should trouble any democracy – Orwellian surveillance and having almost two million people in re-education camps because of their religion is a chilling reminder of Europe's own unhappy experiences and too often greeted with an unflattering passivity – but these actions by the Chinese Communist Party reflect the larger domestic political dilemmas facing China's leadership as they struggle to maintain control.

The central problem for the Chinese Communist Party is how to ensure the Party's continued rule. Xi Jinping, who before taking office studied the reasons for the demise of the Soviet Union in order to avoid them, uses a variety of measures to maintain Party control. These include expanding controls on information and speech, abetted by technology, aggressive mercantilism supported by government subsidies and industrial espionage, accompanied by appeals to the nationalist sentiment that remains powerful in China. Continued economic growth and technological improvement is crucial for the narrative that supports unchallenged Party rule, and it is these domestic political forces that have helped create and frame the technological competition with the US.

The competition between the US and China is also the result of decisions by the Chinese government to assert its dominance regionally and to challenge the post-1945 world order, built by the US and its allies and believed by China to be designed to advance US economic and military interests. This more confrontational policy is unlikely to change in the foreseeable future. China's new posture creates many problems for the United States and other nations, including the problem of how to reduce the flow of Western technology for potentially sensitive military applications to a potential military competitor.

This is more than a military contest. It can be seen as a continuation of the long contest between two economic and political systems that differ markedly on the role and rights of party, state and citizen, but it is not a repetition of the Cold War. We are not in a bipolar world, ideology is not the central issue in this contest, and the economies of the two countries are deeply intertwined. The trajectory of each system suggests that in the near term, China will grow stronger and the US will decline, but China's continued rise is neither preordained nor assured.

China's economy has grown because of a combination of government policies that date back to Deng Xiaoping's opening to the West. These include heavy investment in companies, infrastructure, research and education, barriers to trade and foreign investment, and a massive effort to acquire Western technology, including the use of major and long-lasting espionage campaigns. At first, most nations and companies ignored China's behaviour because its economy was small and because of a desire to preserve access to China's rapidly growing market. As China has grown (and grown more assertive) there is less tolerance in the US, and mercantilist policies and espionage guarantee tension with the US and other nations, particularly as China positions itself as a military challenger (in the region) and seeks greater influence and control in global institutions and rules. China's willingness to spend to support economic growth and to use its coercive powers (particularly in manipulating Western companies and governments by granting or denying market access) make it a formidable opponent.

Deng's decision to relax government control and open China's economy to foreign participation is the most important factor in explaining the growth of China's technology base. China is still dependent on the West for advanced technology. If China had decided to continue a socialist industrial policy with firms directly managed by the government, growth would have been slow. If China is moving back to an economic model where government plays a more directive role (a move motivated by the domestic political imperative to retain Party control), this has implications for China's continued growth and modernisation.

China is the last Leninist state, and while by no means an adherent of Marxism, it is still using the techniques and tools of Leninism for public control and to maintain party dominance even as it has largely abandoned the dogma of Marxist-Leninism. Leninism and the Comintern still shape the world view of China's leaders, but this view is also conditioned by a longer Chinese history that in the current national narrative emphasises China's "century of humiliation" at the hands of Western imperialism and its return to an "era that will see China move closer to the *center* of the *world stage",* e.g. the central polity for world affairs.

This helps explain one of China's signal successes in shaping global opinion. China has persuaded the world of its inevitable rise. This is a triumph of propaganda, and as with many other pronouncements of success from Beijing, it deserves a skeptical look. Statistics from China are shaped to serve political ends and are routinely inflated. The argument, to paraphrase critics of the Soviet Union, that things today are better than they were ten years ago, therefore they will be better yet ten years hence is contingent on assumptions that current trends will hold constant. The engine that propelled China's amazing economic rise (albeit from a very low starting point) is, however, beginning to show signs of strain as it faces immense debts, higher labour costs, and worsening relations with Western nations (upon whom it still depends for advanced technology).

Leninism, even with Chinese characteristics, is unappealing – there is no global rush to buy the latest edition of Xi Jinping thought – pervasive surveillance creates both political and economic damage, and government-led central planning is inherently inefficient. These are China's greatest challenges. At the same time, the US faces significant challenges of its own. These challenges are shared by America's allies. An increasingly immense income disparity creates economic harm and political discontent. A feckless strategy that led to a squandering of resources since the 2003 invasion of Iraq has left the US militarily weaker. Most importantly, a strong disinclination to spend on public goods like research, education and infrastructure, limit the potential of the American economy (and may be the source of China's greatest advantage – there is no hesitation in Beijing to spend billions for long periods for public goods).

This problem was unexpected, and Western nations built close economic ties with China in the last forty years on the expectation that China would be a friendly power. Companies took advantage of China's cheap labour and growing market. These were profitable times. In turn, the Chinese used the threat of withholding market access, combined with an immense commercial espionage campaign, to acquire Western technology. Until Xi Jinping, this was a trade issue of China not living up to its WTO commitments (without serious objection from the West). It is no longer a trade issue.

American Power in Decline

In contrast, the US basked too long in its Cold War "victory" and now faces significant problems. The core problems are the lack of strategic focus, deep social inequality that undercuts political stability, and under-investment in public goods. America spent over US$7 trillion on its misadventures in the Middle East. China spent similar sums on research, education, and industrial subsidies. The US cut government spending on basic research (except in healthcare), choking off what had been the most powerful source of American growth since the 1930s. Its political leaders have, since 1994, made cutting taxes their principle objective. Since it was politically unfeasible to directly cut social services, much of this fell on discretionary spending including research, infrastructure, and education.

These cuts were justified on the grounds that the private sector would outperform government in providing public goods – this has proven not to be the case – and that security could be guaranteed by increased spending on defense rather than economic investment. This badly misinterpreted the changing nature of interstate conflict, where conventional military forces play a smaller role in producing global influence while strength in innovation and technology are more important.

One fundamental problem for the US is a shift in social attitudes about science and government (an aspect of what can be shown to be a larger decline in the legitimacy of existing institutions). A significant minority of Americans question both science – the "anti-vaxxers" who refuse to vaccinate their children because of strange conspiracy theories – and the value of government funding for science. Among political elites, there has been a belief that private funding for research and market forces are enough to ensure progress[1]. This is bipartisan: Democrats look to Silicon Valley to provide growth, Republicans to Wall Street. This larger skepticism about government is reshaping

[1] *Americans, Politics and Science Issues*, Pew Research Center, 1 July 2015.

American politics and creates a reluctance to use what Franklin Roosevelt called the "instruments of public power". These trends put America at a competitive disadvantage.

The relationship between government investment, private sector activity, and technological strength would benefit from a more complex and longer discussion, but the conclusions would remain the same. America built an innovation engine in the 1950s and turned it off in the 1990s. It is now gently coasting down, something that was tolerable when the US did not face challengers but that is no longer the case. The private research that was supposed to replace investment in public goods is focused on developing new products from existing technologies, not on the basic research that is the primary source of innovation[2].

Underinvestment in research hampers the US strategy for competing with China in technology. The core of that strategy, which has only emerged in the last two years, is defensive, seeking to block technology transfers through regulations on investments or exports. But the US also seeks to "run faster" in developing new technologies in order to stay ahead of its competitors. A purely defensive strategy that seeks to block technology transfer to China can at best only slow decline, but the call to run faster would be more persuasive had it not first been heard (but not implemented) in the late 1990s. The attraction of a defense based on regulation, however, is that it requires very little in the way of additional government spending and is consistent with an ideology that downplays government and relies on private sector activity.

Can There Be a Divorce?

Disentangling the close commercial, financial and technology relationship between China and the US built over four decades

[2] See, for example, A. Arora, S. Belenzon, A. Patacconi, and J. Suh, *The changing structure of American innovation: Cautionary remarks for economic growth*, National Bureau of Economic Research, 28 March 2019.

will not be easy, but we do not want to overlook a key point that complicates any separation. It is not just that the US and China share a supply chain for technology. It is that the supply chain has become global, with companies developing products and selling them with a range of international partners in Europe, Japan, Israel, India, Asia and North America. The end of the Cold War and its bifurcated trade system led to a profusion of interconnections. The connection between the US and China is one of the most important, but it is not unique and if it were to be severed both would be damaged, but China would currently suffer more damage, given its dependence on Western technology.

In thinking about how and where to restrict technology transfer, the central determining question for the US is whether it loses more than it gains from restriction. The answer to this question is not always easy, both because the consequences of restriction can be indirect and accompanied by collateral damage to markets or innovation, and because they can change over time, with something that makes sense in the short term turning out to be damaging in the long-term, like a transfer that provides immediate economic benefit but has the long term effect of building a competitor. China uses five techniques to extract technology:

- Coercive business arrangements in China used to extract technology and build competitors.
- Acquisition of Western companies or financial arrangements that provide access to technology.
- Purchases of advanced technologies.
- Espionage, both human and cyber.
- The use of Chinese students and workers in the US as intelligence collectors.

If the US is serious about reducing the flow of technology to a hostile competitor, each of these methods must be addressed. All pose political difficulties because of commercial and academic pressures to continue lucrative arrangements with China (and the Chinese count on this). In some cases, such as using regulatory powers to restrict foreign investment and technology exports, Congress has given agencies the authority to take action against China. In other cases, such as coercive business practices in China or the presence of Chinese students and workers in the US, existing authorities may be inadequate, and it remains uncertain if the trade talks now underway will change this. In all cases, an over-reliance on restrictions (such as limiting or even banning Chinese researchers) would be counterproductive and harmful to US interests.

The dispute with China over its aggressive mercantilist policies and constant theft of intellectual property does not change this, and it is unlikely that any "trade deal" will solve this (and any deal is unlikely to be sustainable). However, the attention given to the risks of doing business with China have created market effects that slow China's growth. Essentially, the cost of manufacturing in China has gone up. Companies are increasingly reluctant to trust their IP to Chinese firms and while in some instances this means that manufacturing is returning to the US (which has one of the most advanced and efficient manufacturing bases in the world) it also means that firms are moving beyond China to other countries (like Vietnam) to gain the advantage of differential costs in labour.

Technology and Competition

The complex pattern of commercial and research relationships challenges both nations. A straightforward correlation between technology and power can be challenged – having the best technology does not guarantee influence, power, or victory (as we have seen in the last 15 years, as the most technologically advanced military power confronted ragtag groups of insurgents in Afghanistan). The diffusion of technology and access to the commercial services provided by new technologies (such as space remote sensing) create challenges in both the economic and military spheres. From a military perspective, having indigenous capabilities to produce advanced technology may be becoming less important than the ability to exploit advanced technologies produced elsewhere.

Technological leadership does not automatically confer power. Political culture, national strategies, and business policies play a greater role, as do geographic size or population. Technology is one element among many in determining national power. The World Economic Forum once found Finland to be the most technologically advanced nation, and while this may translate into wealth for the Finns, it does not translate into power and influence. Both China and the US have innate advantages and disadvantages, but over the long term, the US has had a more consistent record of success – the real question is whether it has abandoned the policies and social constructs that provided this success.

America is hampered in this technological competition by its inability to finance public goods like research and its political discord. Such discord is suppressed in China, but other factors may hamper its continued technological improvement. First, greater government involvement in investment decisions politicises the process and introduces inefficiencies. Market-based investments generally outperform central planning. China's leaders know this and hope that an ability to mirror and copy Western market signals (perhaps using artificial intelligence tools to create "synthetic" market signals) will help compensate for this.

Second, China's innovation capabilities grew during a period of relative political openness. As this openness is reversed, it will be necessary to watch whether the ability to innovate will be damaged. The correlation between innovation and openness is imprecise but intuitively appealing. China hopes to compensate for any decline through increased espionage and investment (including, perhaps, performance-based incentives for successful Chinese companies).

Finally, there is the international reaction to China's policies. That the US regards China as a threat is one thing, but to have the European Union declare it a "strategic competitor" and to have Japan restrict technology transfers suggest that Xi may have gone too far. The advanced technology that China relies on will become more difficult to obtain. This international reaction was largely unexpected by the Chinese, a handicap created by their self-imposed censorship of news that does not agree with the CCP's narrative (which included assertions that China and its leadership are widely admired in countries around the world).

There has been some debate in China on whether Xi Jinping had been premature in abandoning Deng's policy of keeping a low profile internationally. In his defense, Xi was in part impelled by domestic requirements to buttress the Party's legitimacy and standing by demonstrating the centrality and success of its rule, but some Chinese commentators now urge a more restrained public posture.

Long-term trends favour China (*ceteris paribus*) but the immediate picture does not speak of inevitable rise. Another way to compare China and the US is to look at changes in GDP, which are, after all, one of the primary motivations (along with military power) for technological innovation. This very coarse measure shows an unexpected pattern. Both economies have grown in the last five years, and China's has grown at a faster rate (if we take its GDP figures at face value), but the "wealth gap" between China and the US has remained constant, with the US remaining US$7 trillion wealthier than China. Putting aside the inaccuracies of China's official data (which routinely overstate growth for political reasons), if the trends in both countries continue unchanged, China would have to increase its GDP at a faster rate to catch up to the US.

We can look at different sectors to assess the comparative strength of US and Chinese technological capabilities. One approach would be to look at new technologies that provide strategic capabilities – cyber, space and anti-satellite, precision-guided munitions, unmanned aerial or undersea systems, and hypersonic strike vehicles.

Tab. 3.1 - Comparison of US and Chinese Gross Domestic Product "Gap"

Year	US GDP	China GDP	"Gap"
2017	$19.4	$12.2	$7.2
2016	$18.6	$11.2	$7.4
2015	$18.1	$11.1	$7.0
2014	$17.4	$10.4	$7.0
2013	$16.7	$9.6	$7.1

Source: World Bank

In some areas, particularly hypersonic strike systems, intelligence reports suggest that China has made good progress. Alarmist intelligence reports even suggest that China has an advantage in this area. China's cyber capabilities have also improved in the last few years. In other areas, such as space systems, unmanned vehicles or precision-guided munitions, China still lags in varying degrees.

We can also ask how these new strategic military capabilities map to "emerging technologies". A 2017 Defense Department Report[3] described Chinese efforts in Silicon Valley to acquire advanced technology through investments and partnerships. In response, Congress passed the Foreign Investment Risk Review Modernization Act (FIRRMA), accompanied by the Export Control Reform Act (ECRA). President Trump signed both into law in August 2018. Additional restrictions were imposed by Defense authorisation legislation and Commerce Department regulatory actions, including the ability to "blacklist" specific Chinese companies.

FIRRMA closed many of the gaps in technology transfer regulations that had been used by China to acquire American technology. FIRRMA expanded reviews of foreign investments by the Committee on Foreign Investment in the United States

3 https://admin.govexec.com/media/diux_chinatechnologytransferstudy_jan_2018_(1).pdf

(CFIUS) to block risky acquisitions, and ECRA expanded technology controls on "emerging" and "foundational" technologies that are "essential to the national security of the United States". As part of this expanded review function, the Department of Commerce published an initial list of emerging technologies. This preliminary list included fourteen general categories of technology:

Biotechnology, Artificial Intelligence, Position, Navigation, and Timing (PNT) technology, Microprocessor technology, Advanced computing

Data analytics technology, Quantum information and sensing technology, Logistics technology, Additive manufacturing (e.g. 3D printing), Robotics

Brain-computer interfaces, Hypersonics, Advanced Materials, Advanced surveillance technologies

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China leads in a few areas, lags in many others, and is a peer in several. China may have an advantage in hypersonic vehicles and the development of advanced materials, including "energetics". It lags in microprocessor technology and robotics. In other areas it has peer or near peer capabilities. The areas of competition that have attracted the most attention are artificial intelligence (AI), quantum computing, and 5G telecommunications. To this list it is necessary to add hypersonic as the most salient military technology. In each, there are strong Chinese competitors, but the US maintains an advantage.

Much of the Western discussion of AI exaggerates risk and leads to misapprehension over China's progress in the field. AI describes a set of powerful tools for automation that do not by themselves confer advantage. AI applications have been present (although perhaps not visible to the popular culture) and used by businesses for more than a decade. The elements of AI include widely available mathematical and statistical formulas that are encoded into algorithms and software, which do not in themselves provide advantage. Advantage in AI comes from the ability to develop applications, and this depends on access to data.

China does not have a clear data advantage. While Alibaba and other Chinese companies have access to the data of hundreds of millions of Chinese users, they have less access in other markets (an outgrowth of widespread negative perceptions of China's pervasive surveillance and the degree of control it exercises over its companies)[4]. In contrast, Facebook, Google and others service the rest of the world, and have access to twice as much data as Chinese companies. Facebook has 3.4 billion users, more than twice the population of China.

Where China may have an advantage is in the limited scope of its privacy regulations. Restrictive or badly implemented privacy regulation in the West, along with efforts at data localisation in countries like India, could give China an advantage in the development of AI. China does have privacy regulations that are loosely modeled on Europe's GDPR, but their effect is less limiting. In the US, national privacy regulation is still in a formative period.

As an aside, the best example of the advantage conferred by weak Chinese regulation is in biotechnology, and China has made progress in developing its own biotech industry. In China, companies enjoy streamlined and accelerated clinical trials, which lower costs[5]. Chinese investors are still attracted to the US biotech industry, however, because biotech is the one technology where research is well-funded by the US government, an interesting indicator of the benefits of public spending and the damage caused by the US decision in the 1990s not to fund hard science at an equal level[6].

China's Huawei, a heavily subsidised private maker of telecommunications equipment, is a world leader in 5G systems,

[4] Expanded use of encryption and clashes with the US serves to insulate American companies from similar suspicions.

[5] UBS Chief Investment Office, "China's Biotech Revolution", 2 August 2018.

[6] E. Emanuel, A. Gadsden, and S. Moore, "How the U.S. Surrendered to China on Scientific Research", *Wall Street Journal*, 19 April 2019.

second only to Eriksson (the other leading 5G companies are, in order of market share, Nokia, ZTE and Samsung). Huawei says it is the only company to offer all the elements of 5G networks from handsets to core telecom (Samsung also states that it can make a similar offer) but this leaves out the crucial point that Huawei is still dependent on US technology, particularly from Intel, Qualcomm, and other advanced chip makers like Xilinx. Without these US components, Huawei could not make 5G systems and while China is spending heavily to become independent (part of a larger national effort to develop an indigenous semiconductor industry), it will be some years before it can attain this[7].

In some areas, such as quantum encryption, China has made significant strides. In other areas, such as making quantum computing chips, it lags behind. The performance of China's "Micius" quantum satellite is impressive, offering China a potential avenue for more secure communications. But many Chinese-made information technologies can have serious vulnerabilities, as the recent UK review of Huawei technology found. China has brilliant researchers, and dynamic entrepreneurs, but its skilled workforce is still inadequate, it lacks the "know-how" for building advanced technology, and as its political system grows more repressive, may discourage innovation.

China's technology strategy resembles the older, pre-globalisation approach to policy based on a territorial concept of industrial policy. These policies worked best when China was a developing economy where resources are under-utilised, and markets are inefficient. Now, a government driven approach to investment faces real dangers for mis-investment or mis-allocation. Continued success in the global economy means that Beijing may need to cede even greater control over investment and operations to its private sector and to foreign companies if it is to keep China competitive. But China's leaders have

[7] J. Lewis, "Learning the Superior Techniques of the Barbarians: China's Pursuit of Semiconductor Independence", Washington DC, Center for Strategic and International Studies (CSIS), January 2019.

increased the role of the party in investment and corporate management.

Developing a new model for technological innovation that is not based on a reliance on national research and industries is a challenge for all nations. In this global context, the government-driven investment and incentive model that has succeeded for the US has reached the limits of its effectiveness, but there has been no serious effort to replace it (and pro-forma invocations of the benefits of public-private partnerships do not count). What form this new model should take is unclear, but one key characteristic may be the openness needed to benefit from a transnational research base. In this, the US may have an advantage over the ethnically homogenous China.

China's technology strategies have global consequences – not just for the US but for all advanced economies and for important emerging markets, such as India. The effects of China's efforts are not just economic, but part of a larger reshaping of global influence and power where technological leadership plays a central role. The reorientation of American policy towards nationalism and retrenchment gives China an advantage. But this race is not over, and it will be easier for the US to change course than it will be for China. The best outcome for both countries and the world would be a return to partnership on equal terms and on the basis of reciprocity in trade and business, but it may be impossible for the Communist Party to make such concessions. China's rise is no longer peaceful, its economic policies harm the US and Europe and create global instability.isation We cannot go back to the Cold War, with two separate systems, one Western and one Communist, more or less sealed off from each other, but it is hard to see how we can return to a stable outcome before there is increased conflict.

4. A Green China. Impacts on Regional and Global Energy Security

Fabio Indeo

In less than 10 years' time, China has become a leader in renewable energy: currently it is the world's largest producer, exporter and installer of solar panels, wind turbines and electric vehicles, and it accounted for over 45% of global investment in renewable energy in 2017[1].

The increasing use of solar, wind and hydroelectric power is progressively modifying the national energy mix, with the strategic goal of strengthening domestic energy security aimed at reducing dependence on coal (also cutting polluting emissions) as well as oil and natural gas imports. Moreover, China has invested several billions to develop a modern clean energy technology, becoming the largest global manufacturer and exporter of solar panels, electric vehicles, batteries and wind turbines.

The aim of this chapter is to show how technological development is a strategic tool for China in order to increase its domestic-endogenous energy production of clean electricity, consequently reducing its reliance on hydrocarbon imports. Furthermore, its role as the largest exporter of clean energy technologies could allow China to become the global leader of the expected energy transition from a fossil fuel system to a non-polluting energy system based on the use of renewable sources, as recommended by the Paris Climate Agreement.

[1] A.Z. Amin, "Renewable Energy: Will China Be The Superpower?", *Newsweek*, 24 January 2019

The realisation of global energy interconnection appears an ambitious geopolitical task to achieve, but the implementation of a regional energy cooperation with ASEAN countries based on the integration of clean electricity interconnection is currently underway: Chinese investments to develop renewable energy projects in Laos or Myanmar could help them enhance their energy security following a different and non-polluting paradigm of development.

China and Renewable Energy Sources: The History of an Ongoing Success

In recent years, China has significantly increased the use of solar, wind and hydroelectric power in the domestic energy scenario, strengthening and diversifying its energy security with the aim of reducing dependence on coal as well as oil and natural gas imports.

According to the National Energy Administration (NEA), in 2018 China's renewable energy installation capacity had reached 728 GW, an increase of 12% from a year earlier[2]. Hydro is the largest source (352 GW), followed by wind (184 GW), photovoltaic (174 GW) and biomass (17,8 GW). While hydro was developed a long time ago, particularly important are the growth of wind and photovoltaic (PV), which respectively increased by 12.4% and 34% compared to the previous year[3]. Last year China was able to add another 20.59 GW of new wind power capacity to its grid, while new solar capacity reached 44.3GW after the first 100-megawatt solar power plant – located in in Dunhuang in the Northwestern province of Gansu – became operational[4].

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[2] National Development and Reform Commission People's Republic of China, *National Energy Administration*, official website.

[3] Ibid.

[4] "China powers up renewable energy but some wind farms still struggle to plug into grid", *South China Morning Post*, 28 January 2019

In the hydropower sector, since 2012 China has been able to benefit from 22,500 megawatts of clean electricity generated by the Three Gorges Dam (the largest hydroelectric dam in the world), located in the middle of three gorges on the Yangtze River (the third longest in the world) in the Hubei Province of China[5].

At present renewable energy accounts for 38.3% of the country's total installed power capacity[6]. According to NEA official statistics, power generation from renewable energy sources reached 1,870 TWh in 2018 – an increase of 170 TWh – and made up 26.7% of the country's total, while hydro contributed 1,200 TWh (up 3.2%), wind – 366 TWh (up 20%), PV – 177.5 TWh (up 50%) and biomass – 90.6 TWh (up 14%)[7].

These record-breaking data are the results of the so-called "energy revolution" launched by President Xi Jinping in June 2014, aimed at "curbing energy consumption by reducing coal share (a major source of pollution and climate-warming greenhouse gas emissions) and increasing the shares of non-fossil fuels in China's primary energy consumption"[8], also enhancing energy efficiency measures.

A reduction in coal use is one of the main issues to address in order to achieve these energy goals: at present China is the world's largest consumer of coal and consequently the world's largest emitter of greenhouse gases[9]. Following China's com-

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[5] "Three Gorges Dam", Encyclopaedia Britannica.

[6] "China powers up renewable energy but some wind farms still struggle to plug into grid"…, cit.

[7] National Development and Reform Commission, (NDRC) People's Republic of China, *National Energy Administration*, official website; Liu Yuanyuan, "China's renewable energy installed capacity grew 12 percent across all sources in 2018", *Renewable Energy World,* 6 March 2019.

[8] M. Vaid, "China's energy revolution strategy", *The Asia Dialogu*e, 30 March 2018.

[9] A. Hafner, P. Janoska, C. Lee, *Commentary: The importance of real-world policy packages to drive energy transitions*, International Energy Agency, July 9, 2018, https://www.iea.org/newsroom/news/2018/july/commentary-the-importance-of-real-world-policy-packages-to-drive-energy-transiti.html A. Hafner, P. Janoska, and C. Lee, *The importance of real-world policy packages to drive energy transitions*,

mitment to supporting the Paris Agreement based on a global commitment to reduce polluting emissions, Beijing has seriously adopted an increasing number of measures to reduce coal consumption and its share within the national energy mix (in which it accounted for 65% in 2015), paving the way to shifting towards a cleaner energy system.

On 25 April 2017 the National Development and Reform Commission released the "Energy Revolution Strategy" (ERS), which sets out the key targets and strategies for China's energy sector by 2030. The ERS clarifies that to achieve clean and low-carbon development, the share of non-fossil fuel in the energy mix should account for 15% in 2020 (12% in 2015) and 20% in 2030, while the proportion of coal consumption should fall below 58% (2020) and natural gas consumption should reach 10% (5.9% in 2015)[10].

We can observe that China's decision to largely develop renewable energy sources appears as a combination of the need to enhance and diversify its energy security condition, to handle environmental concerns and to ensure domestic stability.

Renewable energy has become a strategic priority for the Chinese government in order "to efficiently tackle problems of air and water pollution, and mitigate risks of socio-economic instability"[11]. As a matter of fact, environmental issues are a major reason for mass protests, and domestic political stability and security represent the top priority for the Chinese authorities[12].

Furthermore, achieving energy security is linked to reducing reliance on oil imports, which are mainly shipped through maritime routes (75% of total Chinese oil imports). This dependence poses geopolitical and security concerns, because it is necessary to provide security along the sea lines of communication, even if the development of alternative land energy

International Energy Agency, 9 July 2018.

[10] M. Vaid (2018). M. Vaid (2018).

[11] D. Chiu, *The East Is Green: China's Global Leadership in Renewable Energy*, Center for Strategic and International Studies (CSIS), 6 October 2017, p. 4.

[12] Ibid.

routes along the Belt and Road Initiative partially remedies this vulnerability[13].

In economic terms, solar, wind, hydro and biomass are domestic and endogenous energy productions that will push Beijing to reduce its dependence on imports.

The Chinese authorities have released several strategic documents that show a concrete political engagement to move towards a cleaner energy system based on a rising use of renewable sources. In the 13th Five-Year Plan for Economic and Social Development of the People's Republic of China (2016-2020) China defines its ambition:

> We will make a strong push to advance the energy revolution, giving impetus to a transformation in the way energy is produced and used, improving the energy supply mix, and elevating the efficiency of energy utilisation. We will build a modern energy system that is clean, low-carbon, safe, and efficient, and will safeguard the country's energy security[14].

The problem of reducing coal production and its share in the national energy mix represents a political challenge for the Chinese authorities, who are committed to restricting the production volume of coal in 2020 to 3.9 billion tons[15].

The 13th Five Year Plan for the development of renewable energy outlines the main targets for energy development based on renewable sources during 2016-2020: according this document,

> the wind power integrated into grid should be more than 210 million kilowatts by 2020, while the solar power integrated into the grid should be more than 110 million kilowatts, among

[13] F. Indeo, "China's New Energy Sourcing: Disrupting and Competing or Improving Global Energy Security?", in A. Amighini (ed.), *China: Champion of (which) Globalization?*, ISPI, Milan, 2018, pp. 124-125.

[14] National Development and Reform Commission People's Republic of China, *The 13th Five-Year Plan For Economic And Social Development Of The People's Republic Of China, Chapter 30 Build a Modern Energy System*, p. 84.

[15] T. Yatsui, *China's Energy Policy and Related Issues towards 2020*, Mitsui Global Strategic Studies Institute, Monthly Report, April 2017, p. 2.

> which 60 million kilowatts come from distributed photovoltaic, 45 million from kilowatts photovoltaic power plant, 5 million kilowatts from thermal power generation and conventional hydropower scale will be 340 million kilowatts by 2020[16].

Annual average increases in facility capacity are 21.2% in solar power and 9.9% in wind power where high growth is expected, though it is only 2.8% in water power[17]. By 2020, all renewable energy power generation capacity will be 680 million kilowatts, generating capacity 1.9 trillion kwh, accounting for 27% of all generating capacity. Lastly, the Five Year Plan for Electricity (2016-2020) aims to raise non-fossil fuel's share of total electricity production from 35% to 39% by 2020, while one-fifth of national electricity consumption will be met by non-fossil fuel sources by 2030[18].

Furthermore, these programmatic documents also establish initiatives to resolve the existent hindrances that hamper a complete implementation of renewable energy sources, mainly to overcome the restrictions on transmission capacity that are curbing power generation. As a matter of fact, the Chinese authorities have observed that the potential of wind and solar power generation is not fully utilised. For instance, in the northwest region with large-scale wind and solar capacity, electricity demand is lower and there are also constraints on the capacity of the power grid to provide electricity on the coast, which is the major region for electric power demand[19].

Consequently, one of the main actions to deploy is to promote a balanced introduction of facilities among regions, allocating increasing wind, solar and hydro power generation also to the east, the south and the north of the country. The efforts should be concentrated to strengthen power grid planning

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[16] *13th Five Year Plan for the development of renewable energy* , 10 December 2016, translated and published by Asian and Pacific Energy Forum.

[17] T. Yatsui (2017), p. 3

[18] D. Chiu (2017), p. 5.

[19] T. Yatsui (2017).

and construction, also improving dispatch operations in order to promote a large-scale integration of renewable energy into the power system[20]. The further implementation of the large-scale electricity transmission project called "West to East" is an infrastructure development priority. These expected three electricity-transmission corridors are conceived to transport clean electricity from the west – which has an energy surplus, especially from hydropower – to the east, where the main manufacturing and exporting regions (Guandong, Shanghai) are located, as well as densely populated areas[21]. According to the 13th Five-Year Plan for Hydro Power Development hydropower transmission capacity should reach 100 million kilowatts by 2020[22].

Global Leadership in the Renewable Energy Sector

The overwhelming domestic success in the renewable energy sector allows China to harbour ambitions to become the world's leader in green energy, even if current data and statistics already confirm this as Beijing's global role.

At present China is the world's largest producer of solar (more than half of global solar power capacity) and wind energy, and the largest investor in renewable energy: in 2017 China decided to invest US$97 billion for renewables (which accounted for over 45% of global investments in renewable energy), while by 2020 the investments in RE will rise to US$360 billion[23].

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[20] *13th Five Year Plan for the development of renewable energy*…, cit.

[21] D.T. Gibson, *Map: China's West-East Electricity Transfer Project*, Washington DC, Wilson Center, 19 February 2013.

[22] *13th Five-Year Plan for Hydro Power Development*, 2016, translated and published by Asian and Pacific Energy Forum.

[23] N. Shani, "Learning to Shift to Cleaner Energy from China", *ASEAN Energy*, 31 May 2018; Global Commission on the Geopolitics of Energy Transformation, *A New World. The Geopolitics of Energy Transformation*, International Renewable Energy Agency (IRENA), 2019, p. 28.

According to the International Energy Agency, the Chinese public and private sectors will invest more than US$6 trillion in low-carbon power generation and other clean energy technologies by 2040[24]. The installed solar power capacity is more than double that of the United States and Germany, while in the wind sector China has emerged as a frontrunner in both onshore and offshore growth: in 2018, for the first time, China installed more offshore capacity than any other market (1.8 gigawatts)[25].

In addition to its investments, China has become the largest global manufacturer of these clean energy technologies: wind turbine components, crystalline silicon PV modules, LED packages, and lithium-ion battery cells[26].

The governmental policy to concentrate huge and growing investments to develop modern technologies has led to high-quality production, reducing the global costs of these energy manufactures which are exported worldwide: for instance, the global prices of solar-panels were reduced approximately by 80%, and similar results can be achieved also on battery prices, following massive investments of Chinese companies[27].

Last year, nine of the top ten biggest panel exporters were based in China, which together accounted for 66 gigawatts (GW) of the 91.5 GW of the solar panels commercialised in 2018, meaning a market share of 70%[28]. For instance, Trina Solar is one of the largest solar panel manufacturers in the world, and has invested in increasing the efficiency of multi-crystalline-silicon solar cells[29].

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[24] A.M. Jaffe, "China's Coming Challenge to the U.S. Petro-Economy", Council of Foreign Relations Blog Post, 22 February 2018.

[25] A.M. Jaffe, "Green Giant, Renewable Energy and Chinese Power", *Foreign Affairs*, 13 February 2018; Global Wind Energy Council, *Global Wind Report 2018*.

[26] *A New World. The Geopolitics of Energy Transformation*…, cit., p. 40; A.Z. Amin (2019).

[27] A.M. Jaffe, "Green Giant, Renewable Energy…, cit; Global Wind Energy Council (2018).

[28] D. Kirton, "China's Solar-Panel Makers Dominate Global Exports", *Caixin*, 24 January 2019.

[29] "Trina Solar Panel Review", *Clean Energy Review*, 9 April 2018.

The Made in China 2025 initiative's special focus on green development significantly expresses the profitable convergence of political and economic interests existing in the country, which will strongly support China's ambition to become a global manufacturing and technological power in the industry of energy-saving and new-energy vehicles, through innovation, product quality, efficiency, and integration-driven manufacturing[30]. The aim is to invest in research and development sectors with the goal of progressively reducing China's dependence on foreign technology imports and to focus investments on the innovation of domestic companies, which should become more competitive in the global market. One of the main tasks is to enhance domestic manufacturing processes to produce not only essential components but modern and competitive final products[31].

The production of electric vehicles is one of the strengths of the Chinese "energy revolution", thanks to the concession of large state subsidies to the car industry and to promotion of their use. The new electric vehicles (NEV) include battery electric vehicles, plug-in hybrid electric vehicles and fuel-cell electric vehicles. The government set targets for sales of one million domestic NEVs by 2020 (70% of market share) and three million by 2025 (80% of market share)[32]. At present the Chinese car manufacturer BYD is the largest producer of electric vehicles in the world, while another six Chinese firms rank in the top 20. In 2018 more than one million electric cars were in use in China (almost double the number in the United States) and Beijing's authorities plan to increase them to five million by 2020[33].

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[30] Institute for Security & Development Policy, *Made in China 2025 BACKGROUNDER*, June 2018.

[31] Ibid.; A. Amighini, *What the MIC 2025 Means for the Chinese Economy*, ISPI Commentary, 3 August 2018.

[32] G. Young, *"Made in Chiana 2025": The development of a new energy vehicle industry in China*, Area Development and Policy, vol. 4, no. 1, 2019, pp. 39-59.

[33] A.M. Jaffe, "Green Giant, Renewable Energy…, cit.

The predominant position in the rare earth elements market is another factor that helps to explain why China will be able to lead the global success of renewable energy sources. Rare earth elements are widely used in clean energy technologies, to produce solar panels and wind turbines: even if these elements are present in many countries, China currently holds a kind of monopoly over mining, producing and processing rare earth elements: consequently, producer countries usually send their rare earth elements to China, where they are processed and shipped back, making China the indisputable global supplier of these minerals, also considering that China and Russia together hold 57% of global reserves[34].

Moreover, other raw materials – mainly lithium, cobalt and indium – are also widely used in clean energy technologies. Lithium ion batteries are used to help manage the intermittency of solar and wind power and in electric vehicles[35]. China is one of the largest lithium producers and the global demand for this mineral will necessarily increase following the spread of electric vehicles as non-polluting cars with cost-competitive prices compared to traditional automobiles. China and the Democratic Republic of Congo are respectively the world's largest providers of indium and cobalt, which are also used in renewable energy technologies to produce solar panels and batteries[36].

Considering that China holds large reserves of bauxite/aluminium, copper, iron and lead – which are the key minerals required for the production of solar and wind technology as well as for electric vehicles and energy storage – the Asian country can consolidate its predominant position in the production and export of renewable energy technologies[37].

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[34] M. O'Sullivan, I. Overland, and D. Sandalow, *The Geopolitics of Renewable Energy*, Working Paper, New York, Center on Global Energy Policy, July 2017, p. 12; U.S. Geological Survey, *Rare Earths*, Mineral Commodity Summaries, 2016.

[35] M. O'Sullivan, I.Overland, and D. Sandalow(2017), p. 12.

[36] Ibid.

[37] International Institute for Sustainable Development, *Green Conflict Minerals: The fuels of conflict in the transition to a low-carbon economy*.

The widespread global consciousness of environmental problems and of the need to reduce greenhouse gas emissions will lead many countries to undertake a shift in their energy strategy, focusing on the development of renewable sources. Achievement of the Paris Climate Agreement targets will have enormous implications for the role of renewables: according to the International Energy Agency, renewables will account for 40-45% of the primary energy supply, while IRENA envisions a share of 65%[38].

Consequently, the demand for clean energy technology will increase in order to exploit the potential of renewables (solar, wind, biomass, geothermal) and China is well in position to become a global exporter. Furthermore, Trump's decision to withdraw from the Paris Climate Agreement marks a disengagement of the United States from the green energy revolution, leaving room for China as a future renewable energy superpower.

The results of this evolution will be a reshaped global energy scenario, within which China will act as global partner to promote green energy, supporting the efforts of other countries and granting them loans, offering clean energy products and goods at competitive prices, providing its technology, upgrading transport and energy infrastructures and also promoting a better integration of transport grids.

Regional Grids and Interconnections: China-ASEAN Energy Cooperation

Moreover, China will be able to enhance its global leadership in the renewable energy revolution also by promoting the creation of a cross-border energy super grid, aimed at exporting clean electricity or generally implementing cross-border electricity trading through the integration of regional interconnections.

[38] International Energy Agency (IEA) and International Renewable Energy Agency (IRENA), *Perspectives for the Energy Transition*, 2017.

This regional energy cooperation is one of the steps in the ambitious long-term goal – expressed by the State Grid, China's largest state-owned company – to create the "Global Energy Interconnection"(GEI), a US$50 trillion worldwide wind and solar power grid which will link every continent with underwater transmission cables to provide green electricity around the world by 2050[39].

China intends to implement the Global Energy Interconnection project within the Belt and Road Initiative (BRI) framework, which explicitly envisions "to foster green energy cooperation, improving regional energy security through the integration of the energy markets and encouraging the efficient development and utilisation of clean energy. Furthermore, BRI promotes the creation of cross-border power transmission line construction, so upgrading the regional power grid"[40].

In the regional framework, China and ASEAN countries (Cambodia, Vietnam, Laos, Thailand, Indonesia, the Philippines, Brunei, Singapore, Malaysia and Myanmar) have started to work together in order to enhance energy and power cooperation, for the purpose of promoting efficient utilisation of energy and power within the ASEAN region, improving and expanding power grid operation and power accessibility[41]. China could play a role of reliable energy partner for ASEAN countries, supporting their efforts to boost domestic energy security through a growing use of clean electricity produced by renewable sources and reducing hydrocarbon imports and their use in the national energy mix.

ASEAN is now one of the most dynamic economic regions in the world: if ASEAN were a single country, it would be the world's fifth largest economy, after the United States, China, Japan and Germany. According to IRENA and the ASEAN

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[39] A *New World. The Geopolitics of Energy Transformation*…, cit., p. 49; *Global Energy Interconnection Development and Cooperation Organization* (GEIDCO), official website.

[40] National Energy Administration, *Vision and Actions on Energy Cooperation in Jointly Building Silk Road Economic Belt and 21st-Century Maritime Silk Road.*

[41] ASEAN Center for Energy, *ASEAN Power Cooperation Report*, 2017.

Center for Energy, "the expected population increase in the ASEAN region – from around 615 million in 2014 to 715 million by 2025 – will lead to a 4% annual growth in energy demand until 2025, amounting to a rise of 50% over the 2014 level, and electricity demand will double between 2014 and 2025"[42].

In this context, renewable energy appears to be the best option to increase the region's energy security through greater diversification of the energy mix and by reducing demand for imported fossil fuels.

In 2015 ASEAN countries adopted the Plan of Action for Energy Cooperation (APAEC) 2016-2025, which includes the ambitious goal of achieving 23% renewable energy in total primary energy supply by 2025, which implies a two-and-a-half-fold increase in the modern renewable energy share compared to 2014[43].

Renewable energy sources are abundant in Southeast Asia – hydro, geothermal, solar, wind – but most of them still remain untapped[44]. China's task will be to support ASEAN countries in developing their renewable energy potential, helping to promote an endogenous production of clean electricity and to expand the ASEAN Power Grid (APG) project, realising sub-regional interconnections linked to China and thereby promoting cross-border clean electricity trading. The ASEAN Power Grid project has been conceived as an inclusive initiative, moving from a cross-border bilateral dimension, then expanding to a sub-regional basis and finally to a totally integrated regional system. This project will become the centrepiece of the regional power architecture, enhancing electricity trade across regional borders, which would provide benefits to meeting rising energy demand with clean and sustainable electricity supplies delivered through integrated infrastructures[45].

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[42] International Renewable Energy Agency (IRENA), Abu Dhabi and ASEAN Centre for Energy (ACE), *Renewable Energy Outlook for ASEAN: a REmap Analysis*, 2016, p. 10.

[43] ASEAN official website, *ASEAN-EU Plan of Action (2018-2022)*, 2017, p. 5.

[44] International Energy Outlook, *Southeast Asia Energy Outlook 2017*, 2017.

[45] A. Gnanasagaran, "Building ASEAN's power grid", *The Asean Post,* 30 May 2018.

Following the implementation of additional APG interconnection projects, it is expected that power exchange and purchase will almost triple from 3,489 MW in 2014 to 10,800 MW in 2020, and further increase to 16,000 MW post-2020[46].

The APG project is an interesting one of regional cooperation combining the different renewable energy sources that ASEAN countries are able to produce[47]. Laos is the leading ASEAN country in terms of hydro-power potential, with 39 operative hydro-power plants and more than 90 that will be on stream by 2020[48]. Furthermore, the Philippines and Indonesia are the second and third largest producers of geothermal energy in the world.

China is actively investing in the development of renewable energy sources in Southeast Asia with hydroelectric projects in Cambodia, Laos, Vietnam (due to the untapped hydropower potential of the Greater Mekong sub-region) and Myanmar, and thermal power-generation projects in Indonesia, Vietnam and Singapore[49]. The China Southern Power Grid (CSG) is working with Laos to develop that country's electricity infrastructures and it plans to create a regional power grid that will link China, Vietnam, Laos, Myanmar, Thailand and Cambodia. Given the abundance of water energy resources, Laos is defined as the "ASEAN battery" and the future regional power hub: at present Laos already plays this role of clean-electricity regional supplier, selling power to Thailand, Vietnam, Cambodia, Malaysia, China and Myanmar. China's Electric Power Planning and Engineering Institute is helping Laos with its plans to develop as a regional power hub supplying electricity to Southeast Asia

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[46] ASEAN official website (2017), p. 8.

[47] F. Indeo, "ASEAN-EU energy cooperation: sharing best practices on renewable energy sources and the regional/global dimension", *Global Energy Interconnection (Geidco Journal)*, 2019 (forthcoming).

[48] Mekong River Commission, "MRC ready to support review and update of Lao hydropower strategy and plan", 15 August 2018.

[49] S. Songwanich, "China's ambitious plans to power Southeast Asia", *Mekong Eye*, 24 July 2018.

and China's Yunnan province, as one of the key segments of the planned world's first global electricity network by 2050[50].

The implementation of the Laos-Thailand-China power integration project (as well as the Myanmar-Bangladesh-China power integration project) is conceived to deepen regional energy interconnectivity, providing secure supplies based on clean electricity.

Furthermore, Chinese companies have heavily invested to develop Myanmar's hydropower sector, especially in the north of the country, which shares a border with China. The Shweli River Hydropower Station is one of the main examples of this fruitful regional energy cooperation: the installed capacity of the power station is 600MW and the designed annual generating capacity is 400MW[51]. Beijing's State Grid Corporation of China has invested and launched a 230 kilovolt (KV) Nabar-Shwebo-Ohntaw power transmission line and a substation project in Shwebo in Myanmar's northwestern Sagain region[52]. Nevertheless, another big project – Myitsone Hydropower Dam project in Myanmar's northern state of Kachin – appears frozen due to unsolved disputes between the two governments concerning unbalanced electricity distribution (90% to China and only 10% to Myanmar, even if free of charge) and for its high social and environmental costs[53].

In Indonesia Chinese companies are interested in investing in hydroelectric projects in dams around the Kalimantan and Sulawesi regions. Since 2014 the Chinese manufacturer Yingli Green Energy Holding Company has made the solar panels for the biggest solar power plant in Malaysia at the time[54]. Moreover, CSG – together with other Chinese and Vietnamese

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[50] Ibid.

[51] *ASEAN Power Cooperation Report*…, cit., pp. 16, 18-19.

[52] A. Gnanasagaran, "China's energy ambitions in Southeast Asia", *The ASEAN Post*, 17 August 2018.

[53] S. Ramachandran, "The Standoff Over the Myitsone Dam Project in Myanmar: Advantage China", *China Brief*, vol. 19, no. 8, 24 April 2019.

[54] A. Gnanasagaran (2018).

companies – has funded the Vinh Tan 1 thermal power plant located in Vietnam's southern Binh Thuan province, together with China Power International Development and the Power Corporation of the Vietnam National Coal-Natural Industries Corporation[55].

Definitely, ASEAN countries are also an interesting and promising market for China's clean energy technology exports, such as photovoltaic cells and electric cars, considering the expected growth of the Southeast Asian population and the need to cut polluting emissions.

Conclusion

The large use of renewable energy sources in the domestic energy mix, the huge investments to develop a modern energy technology that is exported worldwide to meet the growing demand for clean electricity, the geopolitical ambition to promote regional and global energy interconnections fuelled with clean electricity are allowing China to play the role of global leader in renewable energy sources.

It is interesting to observe that this new global energy landscape based on a rising use of renewable sources could also change the common perception about Chinese ambitions on the international chessboard: as a matter of fact, China could progressively appear as a reliable energy superpower that aims to promote the worldwide use of renewable energy sources, offering its clean energy technology to other countries and allowing them to become energy producers. The possibility of exploiting their endogenous-renewable energy potential would mean reducing their dependence on oil and gas imports and coal use, meeting environmental targets as well as enhancing their energy security.

[55] He Wei, "China-ASEAN to cooperate on new energy vehicles", *China Daily*, 11 July 2018.

However, the success of this Chinese strategy strongly depends on the future position of the United States and other countries, which complain and are wary about Chinese geopolitical ambitions and the debt-trap deriving from the BRI-labelled Chinese investments: trade disputes can emerge, with countries that try to preserve their national industries and production through protectionist measures and tariffs, like Trump decision to levy 30% tariffs on solar cell and module imports to try to protect domestic manufacturers.

The implementation of regional or global electricity interconnections could ensure regular energy supplies for all involved countries, promoting new frameworks of cooperation and relations. However, similarly to the case of transnational pipelines, the regional electricity interconnections could also be exposed to threats of interruption (transiting through a third country) and vulnerabilities that will become serious if a country is strongly dependent on clean energy imports.

5. Case Study: China's "Giant Leap" Towards Fintech

Paolo Giudici

China's race to global technology leadership includes the development of a strong financial technology (fintech) sector among its priorities.

Financial technology platforms lead to cost reduction, and to an improved user experience. However, these improvements may come at the price of inaccurate risk measurements, which can hamper a platform's users and endanger the stability of a financial system. In this chapter, we propose how to improve the credit risk accuracy of peer-to-peer platforms, to make them sustainable regardless of the country in which they are based. To achieve this goal, we propose augmenting traditional credit-scoring methods with centrality measures derived from network models of borrowers, estimated from their financial activity. We apply our proposal to fintech platforms in China and Italy characterised, respectively, by a large and a small incidence of fintech activities. Our empirical findings show that, in both cases, the inclusion of network centralities improves credit risk models and, therefore, makes fintech innovations sustainable.

In recent years, the emergence of financial technologies (fintechs) has redefined the roles of traditional intermediaries and has introduced many opportunities for consumers and investors. Here we focus on peer-to-peer (P2P) online lending platforms, which allow private individuals to directly make small and unsecured loans to private borrowers, such as individuals and small/medium enterprises.

The recent growth of peer-to-peer lending is due to several "push" factors. First, when compared to classic banks, P2P platforms have much lower intermediation costs. Second, the evolution of big data analytics and Artificial Intelligence enables P2P platforms to provide banking services that can improve personalisation and, therefore, user experience. A third push factor is the presence of favorable, or absent, regulation. An example of favorable regulation is the European Payment Service Directive (PSD2), which discloses bank clients' account information to fintechs through application payment interfaces (API) that take consumer's consent and ethics into account.

P2P lending business models vary in scope and structure: a comprehensive review is provided by Claessens et al. (2018). Here we specifically refer to the platforms that lend themselves to small and medium enterprises (SME), as in the paper by Giudici, Hadji-Misheva and Spelta (2019). A key point of interest to assess the sustainability of P2P lenders is to evaluate the accuracy of the credit risk measurements they assign to the borrowers.

While both classic banks and P2P platforms rely on credit-scoring models for the purpose of estimating the credit risk of their loans, the incentive for model accuracy may differ significantly. In a bank, the assessment of the credit risk of the loans is conducted by the financial institution itself, which, being the actual entity that assumes the risk, is interested in having the most accurate model possible. In a P2P lending platform, the credit risk of the loans is determined by the platform but the risk is fully borne by the lender (Serrano-Cinca et al., 2016). In other words, P2P lenders allow for direct matching between borrowers and lenders, without the loans being held on the intermediary's balance sheet (Milne and Parboteeah, 2016).

From a different perspective, while in classic banking the financial institution chooses its optimal trade-off between risks and returns, subject to regulatory constraints, in P2P lending the platform maximises its returns, without taking care of the risks that are borne by the lenders.

Another factor that penalises the accuracy of P2P credit-scoring models is that they often do not have access to the borrowers' data usually employed by banks, such as account transaction data, financial data and credit bureau data. For these reasons, the accuracy of credit risk estimates provided by P2P lenders may be poor. However, P2P platforms operate as social networks, which involve their users and, in particular, the borrowers, in a continuous networking activity. Data from such activity can be leveraged not only for commercial purposes, as is customarily done, but also to improve credit risk accuracy.

We believe that networking information can offset the aforementioned disadvantages and can improve the credit risk measurement accuracy of P2P lenders. From a regulatory viewpoint, this implies that P2P lenders should not be penalised with heavy compliance rules, or with the imposition of high capital buffers.

Classic banks have, over the years, segmented their reference markets into specific territorial areas and business activities, increasing the accuracy of their ratings, but also their concentration risks. They automatically receive data that concern the transaction of each company with the bank and can easily obtain further information about the financial situation and payment history of each company.

Differently, P2P platforms are based on a "universal" banking model, fully inclusive, without space and business type limitations, that benefits from diversification. P2P platforms automatically receive data from the participants in the platforms that concern the transactions and/or relationships of each company not just with the platform but also with each other. Provided that enough companies populate the platform, the resulting networking data is richer than that of banks as it contains more information. In particular, it contains data about how companies and individuals interact with each other, in terms of payments, demand and supply chains, control and governance.

The latter information can be used for the purpose of creating a network model that can quantify how borrowers are interconnected with each other. A model that can be employed to improve loan default predictions.

We aim to build a network model from the available platform data. To achieve this goal, the issue is to quantify the information contained in networking data, often available from different perspectives: financial transactions between companies, economic similarities, common holdings, presence in common demand or supply markets and so on, giving rise to a "multilayered" network.

The quantification of multilayered information requires the development of an appropriate statistical methodology. In this paper we follow the multilayer network approach suggested in Montagna and Kok (2015), Poledna et al. (2016), Aldesoro et al. (2016) and Avdjiev et al. (2018), for the analysis of multilayer interbank lending networks. In particular, we closely follow Avdjiev et al. (2018) who represent the aggregate financial exposures of each country as a multilayer financial network, in which each network represents a type of borrower (financial sector, private sector, public sector).

In principle, this approach could be extended to peer-to-peer lending platforms for individuals and for SMEs, looking at the "physical" peer-to-peer financial transactions that occur between the borrowers in a platform, whether they are individuals or small/medium enterprises. This is the approach we will follow in application to a Chinese platform for private individuals.

However, such data is not typically disclosed by P2P lenders so that, aiming for a generally reproducible analysis, we may need to look for alternative networking data. This is the approach we will follow in application to Italian platforms for SMEs.

Indeed, when physical transactions are not available we can look at statistically correlation networks that can be deduced from time series of publicly available information on SMEs, standardised according to common accounting standards. Correlation network models have proven to be effective, even in the interbank lending context, where transactional data is usually available (see eg. Brunetti, 2015 and Giudici et al., 2017).

Here we extend correlation networks to the P2P context, linking network models, that are often merely descriptive, with logistic regression models, thus providing a predictive framework.

The paper is organised as follows. The technical appendix explains the methodology we propose to achieve the stated research goals. Section 2 presents the results obtained applying physical network models to a Chinese P2P personal lending platform. Section 3 presents the results obtained applying correlation network models to Italian SMEs, potential customers of P2P platforms. We conclude with a final discussion, in Section 4.

Peer-to-Peer Personal Lending in China

Data

In this section we empirically verify whether P2P credit scoring for personal loans can be improved using physical network models. The results we present are taken from the paper by Chen et al. (2019) to which we refer for further details.

The data used in the analysis is obtained from Renrendai, one of the largest peer-to-peer lending platforms in China. Founded in 2010, it now has over 1 million members located in more than 2,000 cities across the country. The transactions taking place at Renrendai are typical P2P lending transactions. Anybody with a Chinese identity card number can borrow or lend money on the website. On Renrendai, borrowers can post loan listings, adding information about loan usage, borrowing amount, interest rate, and duration. Renrendai only provides basic verification on borrowers' national identification cards, credit reports, and locations. Once a loan listing is posted online, lenders may place bids by stating the amount they want to fund. With a minimum bid amount of RMB 50, a listing typically requires dozens of bids to become fully funded. A listing that achieves 100 percent funding status is a successful listing; otherwise, the borrower receives zero funding.

We consider all loan listings and the corresponding lending records created on Renrendai between January 1, 2011 and December 31, 2015.

For each loan listing, we have the corresponding lending records, including the lender's ID, the interest rate, the amount, and the duration of the investment. While personal information on the borrowers is disclosed, that about lenders is not. However, the ID number of all borrowers on Renrendai is available and, therefore, if a lender has posted a loan listing as a borrower on Renrendai, we can match it according to his/her ID and obtain personal information on the lender as well.

The considered data includes 44,481 loan listings from 17,585 individual borrowers, of which 23,365 are successfully funded while the remaining 21,116 are not funded. Among all listings that are successfully funded, there are 3,618 defaults.

Empirical findings

We now present the application of networks models to describe the relationships between the borrowers in the Chinese P2P platform.

Figure 5.1 presents the evolution of the amount of total lending in the network, over the years. It shows that the amounts lent through the network have considerably grown over time. This with a peak around month 24, following by a subsequent decline.

Fig. 5.1 - Evolution of the total lending in the network

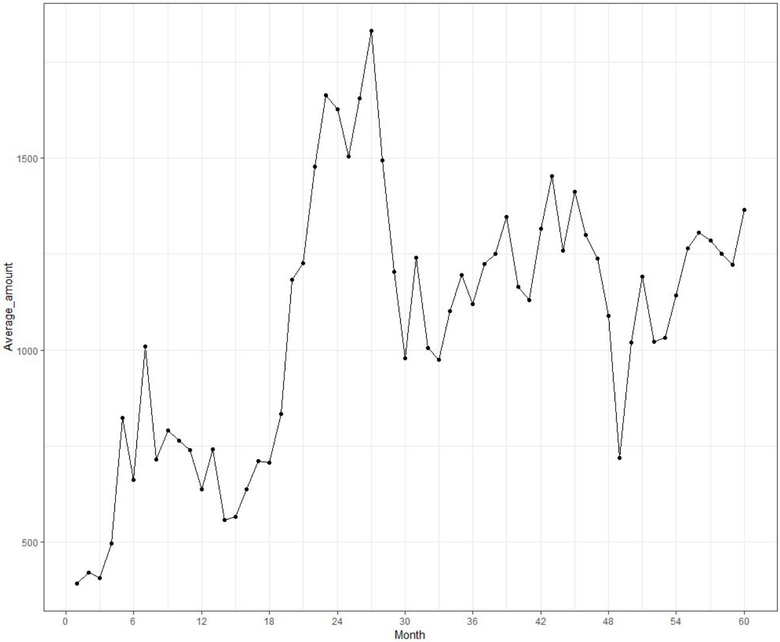


Figure 5.2 shows the time evolution of the estimated networks, summarised in terms of the number of borrower nodes and of total links between such nodes. It also shows that the network has indeed increased the number of nodes, but has not correspondingly increased the number of links between them. In other words, the network has become sparser.

Fig. 5.2 - Evolution of the network complexity

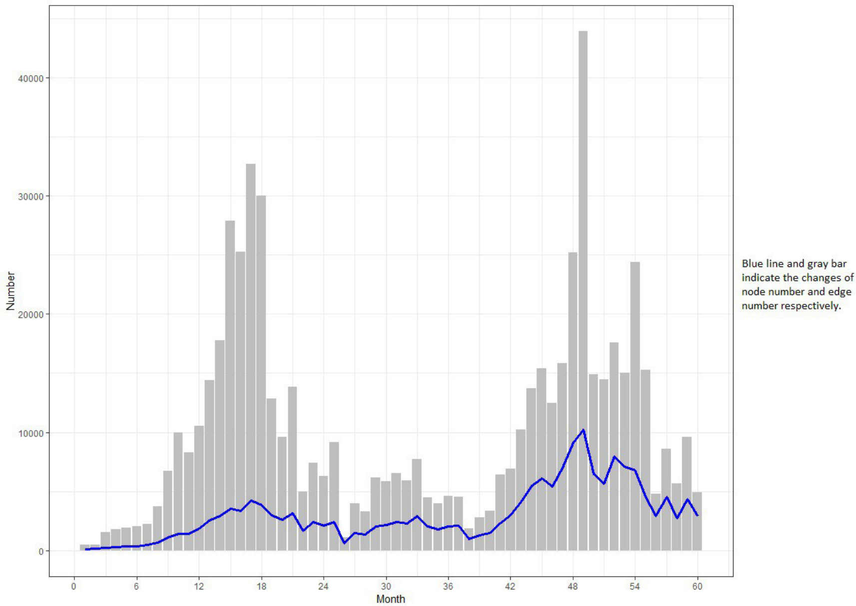


Figure 5.3 shows a measure that is related to the "sparseness" of the network: the average path length. From Figure 5.3 note that the sparseness of the network has increased over time, due to the increase of the number of nodes, not balanced by a proportional amount of transaction volumes.

The effects of networking on the probability of default, measured by (physical) network based logistic regression models, described in the previous section, can be summarised as follows (for more details see Chen et al., 2019).

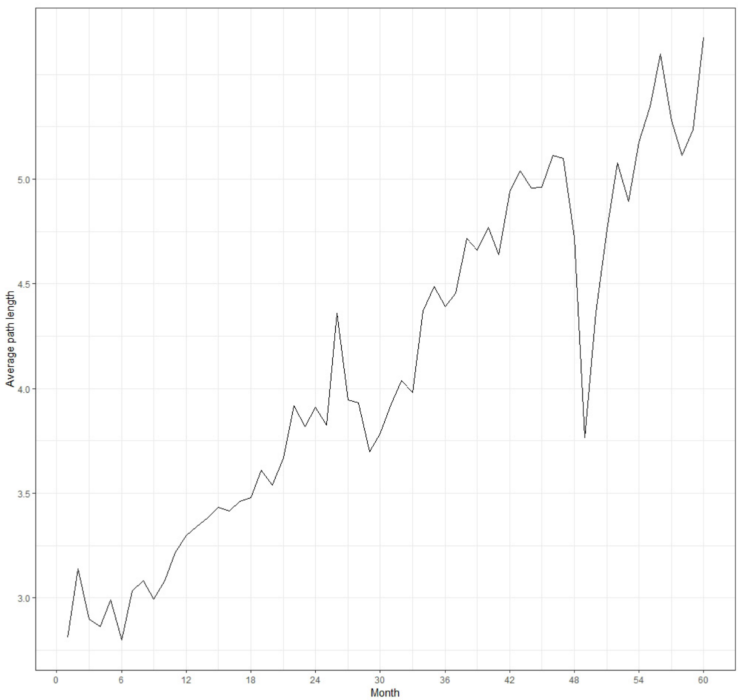
In terms of the obtained interest rate, all centrality parameters are negative and significant, indicating that the higher the centrality of a borrower, the lower the interest rate he/she obtains. This is probably because borrowers that are more connected enjoy a good reputation and, therefore, can borrow at lower interest rates.

In terms of funding success, the results indicate that the more central borrowers are in P2P lending, the easier it is to get loans. This again can be explained by the stronger network reputation of the most central nodes.

In terms of loan performance, borrowers with more connections are less likely to default. This implies that networking has a restrictive effect on borrowers' moral hazard.

Finally, in terms of loan recovery rates, centrality parameters are not significant. This is in line with the intuition that recovery is a process that may be affected by administrative and structural characteristics that do not relate so much to peer-to-peer networking.

Fig. 5.3 - Evolution of the avarage path length



To summarise, all results from the different logistic regressions indicate that the greater the centrality, the better the borrowers' performances, with a lower interest rate, a higher rate of success, and a lower default rate.

Peer-to-Peer SME Lending in Italy

Data

In this section we empirically verify whether P2P credit scoring for SME loans can be improved using correlation network models. The results we present are taken from the paper by Giudici et al. (2019) to which we refer for further details.

Data is obtained from mode finance, a European Credit Assessment Institution (ECAI) that supplies credit scorings to P2P platforms specialised in business lending. Specifically, the analysis relies on data about 727 borrowing SMEs, mostly based in Italy covering the period [2007-2015]. The proportion of observed defaults in the sample is equal to 23%, a large proportion, in line with the observed impact of the recent financial crisis in Southern European countries.

The available data include the status of the companies, classified as [1 = Defaulted] and [0 = Active] as well as information on their most important financial characteristics. This information can be used to estimate a credit-scoring model aimed at predicting default status on the basis of the observed values of a set collection of financial variables, derived as ratios from the yearly balance sheet of each company. As financial indicators we can choose, without loss of generality, those most frequently reported in the literature.

Empirical findings

We now present the application of correlation networks to describe and summarise the relationships between the borrowing SME in the P2P platform.

As previously discussed, our proposed correlation network models aim to infer the networking properties among the borrowers in a P2P platform from the time comovement among the values that a given set of random variables take, when applied to their yearly financial statements.

We propose to choose, as base variables, three well-known financial ratios, among those in Table 5.1: the (1) activity ratio, expressed as the ratio between sales and total assets; (2) the solvency ratio, expressed as the ratio between net income and total debt and (3) the return on equity ratio. The choice of these variables reflects the need to consider company similarity according to the most important aspects: business sustainability, financial sustainability and operational performance.

Following this choice of variables, three time series of data can be extracted, for each of the 727 considered companies. Consequently, three 727 x 727 correlation matrices (weights) are obtained. Instead of using a fully connected correlation network, with all edges present, which would be as many as $(727 \times 726)/2 = 263901$, we consider a more parsimonious network, in which an edge between two companies is present when the corresponding test in (2) is significant at a level of $\alpha = 0.01$. The application of the test gives rise to three 727 x 727 adjacency matrices, in which an edge is either present or absent, depending on whether the corresponding correlation is significant or not significant.

Figure 5.4 shows the network obtained using the activity indicator to calculate correlations. In the figure, nodes are colored based on their status, with red indicating companies that have defaulted in the considered period, and green still active companies. The nodes are not equal but, rather, have a size proportional to their degree of centrality, with bigger nodes indicating more connected ones. Edges are instead colored according to the sign of the found correlation: green for a positive correlation, and red for a negative correlation.

Fig. 5.4 - Correlation network based on the activity indicator. Number of nodes= 386

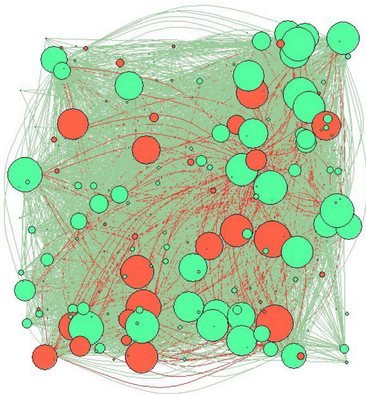


Figure 5.5 shows the network obtained using the solvency indicator to calculate correlations. The figure is based on the same assumptions used for the activity ratio, in terms of the significance level, and about the coloring and dimensioning of nodes and edges.

Figure 5.5 indicates that the central companies are less than before (288) and that most of them are good companies.

Finally, we consider the network model that emerges using the correlations between companies calculated in terms of the return on equity indicator over the considered period. Figure 5.6 presents the corresponding representation, maintaining the same assumptions as before.

Looking at Figure 5.6, the correlation network obtained using the return on equity indicator shows a low number of central nodes (226) and a limited presence of defaulted companies. These findings point towards the idiosyncratic nature of the return on equity indicator, which appears company specific, rather than driven by a systematic driver, consistently with the economic intuition.

We now present the application of correlation networks to describe the relationships between the borrowers in a P2P platform.

Fig. 5.5 - Correlation network based on the solvency indicator. Number of nodes= 288

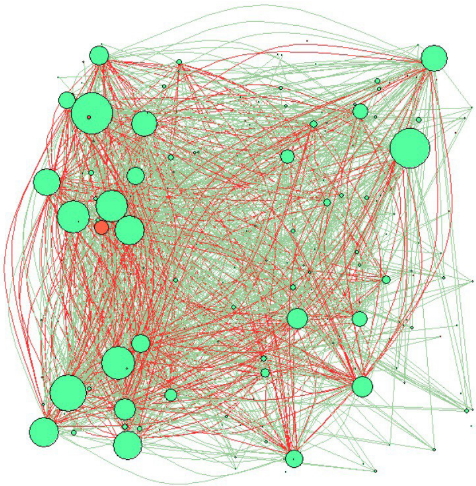
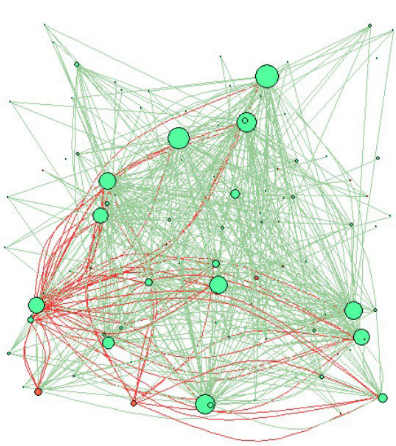


Fig. 5.6 - Correlation network based on the return on equity ratio. Number of nodes= 226



We now estimate a credit-scoring model. First we estimate a baseline logistic regression model as a departure point, before moving towards the application of our proposal, a correlation network based logistic regression model.

Table 5.1 summarises the results from the application of a logistic regression model to the available data.

Tab. 5.1 - The estimated baseline regression model

	Estimate	P Value	Significance
Intercept	18.040	0.000	***
Activity ratio	-3.897	0.000	***
Cash over total assets	-0.636	0.772	
Coverage	0.000	0.672	
Current ratio	0.100	0.557	
Return on assets	-0.072	0.277	
Return on equity	-0.023	0.206	
Solvency ratio	0.004	0.774	
Total assets	-2.630	0.000	***
Area Under the Curve			0.622

From Table 5.1 note that two variables are found significant and those are: the activity ratio and the total assets. The significance of the former is in line with the observation that, in the considered period, the companies in southern Europe, to which the companies in our sample belong, have suffered from a considerable decrease in GDP. However, companies have reacted differently to recession: some, and especially those more oriented toward the internal markets, have shrunk their sales;

others, and especially those more export-oriented, have maintained or increased their sales, thus explaining the significance of the activity ratio: companies that are better able to use their assets to generate sales are less likely to default.

From Table 5.1 note that the estimated coefficient for the total asset variable also has the expected negative sign, suggesting that larger companies are typically less likely to default, compared to companies with smaller assets.

To improve model accuracy, we employ correlation networks. To this aim, we augment the available data matrix with the degree of centrality measures, calculated for each node on the basis of the correlation network models derived in the previous section. More specifically, we have added to the baseline logistic regression model the three variables corresponding to the degree of centrality of each company in the Activity, Solvency and Return on Equity ratio. To avoid double counting, we have removed the original three variables from the logistic regression. Table 5.2 reports the results from the network based logistic regression model.

Table 5.2 shows that the degree of centrality based on the activity ratio is significant, whereas those based on solvency and ROE are not. The sign of the significant centrality is positive. This means that the higher the centrality degree of a particular company, the higher the probability that it would be connected with a defaulted company, and this may negatively impact its overall probability of default. On the other hand, note that the negative sign of the Total Assets variable is confirmed, although with a lower magnitude. The variable Return on Assets becomes significant, with the expected sign (higher values leading to a lower probability of default).

Tab. 5.2 - The estimated network based regression model, with all type centralities

	Estimate	P Value	Significance
Intercept	-0.241	0.814	
Cash over total assets	0.600	0.612	
Coverage	0.001	0.672	
Current ratio	0.051	0.632	
Return on assets	-0.143	0.001	***
Total assets	-0.285	0.062	*
Degree centrality (Activity)	0.011	0.008	***
Degree centrality (ROE)	-0.038	0.412	
Degree centrality (Solvency)	-0.017	0.355	
Area Under the Curve			0.8357143

In terms of predictive accuracy, the model in Table 5.2 leads to an AUROC of 0.835, much higher than the AUROC in Table 5.1, equal to 0.622. This suggests that the inclusion of network centrality parameters, besides improving explainability, also improves predictive accuracy.

Conclusion

In the paper we have shown that the business model on which peer-to-peer lending platforms are based (networking) can be exploited also from a risk management viewpoint.

This applies especially to large peer-to-peer fintechs, like those present in China, but can apply also to smaller European fintechs, as the Italian case has shown.

Specifically, we have shown that, for both personal and SME lending, credit risk measurement can be improved, both descriptively and predictively, using network-based information.

This allows fintech activity to be more sustainable, not only from the business' side, but also from the users' perspective.

We believe that the main beneficiaries of our results may be regulators and supervisors, aimed at preserving financial stability, as well as investors of P2P platforms, who should be protected against the negative sides of fintech innovations (higher risks) while keeping their positive sides (lower costs and better user experience). For a general discussion of this point see also Giudici (2018). Based on the obtained results, we also believe that China's leadership in financial technology, and particularly in peer-to-peer lending, can be beneficial for the world economy if fintech risk models increase their accuracy as shown here.

Technical Appendix

The most popular statistical model to estimate the probability of a borrower's default is the logistic regression. In the context of P2P lending, logistic regression has been used by Barrios et al. (2013), Emekter et al. (2015) and Serrano-Cinca et al. (2016). These authors classify P2P borrowers in two groups, characterised by a different history of repayments of the loans that were funded through the platform: 0=active (all loans have been paid on time); 1=default (at least one loan has not been paid on time).

A logistic regression model estimates the probability that a borrower defaults, using data on a set of borrower-specific variables. More formally:

$$ln\left(\frac{p_i}{1-p_i}\right) = \alpha + \sum_j \beta_{j x_{ij}}$$

where, for each borrower $i = (1, \ldots, I)$: p_i is the probability of default; $x_i = (x_{i1}, \ldots, x_{ij}, \ldots, x_{iJ})$ is a vector of borrower-specific explanatory variables; the intercept parameter α, and the regression coefficients βj, for $j = 1, \ldots, J$, are unknown, and need to be estimated from the available data.

From the previous expression the probability of default of each borrower can be obtained as:

$$p_i = \frac{1}{1 + e^{\alpha + \sum_j \beta_{j x_{ij}}}}$$

the credit score of *i*, whose default status will be predicted to be 1 or 0 depending on whether *pi* exceeds or not a set threshold θ. Common choices for the threshold are $\theta = .5$ or $\theta = d/I$, with *d* the observed number of defaults.

The previous model, once estimated on a training sample, can be used to predict the probability of default on a new loan, so that lenders can decide whether to invest in it or not. This decision crucially depends on the accuracy of the prediction, which, in turn, depends on the validity of the employed model. As discussed in the introduction, peer-to-peer lending platforms may underestimate the probability of default on a loan, because of a high set threshold or because of a lack of explanatory variables data. While the choice of a threshold remains a subjective decision, the improvement of the explanatory variables can be achieved exploiting borrowers' networking data. We believe that incorporating network information into a credit-scoring model could improve default predictive accuracy. This requires building an appropriate network analysis model.

Network analysis models have become increasingly recognised as a powerful methodology for investigating and modeling interactions between economic agents (Minoiu and Reyes, 2010). In particular, correlation network models, that rely on correlations between the units of analysis (borrowers, in our context), according to a given set of statistical variables, have been proposed by Giudici, Spelta and Sarlin (2017), in the context of interbank lending. The authors compare correlation networks with "physical" networks, based on actual transactions, and show that they can achieve comparable predictive performances.

Mathematically, correlation network models are related to graphical models. A graphical model can be defined by a graph $G = (V, W)$ where V is a set of vertices (nodes) and $W = V \times V$ is a set of weights (links) between all the vertices.

In a graphical Markov model (see e.g. Lauritzen, 1996) the weight set specialises to an edge set E, that describes whether any pair of vertices (i, j) is connected $(i, j) \in E$ or not $(i, j) \notin E$. A graphical Markov model can be fully specified by an adjacency matrix, A. The adjacency matrix A of a vertex set V is the $I \times I$ matrix whose entries are $a_{ij} = 1$ if $(i.j) \in E$, and 0 otherwise.

From a statistical viewpoint, each vertex $v \in V$ in a graphical Markov model can be associated with a random variable X_v. When the vector of random variables $(X_v, v \in V)$ follows a multivariate Gaussian distribution, the model becomes a graphical Gaussian model, characterised by a correlation matrix R which can be used to derive the adjacency matrix. This because the following equivalence holds:

$$(i, j) \notin E \iff (R^{-1})_{ij} = 0$$

which states that a missing edge between vertex i and vertex j in the graph is equivalent to the partial correlation between variables X_i and X_j being equal to zero.

Building on the previous equivalence, a graphical Gaussian model is able to learn from the data the structure of a graph (the adjacency matrix) and, therefore, the dependence structure between the associated random variables. In particular, an edge can be retained in the model if the corresponding partial correlation is significantly different from zero.

In a network analysis model (see e.g. Barabasi, 2016), the set W is a set of weights, which usually connect each variable with all others. In other words, the graph is fully connected.

From a statistical viewpoint, each vertex $v \in V$ in a network analysis model is associated with a statistical unit, and each weight describes an observed relationship between a pair of units, such as a quantity of goods or a financial amount. While the adjacency matrix in a graphical Markov model is symmetric, the weight matrix does not need to be so. For instance, in interbank lending, which is one of the main applications of network analysis to the financial domain, the weights are financial transactions, with w_{ij} indicating how much i lends to j and w_{ji} indicating how much j lends to i. The aim of a network analysis model is not to learn from the data the structure of a graph but, rather, to summarise a complex structure, described by a graph, in terms of summary measures, or topological properties.

A correlation network model (see e.g. Mantegna, 1999; Brunetti, 2017; Giudici et al., 2017) is a network analysis model for which the weights are not directly observed, but are calculated as pairwise correlations between the values of a given random variable X_v, observed at different time instances $(1, \ldots, N)$, for each pair of statistical units.

Note that correlation network models are similar to graphical Markov models, as they are based on statistical relationships between variables. However, differently from graphical Markov models, (and similarly to network analysis models) they relate units, rather than variables, and they are based on correlations rather than on partial correlations.

Note also that correlation networks are different from financial networks, the network analysis models typically considered in the financial literature (see e.g. Battiston et al., 2012). Financial networks are based on data that describe the actual financial flows between each pair of borrowers, in a given time period. If this information is available we could use them as weights, directly. However, this is an approach that we cannot follow when the transactions between borrowers are not available or, even when they are, when they lead to a sparse weight matrix. In addition, Giudici et al. (2017) showed, in the context of international banking, that, even when available and not sparse, financial networks can be matched, or even improved, in terms of predictive performance, by correlation networks.

In the peer-to-peer lending context, each vertex of a correlation network can correspond to a borrower company; while each edge can represent the correlation between the vector of values that a statistical variable takes, a long time, for two different companies.

To exemplify, we can associate with each borrower $i = 1, \ldots, I$ a vector $X^i = (X_t^i,\ t = 1 \ldots, N)$ that contains the values of a random variable, such as the total assets of a company, in N distinct time periods. A weight w_{ij} between any two vertices can then be defined by the correlation between the time series X^i and X^j, as follows:

$$w_{ij} = \frac{N\,(\sum_t x_t^i x_t^j) - (\sum_t x_t^i)(\sum_t x_t^j)}{\sqrt{[N\sum_t (x_t^i)^2 - \sum_t (x_t^i)^2][N\sum_t (x_t^j)^2 - N\sum_t (x_t^j)^2]}}$$

where $x^i = (x_1^i, \ldots, x_N^i)$ and $x^j = (x_1^j, \ldots, x_N^j)$ are the two series of observed values of the random variable, respectively for units i and j, at times $t = 1, \ldots, N$.

According to the above definition, the weight between any two vertices is a correlation coefficient, with the corresponding properties. In particular, a high positive value of w_{ij} means that the two companies are "similar": they move along time in the same direction. Conversely, a high negative value means that they move in opposite directions.

We now extend correlation network models. In analogy with graphical Markov models we replace the weight matrix W with an adjacency matrix E, and associate the absence of an edge in E with a zero correlation between the corresponding pair of companies. More formally, we take $G = (V, \mathcal{E})$, and let

$$(i, j \notin E) \Longleftrightarrow Corr\,(X_i, X_j) = 0.$$

Then, similarly as in graphical Markov models, an edge can be retained in the model if the corresponding correlation is significantly different from zero. If we assume that the underlying random variable is Gaussian, a reasonable assumption in finance, we can test whether the correlation is different from zero employing the t-test given by:

$$\frac{\sqrt{n-2}\; x\; Corr(X_i,X_j)}{\sqrt{1-Corr^2(X_i,X_j)}}$$

which can be shown to be distributed as a student's distribution with $N - 2$ degrees of freedom.

Note that our proposed correlation network model is based on a random variable, X, that takes different values for different borrowers, and in different time periods. In practice, when data on borrower companies are available, for example from their annually reported balance sheet, we may observe many of such variables, and, therefore, we can construct more than one correlation network model. This requires the construction of a multilayer correlation network model.

A multilayer correlation network can be mapped into a tensor $X \in R^{I \times I \times K}$ where I represents the number of borrowers and K the number of considered random variables.

Each element of the tensor, x_{ij}^k represents the correlation between borrower i and borrower j, using variable k, as in formula (1). The tensor is composed by K weight matrices $\mathbf{X} \in \mathbf{R}^{I \times I}$, each of which represents a correlation network between borrower companies, using one variable.

We remark that each weight matrix can be transformed into an adjacency matrix, according to the testing procedure in (2).

A drawback of the proposed multilayer correlation networks is that it gives rise to *K* different correlation networks, which, particularly when the measurements are highly correlated with each other, may be redundant. One way to address this problem is to embed all the information contained in the different layers into a linear model, along with other exogeneous explanatory variables, which is the approach followed in this paper.

It is evident that a multilayer network is a complex object, which requires, to be utilised, some form of summarisation. Centrality measures are useful network summaries that can be extended to the multilayer context, as shown in Avdjiev et al. (2018).

For simplicity, and ease of interpretation, here we consider, for each measurement variable *k*, the degree of centrality, which in our correlation network context indicates the total number of nodes to which a node is significantly correlated. Or, equivalently, the number of edges connected to a particular node.

For a correlation network $G = (V, E)$ described by the binary edge set E, the degree centrality of a node $x \in V$ is defined by:

$$d_x = \sum_{y \neq x} e_{xy}$$

From a statistical viewpoint, the degree of centrality is the simplest and most interpretable centrality measure. In addition, it is quite robust to changes in the topology of a network: for instance, adding or removing one node has a very limited effect, in a large network, as the degree of each node can go up or down at most by one unit.

From an economic viewpoint, the existence of a positive significant correlation between two borrowers can indicate that they have the same buyers, or that they operate in complementary markets. It seems intuitive that, if an active company is positively correlated with several defaulted companies, its credit scoring should be negatively affected. Conversely, the existence of a negative significant correlation between two borrowers can indicate that they compete in terms of buyers and/or markets.

It seems intuitive that, if an active company is negatively correlated with several defaulted companies, its credit scoring should be positively affected.

The final part of our model specification is to embed the obtained centrality measures, one for each measurement, into a predictive model. We propose to incorporate network measures in a linear regression model, to the logistic regression context, and taking the multilayer dimension into account through an additive linear component. More formally, our proposed network-based scoring model takes the following form:

$$ln\left(\frac{p_i}{1-p_i}\right) = \alpha + \sum_j \beta_{jx_{ij}} + \sum_k \gamma_k g_{ik}$$

where p_i is the probability of default, for borrower i; $xi = (x_{i1}, \ldots, x_{ij}, \ldots, x_{iJ})$ is a vector of borrower-specific explanatory variables, g_{ik} is the degree of centrality measure for borrower i, under the measurement k; the intercept parameter α and the regression coefficients β_j and γ_k, for $j = 1, \ldots, J$ and $k = 1, \ldots, K$ are to be estimated from the available data.

It follows that the probability of default can be obtained as

$$p_i = \frac{1}{1 + e^{\alpha + \sum_j \beta_{jx_{ij}} + \sum_k \gamma_k g_{ik}}}$$

We expect that by "augmenting" a logistic regression credit-scoring model, by means of the proposed centrality measures, its predictive performance will improve.

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The Authors

Alessia Amighini is Co-Head of the Asia Centre and Senior Associate Research Fellow at ISPI. She is Associate Professor of Economics at the Department of Economic and Business Studies (DiSEI) at the University of Piemonte Orientale (Novara, Italy), and Adjunct Professor of International Economics at the Catholic University (Milan, Italy). She previously worked as an Associate Economist at the United Nations Conference on Trade and Development (UNCTAD, Geneva, Switzerland).

Paolo Giudici is Professor of Financial Data Science at the University of Pavia. Academic supervisor for about 170 Master's students and 14 PhD students. He is coordinator of the European Horizon2020 project "FIN-TECH: Financial supervision and Technological compliance" (2019-2020) and the European VI programme project on "Multi industry semantic based business intelligence" (2006-2010); and also the honorary member of the Association of the Italian Financial Industry Risk Managers. He is the Director of the University of Pavia Fintech Laboratory (formerly Data Mining laboratory) which, since 2001, carries out research, training and consulting projects, in particular for: public institutions (European Commission, Italian Ministry of Education and Research, Italian Ministry for Economic Development, Bank of Italy, Deutsche Bundesbank, Italian Banking Association); financial institutions (Intesa SanPaolo, Unicredit, BancoBPM, UBI, MPS, BPS, Creval); IT consulting companies (Accenture, KPMG, SAS); telecom companies (Mediaset, Sky). Author of several scientific publications (70 in the Scopus database, with an h-index of 17) in finance, statistics and operations research journals, he is Chief Editor of the review *Artificial Intelligence in Finance*, and Associate Editor of *Digital Finance*.

Fabio Indeo is a non-resident Research Fellow at the Center for Energy Governance and Security (EGS South Korea) and Central Asia analyst at the NATO Defense College Foundation. Research interests: geopolitics in Central Asia: regional security; roles of the external players (Russia, China, NATO, United States, EU); geopolitics of pipelines; Belt and Road Initiative impact on the region. He has worked with with important national and international think tanks (NATO Defense College, ISPI, CeMiSS, Eucam, OSCE Academy) and published several papers and articles, among them: "China's new energy sourcing: disrupting and competing or improving global energy security?" in A. Amighini (ed.), *China: Champion of (Which) Globalization?*, ISPI, 2018.

Yu Jie is China Research Fellow in the Asia-Pacific Program of the Royal Institute of International Affairs, Chatham House, focusing on the decision-making process of Chinese foreign policy as well as China's economic diplomacy. She speaks at and writes frequently for major media outlets; and regularly briefs senior policy practitioners from EU institutions, the UK Cabinet Office, and the Silk Road Fund in Beijing, as well as major corporations. Yu Jie has testified at the House of Commons Foreign Affairs Committee, and was head of China Foresight at LSE IDEAS. Prior to LSE, she was a management consultant, specializing in Chinese state-owned enterprises investments in Europe at the London Office of Roland Berger Strategy Consultants. Dr. Yu has been recognised as a "Leading Woman" of the London School of Economics and remains an associate fellow of LSE IDEAS.

James Andrew Lewis is a Senior Vice President and Program Director at the Center for Strategic and International Studies in Washington. Before joining CSIS, he worked at the Departments of State and Commerce on a range of political-military issues, including policies governing high-tech exports to China. Lewis has authored many publications on the connection between technology and security since coming to CSIS and is frequently quoted in the media. Lewis received his PhD from the University of Chicago.