Innovation and Technology in China

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China's commercial orientation is widely regarded as have successfully transitioned from one of 'copy and improve' to a policy of genuine investment, with a focus on the development, operationalization and commercialization of novel technologies. While China's success in the recent past has largely been as a result of interactions with Western business, the opportunities for adoption of significant technologies in the future will be as a result of Chinese domestic research and development. Indeed, the ascendancy of China in the last decade has arguably been driven by its commitment to indigenous innovation and technology development.

The dominance of China in manufacturing over the last three decades has presented cost and scale challenges for businesses looking to enter China or do business there. China's R&D and innovation practice has

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become increasingly a function of significant investment supported by policies that drive economic growth, with a view to strengthening global influence. In the post-COVID world, one in which the established world order is arguably in flux, the outputs of China's research and development effort are poised to take center stage.

The effects of this are felt everywhere. When entering China, the passport scanner will automatically address visitors in their home language. Use of conventional currency is disparaged; electronic payment is ubiquitous. Technology is not just developed but adopted in a variety of settings; hotels utilize robots for a variety of menial tasks and facial recognition systems to permit access to rooms; drones make e-commerce deliveries; and traffic flows freely due to advanced traffic management systems. Technological sophistication has become a part of the national identity, a source of national pride.

Since the turn of the millennium, China has overtaken Germany and Japan to become the world's second biggest investor in R&D after the USA. China's investments in research and development have grown significantly in the decade 2010 to 2020, and China is expected to maintain increases in funding on R&D by 7% per year. Gross domestic spending in research and development in 2019 was in excess of US$500 billion—a level challenging that of the USA. In respect of intellectual property, China now spends more than 2% of its GDP on R&D and generates more patents each year than any other country. The trade revenue generated by intellectual property charges while currently relatively low is growing strongly (Berteletti et al., 2021). There is no doubt that this shift in emphasis, and burgeoning activity in this domain will enable China to be a very compelling player in technology in years to come.

1 China's Historical Orientation Toward Technology

China has a rich and varied track record in innovation and technological advancement. It has not always been plain sailing. While early in its history, there were significant Dynastic periods when bureaucratic elites provided stability to Chinese society, they did at the expense of the establishment of a dynamic mercantile class. While other regions accrued the benefits of the development and commercialization of innovative practices, isolation from other developing Western economies presented

impenetrable barriers to both the Chinese adoption of new technologies from the West, and the export of China's indigenous technologies to the rest of the world. Despite this cultural and geographical isolation, China was progressive in many ways and is noted as having developed four 'foundational inventions' in the lead up to its adoption of a more open approach to innovation. These four are widely considered to be: the invention of the compass; gunpowder; efficient and consistent paper manufacturing; and printing.

In more recent times, the approach of the Chinese government to supporting technological advancement has progressed through four distinct phases. These have been motivated by the need to prevent China from falling behind the rest of the world in terms of economic development and in recognition of the need for economic growth to be driven by trade with the outside world as much as through internal activity.

The first phase is generally accepted to have been in the decade spanning 1949 to 1959 following the founding of the People's Republic of China and the establishment of a centrally planned economy. The development of heavy industries was the primary focus of this period which resulted in significant economic growth and marked a waypoint in the transition of China from a primarily agrarian society to one with a competitive industrialized base. The second phase, which is generally considered to have lasted from the start of the 1960s into the mid-1970s, was a time of economic stagnation in part bought about by the Cultural Revolution, in addition to the inefficiencies arising as a result of the adherence to an ideology committed to a centrally planned economy. The slowdown put China out of step with the burgeoning post-war global economy and compromised its economic development.

The third phase took China into the twenty-first century and, aligned with China's reopening to the West, was founded on market dynamics and an innovation-driven approach to research. The current phase in which China finds itself relates to developing capability to compete and indeed lead high-technology industries emerging as a result of technological advances in the West. A summary of these industries is provided later in this chapter, but just as new technology has changed the way value is created, so China has sought to adopt a leadership position in the embrace of innovation, in many cases foregoing simple adoption of technology from the West and creating its own version of popular applications instead. This enables the government to maintain better control over the direction in which this technology proceeds thus maintaining an

element of market dynamics but with the guardrails associated with the communist party's tight hold on power and control of its citizenry.

China's adoption of an advanced technological footing has been breathtaking in its scope and scale and has built on decades of reform, structured approaches to economic growth, and the development of world leading industries (Agarwala & Chaudhary, 2019) China is eclipsed only by the USA in many aspects of research and development including spending as a percentage of GDP. The performance of China's universities has been extraordinary with China surpassing the USA in number of academic research papers published in 2016 (*Understanding China's Technological Rise—The Diplomat*, n.d.). However, China is still a net importer of intellectual property. According to the World Bank, China's purchases of intellectual property exceeded revenue from intellectual property by a factor of 22 times. Indeed, compared to the USA, the payments received by China for intellectual property were less than 1% of the revenue paid to the USA for intellectual property usage. So while China might reasonably be seen to be in the ascendancy in respective research and development, clearly the gap to other industrialized countries is still quite large, and the lags between undertaking research and successfully commercializing the outcomes of that research may be significant particularly as many new areas of study such as Internet of Things and electric vehicles require significant investments in infrastructure in order for the full benefits to be felt by the economy. In other words, while China is becoming increasingly dynamic in this domain, and opportunities abound for participation, the gap between China and its Western counterparts is still significant.

According to Schoff and Ito (2019), China is making the most progress in 4 prime areas of innovation. These are: manufacturing; digital platforms and associated markets—especially related to payments technologies; the use of apps and technologies designed to solve societal problems; and basic research and development in traditional areas such as computing and biotechnology.

2 Assessment and Timeline of the Antecedent Conditions Leading to China's Maturity in Technology Innovation

In the 1970s, China recognized that without significant economic reform, the country's economy would languish and the resulting lack of investment capability would put its population at a serious detriment. This understanding led to the program of Chinese economic reform which introduced elements of market-oriented business activity alongside, and in some cases replacing, state ownership and the central planning function of government. Central to this was the decollectivization of primary industry and importantly the opening of China to investment from foreign companies and governments. Most importantly, the Chinese government promoted the idea of entrepreneurship and strongly encouraged the citizenry to start businesses. The message to business however was in some ways mixed as the Chinese government-maintained state ownership of a range of significant an important industry. This led to a second stage of reform where, perhaps following the lead from the newly dismantled Soviet Union, more state-owned industries were privatized. From there, further restrictions—vestiges of the prior centrally planned economy—were progressively removed throughout the 80s.

This created a fertile breeding ground both in terms of cultural acceptance and active government policy support which encouraged the progression of entrepreneurial practice in China. Innovation, and the development and adoption of new technologies are drivers of entrepreneurship. Adoption of new technologies enables the creation of entirely new industries, and innovation enables the entrepreneur to both do new things and do older things in a way that presents compelling differentiation to the end consumer. The opening of China, and the emphasis placed on private ownership and entrepreneurship became important preconditions for research and development, and technology adoption to flourish.

Other factors were perhaps equally as important. The late 80s saw massive investments made in rural electrification and infrastructure development to facilitate large-scale manufacturing and supply chain operations. This was a function of and contributor to enormous increases in population size and growth rate. It is important to note that this growth led to a massive influx of human capital from rural areas into the cities

along China's eastern seaboard, again providing a powerful engine for entrepreneurial focus and activity.

The final, and perhaps most compelling antecedent condition, was the emergence of a middle class in China that had both disposable income and an appetite to break from the shackles of subsistence living and enjoy what was perceived to be the material trappings of a Western lifestyle. This has presented potential Chinese entrepreneurs with markets of significant size which are relatively easy to access but having issues and idiosyncrasies do not present in countries with longer histories of free enterprise and entrepreneurship. As a result, there has been a more gradual progression of technological and infrastructure development that might have arisen in comparable Western scenarios. The resulting need to address these problems spurred policy responses aimed at research and development, and the adoption of technologies which in turn created more markets, and a greater diversity of application.

China also enjoyed extremely low labor costs during this period, another factor which accelerated the growth of entrepreneurial activity and provided China with a competitive advantage over her more developed competitors. The rise of the middle class also made tertiary education accessible, something that was beyond the reach of the mainstream prior to the 1980s. The Chinese government actively encouraged its youth to pursue academic excellence outside of China and return with the understanding of best practice.

3 R&D Policy

China steady rise to ascendancy in research and development and technology applications over the last 25 years has been, as might be expected, the result of carefully devised planning. A series of strategic policies specifically have been implemented which have the specific objective of enabling China to become a world leader in science and technology by 2050. The focus of China's research and development has most recently revolved around several specific nascent technologies, with the intention of leading both implementation and appropriation of standards globally. In this context, the rise of the new digital economy has been unexpectedly quick and is now estimated at more than $3 trillion, or a third of national output.

4 Innovation in Manufacturing

Advanced manufacturing technologies (AMT) consist of the bundle of practices and technologies associated with the design a manufacturer of products. In practice, these specifically relate to higher levels of connectivity and optimized planning of the resources used in production. AMTs have a significant potential to impact on productivity of existing business models, sustainability of new business models, and lessening the contribution to waste streams globally. Most recently, AMT has been manifesting as increases in manufacturing automation and robotics, and the introduction of additive manufacturing enabling greater customization of outputs. Governments around the world have implemented initiatives aimed at increasing the development of and adoption of ATMs' organizations such as the European Commission, and the European factories of the future association actively direct policy aimed at using AMT to reduce waste and inefficiencies in manufacturing.

As the adoption of AMT takes place at the level of the firm, and often represents significant investment, the risks associated with adoption need to be ameliorated before widespread adoption can take place. Stornelli et al. (2021) have identified a series of barriers and enablers that relate to the adoption of AMTs in China. Specifically, impediments such as high cost of capital and barriers to investment justification, organizational constraints including lack of awareness of the potential benefits of AMTs, and other issues related to availability of human capital and integration of legacy technologies are present in all stages of AMT adoption. The report further identifies for enablers of advancement of factoring technology. The first of these is technology selection and strategy—something that the Chinese government has been active in influencing through their stand in relation to agenda-setting on standards globally (Stornelli et al., 2021).

5 Artificial Intelligence

China has implemented the New Generation Artificial Intelligence Development Plan which was launched in 2017. It identifies the AI sector, and the development of AI-related technologies, as a national priority. The plan was included in president Xi Jinping's Grand Vision for China, delivered at the 19th Chinese Communist Party National Congress on October 18, 2017.

This plan is ambitious in scope and sets out three objectives. Firstly, by the end of 2020, it is envisaged that China will close the technological gap with other countries currently active in the field. During this phase, China's AI industry will be poised to hold its own among similarly resourced advanced economies. The second objective, to be achieved by or before 2025, envisages China achieving foundational breakthroughs in AI research with both theory and application achieving world leading levels. In this phase, AI will become the main factor contributing to China's upgrade of industrial and economic transformation. The third and final objective has China expected to become among the world's premier AI innovation centers having developed standards relating to ethical, legal, and regulatory approaches to governing the development and implementation of AI technologies going forward (Wu et al., 2020).

The policy aims to create US $150 billion of AI-related revenue in the short term and is overseen by the Ministry of Industry and Information Technology (MIIT) (Roberts et al., 2021). Subsequent plans identify several milestone tasks to steer the direction of AI-related research and development. These involve nominating targets for the development of smart products. These include network vehicles, intelligent robots, and facial recognition systems. In addition, the plan seeks the development of intelligent manufacturing and the construction of public support system to accelerate the development of intelligent next generation Internet.

Li et al. (2021) identified that there were two sources of competitive advantage in artificial intelligence resource. The first of these is access to data, and the second access to engineering and computer expertise. It is clear that China has an abundance of both. Its large population a relatively lax privacy legislation enables the harvesting of data at considerable scale, and more recent commitment to quality tertiary education outcomes provides China with a rich supply of high-quality computer scientists and engineers.

6 Electric Vehicles

Electric vehicles have presented a clear opportunity for China. China enjoys many location advantages in respect of key components required to produce electric vehicles and has invested significant time and focus in establishing leadership in these areas. China controls about 90% of the world's supply of rare earths, a group of 17 chemically similar elements that are abundant in nature, but difficult and dirty to extract. Rare earths

are essential to the manufacture of electric motors and the specialist semiconductors required to produce electrical vehicles. China has also become a leader in innovation in the design and manufacture of large-scale high-capacity batteries required for electric vehicles. Value adding their advantage through the development of critical component areas such as electrical components, permanent magnets, and even large-scale production of lithium puts the country in a significant strategic position relative to its competitors in this area.

While the Western world is focused on the likes of Tesla, and the product road maps of established manufacturers as they transition from internal combustion engines through hybrid designs to pure electric versions all the best-selling vehicles, China has clearly stolen a march in servicing their internal market. Government has provided significant incentives, support, and partnerships to ease development hurdles and push an agenda that focuses on EVs accelerating their uptake and acceptance throughout the country.

Many of the brands that have helped China achieve this primacy unknown in the West. In a list of the 15 best-selling all-terrain vehicle (ATV) passenger cars including SUV's in China in 2021 (Chang, 2022), only two were models widely available in the West. The list of entrepreneurial EV manufacturers currently active in China echoes the proliferation of automobile manufacturers in the USA at the turn of the last century. As happened with the automobile industry in the West, over time one might reasonably expect the sector to consolidate with a small number of extremely large manufacturers emerging. The growth of this sector will be driven by China's entry into Western markets, although that will require the establishment of new business models, and a range of supporting infrastructure in export destinations. It should be noted that EVs are significantly less complicated than internal combustion vehicles, and subsequently, the servicing and ongoing maintenance requirements are much less onerous. Tesla has pioneered new ways of selling direct to consumers removing the need for extensive dealer networks, and the associated infrastructure and operating costs, and this effectively paves the way for Chinese EV manufacturers to enter the market without the need for integration with dealer networks. The EV industry in China should be viewed as an industry of extraordinary opportunity and one that will shape global dynamics for many years to come.

7 Payments Technologies

Another key area of focus in research and development and technology implementation in China is electronic payment platforms. China is serviced primarily by two major digital players—Alipay and WeChat pay. China's population base has typically been quite geographically dispersed with low per capita income. The country's underdeveloped private banking system presented significant barriers for credit card operators seeking entry to China. When digital payment systems became mainstream in Western countries, China saw the opportunity to bypass legacy infrastructure of small card-based consumer debt and instead move directly to relatively frictionless online payments platforms.

The Alipay and WeChat platforms are now very significant factors in commerce and trade in China and are among the largest in the world with over 1 billion users active on each platform as of 2019. It is estimated that over 90% of people in China's largest cities use these as their primary means of payment with cash being the second most popular payment method (Klein, 2020). Conventional credit card operators have a relatively small market share and have failed to gain traction. The ubiquity of these platforms in China is quite striking and represents something of a challenge for those used to conventional card-based payment systems.

China is currently focused on the development of an electronic fiat currency. In 2014, the People's Bank of China established task force to explore this technology including factors such as the issuance framework, key technologies, issuance and circulation environment, and the need for international experience. It is understood that while the mobile payment platforms discussed above have changed, consumers attitudes toward transacting China still require a convenient and official retail payment service that is safe, interoperable, and inclusive. China's electronic fiat currency needs to incorporate the benefits of distributed ledger technology in a manner with China's approach to societal controls. Existing cryptocurrencies lack intrinsic value, are subject to acute price fluctuations, and require enormous amounts of energy.

While the People's Bank of China had been researching digital currencies since 2014, it was not until December 2019 that a central bank digital currency pilot was launched. In November 2020, the first public stable coin was released called e-CNY. A pilot was run in Shenzen which was then expanded to ten cities in April 2021. In February 2022, the currency was launched more widely during the Beijing Winter Olympic Games.

This electronic currency co-exists with existing cash in circulation and is mainly intended to serve domestic retail payment demands. In providing a form of digital cash, China's PBOC enables its customers to enjoy the convenience of digital transactions while still providing the government with controls and information about usage it requires.

8 Practical Implications for Action in Engagement with China Through R&D

8.1 Commercial Sector

China officially adopted a dual circulation model as part of its 14th five-year plan for the period 2021 to 2025. Dual circulation strategy involves an increased emphasis on China's internal domestic market with a focus on self-reliance in several sectors while simultaneously driving economic development so remaining full value-added engagement with external markets. The strategy arose partly as a result of deteriorating relations with the USA which presented an external environment that was less predictable for China. An increase in protectionist policies being driven by many of China's significant trading partners exposed to strategic weakness which could be addressed by refocusing on economic development through domestic consumption.

China had already tightened the terms by which it enabled outside firms to operate in the country by enacting laws in June 2017 in favor of domestic firms. The legislation required all data generated in mainland China to be stored in mainland China, with transfer of data offshore severely restricted. The Chinese government also began an extensive program of subsidies, land grants, tax breaks, and other incentives to support domestic businesses at the expense of external competitors. Is a firm had achieved market dominance in the domestic market, the experience and scale economies were leveraged to enable that firm to enter overseas markets at a significant advantage. Telecommunications giant Huawei, and CTL—a Chinese battery manufacturer are examples of this approach. This put overseas technology firms seeking market entry to China in order to access the significant domestic market a quite a disadvantage compared to their homegrown competitors.

8.2 Government Sector

Several policies reflect the internal technical development focus and need to be taken into consideration when exploring research and development and technology in China.

Significant among these is the 2006 **Medium to Long-Term Plan for the Development of Science and Technology** (2006–2015). The net objective of this plan was to enable China to become an 'innovation-oriented society' by the end of 2020 and to assume global leadership in science and technology by 2050. The plan was intended to address four significant roadblocks to the development of technological capacity in China. These were China's difficulty in enjoying successful Commercialization of its technology developments; addressing social opportunities through the use of technology (such as environment protection, resource allocation, and public health); leveraging technological advancement for national defense and security; and improving the standards of scientific endeavors in China to attract back expatriate scientists and researchers (Cao et al., 2006).

This policy was followed by ***Made in China 2025***—this policy was announced in 2015 and seeks to move China away from being the world's factory I through exploitation of low labor costs and advantageous supply chain infrastructure. The strategy encourages investment from national and regional governments in preference to investment from overseas entities. The intention of the strategy is to strengthen China's own innovative capacities and thereby strengthen its competitive position globally.

The semiconductor industry is a central focus of this plan with other strategic industries being targeted including next generation IT; high-end numerical control machinery and robotics; aerospace and aviation equipment; maritime engineering equipment and high-tech maritime vessel manufacturing; advanced rail equipment; energy-saving vehicles and new energy vehicles; electrical equipment; agricultural machinery and equipment; new materials; biopharmaceutical and high-performance medical devices (Capri, 2019).

Also unveiled in 2015 was the **Internet Plus** action plan. This was detailed in the 2015 'Government Work Report' and seeks to integrate Chinese domestic industries including those that might be considered 'traditional' in nature by using Internet and other information and communication technologies. The aim here is to facilitate the transition

to an integrated industrial base through cross-utilization of factors such as cloud computing, bid data, and Internet of Things.

Standards 2035 was introduced with the aim of controlling markets through the control of standards that apply within. In this way, China can potentially rewrite the rules of global trade in its own favor. There is debate in the global community about how likely this is to eventuate and precisely what impact this will have on global industries, but the person country that specifies global standards in relation to technology products will enjoy a significant control over the future direction those product road maps may take.

9 The Role of Higher Education in Enabling the Fulfillment of China's Ambition

In China, the government has long recognized the role of academia and sought to build substantial and meaningful pathways between its universities and industry. China has embraced a '**triple helix framework**' to facilitate development of a knowledge-based economy. The triple helix framework links institutions, universities, industries, and the government in a web of reciprocal relationships to facilitate market worthy research and development and innovation. Universities provide human capital and can serve as incubators of new firms; industries provide products and services; while government agencies facilitate contractual relationships between the parties that allows for a steady exchange and focused commercialization of innovation. (Li et al., 2020).

More recently, the Chinese Ministry of Education, Ministry of Finance, and National Development and Reform Commission have implemented the **Double First-Class University** initiative, the largest education development scheme to date which is aimed at the consolidation and recognition of a world class tertiary education sector in China by 2049. Under this initiative, a total of 42 universities and 465 disciplines have been identified as having the potential to become 'world class.' The Double First-Class Initiative is not focused on universities in the cosmopolitan municipalities in the eastern region but embrace a broader geographical spread than previous initiatives, including all provinces and regions in mainland China. It is expected that universities benefiting from this initiative will rise in international rankings and relationships with them will be positively impacted.

The geopolitical implications of this are well and truly on the radar of governments in the West that might have been content to see China as a technological laggard and thus not a threat to the existing balance of power. In 2017, the Trump administration commenced an investigation of China's innovation and intellectual property policies that it deemed to be potentially harmful to the national interests of the USA. As a result of this investigation, the US implemented increases in tariffs by 25% on some $250 billion worth of imports from China. In response to this, China increased tariffs on around $110 billion of imports from the USA. The combined effect of these two actions was to decrease bilateral trade sharply and signal the start of a potentially protracted and escalating trade war between the two countries.

China's investment and continued policy focus on research and technology development and reform presents implications for its trading partners and has become a topic of considerable interest around the world. China has become a significant market for many Western manufacturers especially those from the USA; however, its incomplete transition to a fully free-market economy has resulted in market distortions that have the potential to be harmful to trading partners, and lead to adverse outcomes such as the misappropriation of intellectual property. Future policy development might include a focus on equitable outcomes for trading partners to vouchsafe productive trade relationships current and future. As with the omnipresent influence of Alibaba and Tencent on everyday life, technology is not regarded with the suspicion it often receives in the West. Progress is seen as a way of creating better futures, not dystopic societies. The transition out of old, traditional industries appears to provide employment benefits as the number employed in the tech sector exceeds the number displaced from legacy workplaces. And importantly, the tech is largely 'capital light' reducing the debt load bourn by industry and attendant financial risk.

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