China's Run of the Red Queen – Government, Innovation, Globalization and Economic Growth[1]

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Abstract: China's emergence as an economic and technological power cannot be denied. However, the story is too often conflated as one in which China's rise is unstoppable or even a fait accomplis, or else China's rise is overhyped and its lack of true innovation capability means its economic miracle will soon grind to a halt. Both perspectives misinterpret China's growth experience. China has developed a wide array of innovative capabilities through leveraging opportunities presented by the global fragmentation of production and overcoming institutional obstacles from its political economic climate of "structured uncertainty." Reactions by Chinese firms and regions to the opportunities presented by the global fragmentation of production and the constraining influence of structured uncertainty have created a high-technology economy that is highly competitive in second generation, process and incremental innovation as opposed to the supposedly ideal, and more widely appreciated, novel-product innovation.

If there is one economic "miracle" which is significantly transforming the global economy, it is China's. As Napoleon famously predicted, an awakened China is indeed shaking the world. The country, the most populous in the world, has enjoyed the longest period of sustained rapid economic growth in history with over two decades of more than ten percent annual GDP growth (NSBPRC, 2001-2010; OECD, 2006). It continues to grow, by 10.3% in 2010 and above or near 8% in 2011 and 2012, even as the advanced industrial economies of Europe and the USA continue to contend with their worst economic crisis since World War II. Since the 1970s, this growth has lifted hundreds of millions out of poverty and fundamentally changed the face of China, from an agrarian society to an increasingly urbanized one. China has rapidly climbed the ranks as a producer, and consumer, of high technology goods and services. By some measures – based on very specific interpretations of economic data – China already has the world's largest technology based economy (Porter, Newman, Roessner, Johnson, & Jin,

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2009). The rhetoric of the current US presidential election underscores supposed challenge China presents as a technology thief and unfair competitor. Best-selling publications over the past decade have argued that China's rise represents a tectonic shift of global economic, technological, and political power towards Asia (Fishman, 2005; Jacques, 2009; Kynge, 2006). While the implications, and underlying research, of these trends are subject to debate, understanding exactly how China has accomplished this rise, and what are the actual capabilities fostered, is critical.

We argue that China's economic growth trajectory stems from two intersecting forces: the global fragmentation of production and China's domestic environment of structured uncertainty (Breznitz & Murphree, 2011). The fragmentation of production is the culmination of trends, still ongoing, over the past three decades in which the production of products, components, and services increasingly occurs in discrete stages around the world. Information and Communication Technologies (ICT) have enabled the codification and specific tasks which enables them to be outsourced or offshored. Fragmentation means economic actors need not simultaneously master all stages of production in order to enter a given industry. Rather, they can specialize in specific niches along the production chain, attaining profitability and sustained competitive advantage without vertical integration. Thus, fragmentation of production has provided the points of access to the global economy for new companies in emerging locales (Breznitz, 2007).

China's internal climate of structured uncertainty shapes the ways in which China's companies develop and the specific capabilities they bring to the competitive table. We define structured uncertainty as an agreement to disagree about the goals and methods of policy or economic action. This leads to intrinsic unpredictability and inherent ambiguity in

implementation by political or economic actors (Breznitz and Murphree 2011). For business leaders, would-be entrepreneurs, and local government officials this means they cannot know ex ante which business practictices or reforms will be accepted and while will be barred. This uncertainty constrains and shapes the practices and policies they can and will pursue, which has been a driving factor in shaping both the strengths and weaknesses of the Chinese economy, particularly in high technology sectors.

The dynamic interactions of these two processes, fragmentation of production and structured uncertainty, has enabled Chinese companies to develop strong capabilities in incremental, process, organizational, and business innovation, all of which allow for flexibility and resilience in the face of rapidly changing market demands. Fragmentation provided an array of new points through which to access the global economy and structured uncertainty forced enterprises to develop highly flexible business models emphasizing short-term innovation, quantifiable gains, and low risk.[2] However, the other side of this same development has been a lack of long-term R&D projects necessary for fostering novel product/technology innovation capabilities. Nevertheless, thanks to the ever-growing fragmentation of global production and the interdependencies it creates between Chinese and Western companies, we contend that this trajectory of growth should be sustainable for at least the mid-term.

Despite the obvious accomplishments of China's economic and innovation system, the status quo is not that envisioned by reformers in 1978, nor that desired by the Hu and Wen administration of the 2000s. The initial reform impulse sought to realize the "Four Modernizations" of agriculture, industry, science and technology, and national defense. The

[2] We should emphasize that risk and uncertainty are two related yet highly distinct terms. Risk refers to potential dangers and pitfalls which can be hedged against probabilistically. Uncertainty refers to that which cannot be known or foreseen in advance. The difference between these two, or rather the failure to comprehend the difference, was arguably a major cause of the flaws in the financial models used by investment firms leading up to the 2008 crash.

objective was to create an independent, strong, and wealthy socialist China by the end of the 20th century. For science and technology, since the beginning of opening and reform, China's central government has sought to build a novel product innovation capability and independent technology innovation base. Beginning in the 1980s, the government launched a myriad of centrally administered and funded programs and policies designed to encourage development of science and technology, often with an eye toward creating highly innovative, and independent, state-owned national champions. These include the 863 and Torch Programs, and more recent efforts such as the "mega-projects" under the 15-Year Science and Technology Plan. High technology certification requirements necessary for firms to receive state assistance and preferential policies continue to favor certain sectors and firms, ensuring a strong role for the government in shaping high technology innovation and business (863, 2008; Cao, Suttmeier, & Simon, 2006; ChinaDevelopmentGateway, 2004; ChinaTorch, 2006; CTN, 2008).[3]

The climate of structured uncertainty and global fragmentation of production has fostered an innovation system which excels in producing second generation innovations. China "runs" just fast enough to remain at the cusp of the global technology frontier while not actually advancing the frontier itself through Chinese novel or breakthrough innovations. We call this system the Run of the Red Queen (Breznitz and Murphree 2011). China's behavior is not unlike the fast worldview of the anthropomorphic chess piece Red Queen in Lewis Carol's *Through the*

[3] The 863 Program began in March 1986 with the purpose of facilitating development of high technology and scientific research projects and rapidly commercializing scientific discoveries. The 1988 Torch Program explicitly called for creation of science and technology industry zones and works on improving the environment for high technology industrial development. In 2006, China launched a 15-Year Plan for science and technology development which included investment in major centrally chosen products such as wide body aircraft and supercomputers. Since the 1980s, China's government at the central and regional level has provided an array of incentives for development of high technology busiensses including the provision of tax breaks and subsidies. In order to qualify, a firm must be certified as a "New and High Technology Enterprise" or their product as a "New and High Technology Product." Since 2006, the requirements for these certifications have become much more stringent in the hope of mandating firms to move into more R&D intensive activities and investment more heavily in research and development.

Looking Glass and What Alice Found There.[4] Just as the Red Queen must run as fast as possible just to stay in one place, since the Mirror Land changes so rapidly, China's companies follow technology advances rapidly but do not push the technological frontier. Instead they make use of the global fragmentation of production to generate growth and jobs by utilizing and improving upon innovations first proposed, evaluated and tested elsewhere. Indeed, China's ability to follow on innovations developed elsewhere is now so fast that some Western VC's estimate software or online applications developed in Silicon Valley can be adopted and adapted or reinvented in China within a matter of weeks (authors' Interviews).[5] The global fragmentation of production means the world needs a Red Queen to perform the improvement, design and development innovations for many productions, particularly as relates to design and adaptation for production, as well as production itself; China fills this role.

Reinterpreting Innovation

Innovation is often thought of only as invention or discovery. Hence, the country or firm which invents something first is thought to be highly innovative, and thus ensured of a competitive or economic advantage. However, we must remember that innovation encompasses the full run of activities from invention to commercial development, design, production and supply of new or improved products and services in the market. Thus invention is but one small part of the act(s) of innovation. Furthermore, in a world of fragmented production it is not clear which kinds of innovation (invention, development, production, logistics, after sales services, etc) produce the greatest widespread localized economic growth. Schumpeter himself argued that

[4] Readers should remember that the Red Queen in *Through the Looking Glass* is a distinct character from the unhinged Queen of Hearts in *Alice's Adventures in Wonderland*. The Red Queen behaved queerly but was not calling for executions!

[5] Some VCs go so far as to host dinners where new ideas from Silicon Valley are shared with would-be entrepreneurs who are offered financing should they pursue a similar business in China.

invention matters less than the application of such new ideas to create or improve products and industrial processes (Elliot, 1983; Schumpeter, 1961 (1934)). Indeed, as Rosenberg and Birdzell noted in the 1980s, another time when a rising technological challenger appeared to rock the global economy, scholars and policy makers constantly forget forgetting the true heroes of innovation-based economic growth, such as incremental innovation, while ascribing too much to novelty (Rosenberg, 1983; Rosenberg & Birdzell Jr., 1986).

Innovation today is greatly shaped by the new logic of production in goods and services. Indeed, the story of this round of globalization is in many ways the story of fragmentation of production (also known as modularization, decomposition or unbundling). Industries and services are increasingly spatially fragmented such that specific activities, but not necessarily whole industries, are now geographically clustered, creating regional stage specialization (Breznitz, 2007; Gereffi, 1994, 1996; J. Timothy Sturgeon, 2000; J T Sturgeon, 2002; J. Timothy Sturgeon, 2003; Zysman & Newman, 2006).

Global fragmentation means goods and services are no longer produced or provided by integrated hierarchical companies based in national economies. Instead many organizations separate activities into discrete modules and out-source or off-shore them (Arndt & Kierzkowski, 2001a, 2001b; Dossani & Kenney, 2003; Gourevitch, 2000; Kenney & Florida, 2004; Langlois & Robertson, 1992; McKendrick, Doner, & Haggard, 2000; J T Sturgeon, 2002; J. Timothy Sturgeon, 2003; Zysman & Newman, 2006). Global reorganization of production and services offers a new logic of value creation and new sets of specialization and innovative capacities; hence, we must rethink what different types of innovation at different stages of fragmented production means for economic performance (Breznitz, 2007; Rodrik, 2007; Steinfeld, 2010). Two specific self-reinforcing dynamics significantly impact on how organizations develop

profitable innovation capabilities: production-stage economies of scale and scope, and production-stage specialization.

"Production-stage economies of scale and scope," refers to the effect in which suppliers at each stage of a fragmented production chain pool the demand of many customers, creating economies of scope and scale that in-house divisions cannot (Breznitz, 2007). For a firm operating at a given stage of production, this means they can combine many customers and improve their ability to specialize around a given niche in production without having to concern themselves with or develop costly capabilities in other areas of the production chain. Once specialized at a given level, economies of scope and scale enable suppliers of a component or service to become more efficient and allow them to profitably operate on margins significantly lower than those acceptable to in-house manufacturing divisions. This cost advantage enables them to lower their prices while offering products of the same or higher quality, speeding the trend toward outsourcing of this stage's manufacturing or service-provision activities (J. Timothy Sturgeon, 2000; J T Sturgeon, 2002). While it is still possible for vertically integrated firms to compete, they must be able to excel at all stages of production as well as specialized fragmented providers, a tall order for any company (Berger, 2006).

The most famous example for such a scale-and-scope operation in China is the mass-flexible production capacity of Foxconn's nearly 500,000-worker factory campus in the Bao'an District of Shenzhen in the Pearl River Delta, where the iPhone, iPod, and various Intel, Dell, Motorola, and Sony products are made (Dean, 2007; Johnson, 2011). Foxconn is one of Taiwan's largest private companies and the largest exporter of high-tech products in China. Foxconn employs one million workers across China. Foxconn's business strategy is built around the unique capabilities of the Chinese ICT hardware industry: the ability to inexpensively design,

integrate, source components, assemble and ship variegated products from a common facility and still earn profits even as wages or input costs rise. Taiwanese ownership matters much less than the capabilities it has developed in China such as networks of suppliers and armies of engineers skilled at design for production, production management and improving existing products. These skills are not easily transferable. While American companies once had the organizational and innovational capabilities to run large-scale manufacturing operations (such as Ford's River Rouge Complex in the 1920s and 30s), the American production system, aptly known as Fordism, was focused on mass production of single products and could not flexibly produce such an array of products in the same place on the same production lines. Capabilities of ultra mass-flexible production are increasingly unique to China (Breznitz & Murphree, 2011).

The second dynamic of fragmentation is "production-stage specialization," which is the process by which companies develop superior capabilities at particular stages of the production or service network in response to the breakup of the production chain (Breznitz, 2007). Recent examples of this in the IT industry are Indian IT software consultancies such as TATA, Wipro, and HCL, which are by far the most efficient IT consultancies in the world, basing their competitive position on unique capabilities and tools they developed in project management (Arora, Arunachalarn, Asundi, & Fernandes, 2001; Arora & Athreye, 2002; Arora & Gambardella, 2005; D'Costa & Sridharan, 2004; Dossani & Kenney, 2003, 2007, 2008). Such specialization enables companies to become better and more efficient in a narrow set of activities. It also helps them acquire specialized capabilities and knowledge that more vertically integrated firms cannot.

These capabilities, once acquired, enable firms to excel in innovation for the particular production or service stages and sets of components in which they specialize. Over time, these

two related advantages, in skills and in innovation capabilities, provide these companies with ever greater advantages over in-house divisions in vertically integrated companies. We observe this process in high-technology areas, particularly ICT and electronics but also in more traditional industries, such as bicycles, where product-chain fragmentation allowed one company, Shimano, to become the innovator and market leader in drive-train components (Galvin & Morkel, 2001). Such specialization in turn means that firms and countries need different modes of innovation in order to thrive in different stages of production. Furthermore, once a country starts to develop innovation capabilities that allow it to excel in a certain stage of production, a process of self-reinforcing sequences increases the probability that its national industry will follow a particular trajectory of growth that utilizes those capabilities. This creates a situation of interdependency among firms that constitute global production networks, each set of which has unique innovational capabilities in some stages of production but not in others. Consequently, different nations can achieve rapid and sustainable growth by focusing their innovational activities on particular stages of production and thereby supplying unique outputs and services to global markets (Breznitz, 2007). From a practical perspective, this means that while China has developed an array of capabilities and innovation strengths, these do not constitute the entirety of the innovation system for given products. Chinese firms rely on novel product innovators elsewhere just as foreign firms rely on the expertise of Chinese entities.

Armed with this understanding of how the global economic system has changed, let us now look at how Chinese firms have evolved to take advantage of the opportunities presented by the increased global fragmentation of production.

Firms' Adaptations to Structured Uncertainty

China's entry into the world of fragmented production did not occur in a vacuum. Business in China developed in environment imbued with structured uncertainty. Firms developed specific sets of innovative capabilities allowing them to maximize their profits while minimizing China specific risks and preparing to meet uncertainties as they manifest. These capabilities shape the types of innovation skills of Chinese enterprises while inhibiting others.

Structured uncertainty may be defined as an agreement to disagree about the goals and methods of policy or practice, leading to intrinsic unpredictability, and hence, ambiguity in implementation and enforcement of economic policies, rules and business practices. Structured uncertainty cements a multiplicity of action without legitimizing any specific course or form of behavior as the proper one. This ambiguity leads to some tolerance for multiple interpretations and implementations of the same policy. However, for Chinese companies seeking new opportunities, while plurality of action is tolerated, punishment for deemed transgressors can be severe, abrupt, and seemingly arbitrary. The limits of tolerance are undefined, adding to ambiguity. Local officials and firms cannot know ex ante which, if any, government bodies will decide to rule on or intervene in an area. Similarly, they cannot know which policies are likely to be barred or blessed by higher authorities. Structured uncertainty can thus be thought of as an institutional feature that guarantees a plurality of behaviors will be followed in any specific domain, with none of the actors knowing in advance what should be the appropriate ways to conduct themselves. Structured uncertainty exists to a certain degree in almost all policy domains in most countries. Indeed, it is the main reason why street-level bureaucracy is so important in every society (Wilson, 1968). However, it takes on a different qualitative and quantitative

manifestation in the Chinese system due to the specificities of its halting but continuous transformation from a revolutionary society to a more organized, bureaucratic rule-bound one.[6]

Structured uncertainty has particularly pronounced effects on R&D undertakings. As argued by Kenneth Arrow, even under conditions of perfect market competition there is a tendency for private economic agents to under-invest in R&D (Arrow, 1962). Structured uncertainty, through its impact on the ability to appropriate and increased uncertainty, augments R&D's inherent characteristics of indivisibility, inappropriability, and uncertainty, reducing private incentives to underwrite R&D.[7] Under structured uncertainty the great puzzle for economic theory is why some Chinese companies even perform significant R&D.[8] We find, however, that there are ingenious was of adapting to this uncertain environment which enable firms to not only appropriate returns from R&D but to do so in the absence of the traditional property rights and intellectual property rights stipulations usually called for by innovation scholars.

Chinese organizations use multiple approaches, both official and unofficial, to mitigate uncertainty. These approaches have led to the emergence of a strongly innovative organizational ecosystem, but one different from the West in its focus, and decidedly different from the one

[6] For more on structured uncertainty, see Chapter two of Breznitz and Murphree (2011).

[7] A prime example occurred in the telecommunications market. The Ministry of Posts and Telecommunications (MPT) took the first step toward liberalization in 1994 when it permitted China Unicom to begin competing with the incumbent – China Telecom. As a new entrant, China Unicom faced a highly uncertain environment. Unsure where the boundaries lay, it tried various experimental practices. Most notably, it developed a system known as China-China-Foreign where Unicom would form a joint venture with another Chinese firm with a foreign joint venture partner. Foreign capital could thus be funneled indirectly into China Unicom. By 1998 there were forty-nine such collaborations completed or under negotiation when the MPT abruptly declared three of them "illegal" and the remainder "irregular" leading to their immediate termination. What had been a creative interpretation of policy, pragmatic for business development, had suddenly been deemed a bridge too far and crushed by central authorities (DeWoskin, 2001; Harwit, 2008; Low, 2005; Wu, 2009).

[8] We should note, however, that today there are strong and growing constituencies in China that are seeking change. Leading Chinese companies such as ZTE, Huawei, Lenovo, and Tencent have come to understand that in order to continue to be globally successful their interest now lies with encouraging greater certainty in China's political economy. While we expect change, it will be a long and incremental process in which both central and local government actors as well as business interests will play a significant role.

envisioned and coveted by China's central government. This innovation ecosystem fosters a wide array of innovation activities across the sectors in which Chinese firms are involved but not in novel product innovation.

To ensure an incentive for productive activities, innovators must be able to appropriate returns without resorting to extra-legal means. Organizations must ensure they are secure from predatory officials if they are to seek productive activities. To do so in China, organizations frequently adopt multiple ownership forms and cultivate back channel relationships with government units at different levels – from townships to central government ministries depending on the firm or industry in question – to ensure protection from the fickle winds of government policy and practice and to guarantee chosen markets and industry segments remain viable. Organizations have a variety of options for ownership: wholly-owned foreign enterprises, collectives, private enterprises, state-owned enterprises, amorphous ownership forms such as *minying* and various combinations of these (Breznitz & Murphree, 2011; Segal, 2003). Some firms have more than one registration type and many bring in state-owned enterprises or investment groups as partial owners. By redefining ownership, merging different types of ownership, and extending ownership rights to government at various levels, uncertainty regarding the behavior of officials can be partly mitigated. Where the state has a stake in the firm, it is somewhat less likely to act arbitrarily and the units with ownership stakes can mitigate potential negative actions by other government units. We can see across China's high technology industries that this is the case: an industrial structure of mixed ownership types that offer greater assurance as to the ability to appropriate returns, but with relatively ambiguous channels of management authority by Western standards.

In terms of innovation capabilities, adapting to structured uncertainty means Chinese firms are relatively well able to avoid predations by the state but are less able to move forcefully in any area which demands commitment to high risk activities with long timeframes, exactly what is needed for novel product R&D. However, this limitation does not mean Chinese enterprises have no incentives or ability to innovate. It is critically important to remember the flip-side of structured uncertainty. There is a structured aspect to it. If there is one agreed upon benchmark with which to judge whether a policy or action by local authorities or businesses is "proper," it is revenue growth and job creation. These are seen as categorical goods by both political and economic actors; hence they are pursued over and above all else. The goal of public policy, and research conducted by or within business, is to maximize job creation or revenue as fast as possible while incurring the least amount of risk. It follows, therefore, that enterprises will emphasize short-time horizons and incremental activities in proven technologies and market niches.

Second, organizations in China seek means of appropriating returns in an environment that lacks fully enforced formal property rights. The strategy organizations adopt derives from the industry sector in which the organization operates as well as the human, intellectual and capital resources available to it. Most frequently, Chinese enterprises – particularly small and medium-sized enterprises (SMEs) release incrementally improved models of their products and services with a very short lag time between new versions. This strategy limits the value of copying by would-be competitors and ensures the company manages to keep a profitable edge. With new products, pirates may copy the older models but the market has already moved on. China's strengths in flexible manufacturing enable rapid turnarounds and short-runs of products, thus making this a workable innovation strategy.

A second approach, exercised by large scale enterprises with major internal resources, often in capital-intensive industries, is to specialize in innovation of production methods or large-scale equipment design and fabrication. For these industries, the value of imitation is lower since prospective imitators would require massive capital assets of their own as well as – and more importantly – tacit knowledge in order to successfully pirate the organization's technology. Such high end capital-intensive innovation strategy lends some protection copying by competitors even in the absence of property rights.

Third, the most technologically and scientifically advanced local organizations or, more commonly, branches of foreign MNCs opt to use the highest end local human resources to conduct highly theoretical or abstract research.[9] Such primary research does not lend itself readily to imitation and requires the embedded tacit knowledge and technology transfer practices of the innovating firm in order to capitalize on any findings and deploy them in a final product. While pure knowledge of this sort may be stolen, it is of little value without the ability to translate these abstract concepts into marketable goods or services.

Finally, when dealing with the financial system, firms in China adopt approaches to ensure access to capital. China's financial organizations, even those styled as venture capital, are generally risk averse. This privileges large-scale enterprises, proven business models using already developed technologies, and foreign enterprises (Authors' Interviews; Breznitz & Murphree, 2011; Fuller, 2005, 2010; Huang & Qian, 2008; Segal, 2003; Tsai, 2002). The relative scarcity and weaknesses of both traditional investment capital and venture capital for SMEs mean that the role of government as a financier and support of innovation is greatly enhanced.

[9] The best example of this type of research strategy is exemplified by Microsoft Research Asia in Beijing. This research center is one of the most productive in the world, having an output of papers in leading computer science journals as good as or better than the world's leading universities and research centers. Such a concentration on pure science or technology (such as algorithm development) does not lend itself immediately to commercial applications and thus reduces the benefit from privacy.

However, central government investments often only support ventures which accord with its development plans and its specific understanding of innovation. This means firms developing technologies outside the central state's vision are largely excluded from state-provided capital. On the other hand, those in chosen industries enjoy privileged access to capital. Nonetheless, the general lack of patient venture financing limits the range of R&D activities in which firms may engage, thus further encouraging their specialization in non-novel-product innovation niches.

That is not to say that Chinese firms do not or cannot derive lasting advantages from their innovations. Under fragmentation of production, Chinese enterprises aggressively pursue enduring advantages *within specific phases of production.* Global production networks not only make this strategy viable, but also supply China with the needed inputs in terms of novel ideas or critical components developed elsewhere, and with the necessary market demand for innovations across the production cycle to make it sustainable. *For innovative Chinese organizations, specialization under the new global conditions is significant because it provides types of embedded knowledge that, like novel product innovations, are valuable in granting lasting competitive advantage.* The resulting market competitive advantage benefits to the organization are the same for incremental and novel product innovation. Stage specialization and development of the related skills enables a firm to continue to innovate and grow at a given level without a strong need to excel in novel-product innovation. This turns the traditional view of innovation and national technology and economic upgrading on its head; it is not necessary to follow a path from lowest value added assembly up through own-branded design and invention. Specialization at any stage can afford sustained advantage and profitability.

The fragmentation of production allows Chinese companies to easily access the global marketplace. The story of China's rise is one of international engagement and changes in the

domestic political economy to enable firms to capitalize on shifts in the world economy. It is a story of industrial co-evolution that has been going on a trajectory drastically different then the plans of the central government. To illustrate on these points we now look at ICT hardware production in southern China, an area often overlooked by innovation scholars, both Chinese and foreign.

ICT Hardware Production: Innovating from the Factory Floor Up

Looking at the intersection of the global fragmentation of production and the pragmatic adaptations of firms to the pressures of structured uncertainty, the ICT hardware industry in the Pearl River Delta (PRD) offers a typical example of innovation and market success in domains lying outside industries slated for government promotion.[10] The PRD is geographically defined as a rough triangle in central Guangdong province with vertices at Guangzhou, Hong Kong and Macao. It includes the major industrial cities of Shenzhen and Dongguan as well as other manufacturing bases including Zhongshan, Zhuhai, and the suburbs of Guangzhou. Successful ICT hardware firms in this area have all found means of innovating in the absence of strong IPR protection. They operate with undefined rules of the competitive game, and frequently find themselves shut out of formal bank financing or central government innovation funds.

The PRD is the production base of China's ICT hardware industry. The ICT hardware industry here emerged in tandem with major changes in the global industry. During the 1960s and 1970s, production of electronics such as TVs and radios began to fragment, with final assembly and component production increasingly occurring in Asia's emerging economies, such

[10] Although the central government (seeing the success of PRD-based industries in the early 1980s) encouraged hardware production and export-oriented assembly industries in the first years of reform, this sector of the fragmented global electronics and ICT industry is increasingly disdained due to its relative low-value added, reliance on high-value imported components such as proprietary processors, use of energy and pollution. While not banned, activities in this area are increasingly discouraged and central government support – particularly financial support or promotional policies – has generally been withdrawn.

as Taiwan, Singapore, and Hong Kong (Hobday, 1995; Scott, 1987; J. Timothy Sturgeon & Lester, 2004). By the late 1970s and early 1980s, however, these smaller tiger economies faced a profit squeeze from rapidly rising land, labor, and input costs. When the Shenzhen Special Economic Zone (SEZ), opened in 1980, Hong Kong and other Asian entrepreneurs found a solution to the profit squeeze. The SEZ authorities provided subsidized land, utilities, and infrastructure to foreign investors. As a further incentive to invest, the SEZ offered a fifteen percent corporate income tax rate, half the national rate (Shen, Wong, Chu, & Feng, 2000). Investment flooded in and the economy boomed. The lion's share of foreign investment came from, or through, Hong Kong. Shenzhen's economy grew by 44% per year from 1980 to 1986, and 29% per year from 1987 to 1995 (Guo & Feng, 2007). What had been a collection of fishing villages with few roads rapidly became the wealthiest Chinese city per capita, with over ten million residents. This spectacular growth has relied heavily on the ICT industry (SSB, 2008). Electronics and ICT exports accounted for 76.8% of the 2009 total and accounted for 52.6% of total industrial value added in 2010.

By the end of the 1980s, companies like ZTE and Huawei, now the two leading Chinese telecommunication equipment manufacturers, had commenced operations. The ICT hardware industry continued to expand throughout the PRD as other cities and townships began offering similar preferential policies and incentives to the Shenzhen SEZ. However, as a first mover, Shenzhen remained a major site for foreign and domestic investment. As the SEZ developed and became increasingly crowded, manufacturing moved out from the three SEZ districts directly adjacent to the Hong Kong border and spread across the region (Walcott, 2003).

The PRD has come to dominate China's production of electronics and ICT hardware. In the process, the region – which had very limited high education and research infrastructure when

it opened to the global economy – has developed a formidable innovation capability, although not one in novel-product innovation. Guangdong province produces 35.6% of China's total high technology exports and the largest share of its electronics exports (GSB, 2011). Interestingly, despite its reputation as a locale of low value-added activities, Guangdong produces significantly more patents than Beijing and Shanghai – receiving 119,346 in 2010 versus 34,000 and 48,200 for Beijing and Shanghai respectively (GSB, 2008). Even cities such as Dongguan which still lack a traditional research university produce significant numbers of design or improvement patents, exactly those one would expect to find generated by firms innovating from the shop floor up (DSB, 2008). The PRD's success in innovation is largely the result of a tight integration of suppliers and producers. This symbiosis among firms encourages a high degree of efficiency in production and innovations to further enhance these skills. As one entrepreneur explained when discussing his reason for investing the Dongguan township of Qingxi:

> "I chose Qingxi because [the ICT hardware] industry's production base is in Qingxi. The suppliers are all located here. If I had my company in Beijing, then I would have needed to ship all the parts to from here to Beijing. Since all the parts are manufactured in Qingxi, it is a great advantage for my company to be here. For example, even if, in the morning, I realize that I am missing critical parts, I just call my friends, and within a few minutes, these parts are sent and delivered to me" (authors' interview).

Having access to locally-produced inexpensive inputs, however, is insufficient to foster innovation – no matter how broadly it is defined. For an enterprise to innovate, companies must have an incentive to seek productive activities. This means they must first be safe from predatory officials. As discussed above, throughout China it is common to use a variety of ownership types to avoid running afoul of the state. ICT enterprises in the PRD secured such protection in part through seeking innocuous forms of ownership or even making the state a partial partner. In different regions of China, and particularly in different industries such as semiconductor

manufacturing, bringing the state in as a partial owner and partner is more common than in the PRD. As explored by Bachman, while local state enterprises led the move into market-based electronic production in the 1980s and established some of the first Sino-foreign joint ventures in Guangdong, the governments of PRD cities have generally refrained from creating companies under state ownership (Bachman, 2001).[11] This practice is far more common in Shanghai where the local government is quite active in creation of, or investment in, desired firms. Despite the PRD's reputation as a bastion of private companies, most firms explicitly refuse to describe themselves as private and prefer to claim the title minying. Minying, which literally means "people operated," is actually a largely undefined term (Segal, 2003). The reticence to describe themselves as "private," even among founders who started businesses with their own funds, is due to the fact that by defining themselves as minying, they do not run the risk of falling afoul of possible regulatory changes directed at a given class of enterprises. Uncertainty over the future of property rights, combined with both the central state's disregard for pure hardware manufacturing and local authorities' reticence in creating SOEs, led companies to fully embrace the ambiguous and politically neutral title: "minying."

Second, in order to innovate, enterprises must be able to secure returns from their investments in innovative activity (such as R&D). In the West, this is done through reliance on intellectual property rights. However, as is widely understood, intellectual property rights in China are unevenly and somewhat arbitrarily enforced. In the PRD, ICT firms generally, although not universally, opt to innovate incrementally and rapidly but not radically as a means of ensuring a non-property-rights reliant source of competitive advantage. Bringing up new

[11] This is not to say that it has not happened or that the local government does not take a very active role in spurring the development of desired industries. ZTE, a telecommunications hardware manufacturer and one of the region's most successful firms is a mostly local government-owned enterprise. Similarly, ports, transportation companies and investment firms are also frequently enterprises owned by the local or provincial government.

editions and models rapidly reduces the susceptibility to losses since any pirated model would have already been replaced with a new and improved one. Acknowledging local innovation patterns, regional officials take a rather broad expansive view of innovation, particularly when compared with the central government which considers innovation in terms of novel-product inventions:

> "Here we view incremental innovation on existing platforms very much as indigenous innovation. So long as there is improvement or new features, it counts; we do not need to come up with a wholly new product to have self-innovation" (authors' interview).

Development of a tightly integrated manufacturing industry cluster in the region enables fast incremental innovation. Starting from highly codified models and overseas orders, companies begin with the simplest assembly operations. They take the orders, source the requested and required parts (often from designated vendors) and only provide final assembly services. From this base, they gradually increase the amount of research and product development they perform with the *designs explicitly geared toward ensuring ease of production.* Where production is one's specialty, increasing efficiency and quality at a constant or lower cost is a powerful competitive advantage. As domestic and especially overseas clients come to trust the producer, the firm's degree of design freedom increases, allowing it to increase investment in R&D and to further differentiate its products. They also gain increasing freedom to select and work with their own networks of suppliers. Companies work with their suppliers to improve the quality of components in accordance with the needs or preferences of the final customers, thus bringing even more companies into a network of production-oriented innovation.

The PRD's leading ICT hardware firms have followed this development pattern since the 1980s, moving from low-profit margin assembly-based operations to technology and production innovation and (for some firms) independent brands. In industries as diverse as power supplies, mobile telephony network equipment, mobile phone handsets, and other assembled ICT

hardware, PRD companies lead China. In power supplies, firms such as Zhicheng Champion have steadily upgraded their capabilities through a combination of design innovation and product simplification to keep costs low. They have moved into line-interactive and online systems at ever higher volt-ampere ratings – making them able to compete with world-leading Taiwanese firms in the global marketplace. Similarly, Huawei has moved away from its origins in maintenance and resale of foreign telecommunications equipment, to the point where it now produces late-generation mobile telecommunications equipment for markets from Asia and Africa to the European Union. Indeed, its capabilities have advances such that it now covets access to the lucrative, and technologically demanding, US market.

PRD firms from new national leaders such as ZTE, Tencent, or Huawei, to smaller component and sub-component suppliers have managed to successfully upgrade their technology such that the leading firms in different sectors are now perceived as being as capable as any foreign competitor in producing current-generation technology, while still retaining lower costs. Design for ease in production and implementation has made PRD manufacturing highly competitive even within China. Many Beijing and Shanghai firms source their own domestic production from the specialized, and highly innovative, producers in the PRD.

In interviews, many PRD SMEs explicitly dismissed novel-product innovation as a categorical good. Entrepreneurs and officials repeatedly noted the virtues of using and producing technology appropriate for current market needs, making incremental improvements, and shortening the time to market. Interviewees said these types of innovations were superior to the allure of high technology and novelty. One interviewee was particularly frank in his ambivalent view towards novel product innovation under the industrial conditions he observed in China:

> "Before I started this company, I was in the Chinese Academy of Sciences. Once I moved to industry, I quickly learned that the higher the technology, the less likely [that] products would enter the market, at least in a timely fashion. There are three highs: high price,

> high tech, and high time consumption. These are the three highs people fear. Thirty years ago, wireless technology would be unbelievable, although now it's real. If you had tried to make it thirty years ago [in China], it would have cost a lot and failed" (authors' interview).

Incremental improvements and short time to market ensure companies' products will still be in demand when they become available. This provides an edge over fast-approaching competitors. Indeed, the region's top ICT hardware firms – the telecommunications hardware companies Huawei and ZTE owe their rapid rise to prominence largely by eschewing novel product development and specializing instead in the development of technologies seen as obsolete by foreign MNCs and China's national leadership. For example, ZTE grew rapidly through production of personal handyphone system handsets and equipment, known in China as Xiaolingtong. Although the central government tried to ban or severely restrict Xiaolingtong technology due to its lack of novelty and comparative backwardness compared with 2G and 3G mobile, the then-market demand for inexpensive mobile telephony made it wildly popular – attaining some 91 million users by 2006. During its years of rapid expansion, ZTE eschewed novelty and capitalized on this demand, becoming one of China's four dominant equipment providers (Lin, 2003; Yuan et al., 2006).

One feature that allows the PRD's ICT SMEs to engage in continuous innovation is the gradual development of product-based industrial agglomerations around specific townships throughout the region. Different towns specialize in goods ranging from locks and clocks to computer mice and laptops. As they have matured, many of these agglomerations have taken on more and more features associated with classical manufacturing-based Marshalian or North-Italian clusters (Marshall, (1890) 1920; Piore & Sabel, 1984). These clusters include specialized suppliers and assorted companies that together encompass most of the stages of development and production – from R&D and design to component production and final assembly. In the cluster,

each firm focuses on a specific variety of components or single product. As explained by a manager of a Guangzhou-based hardware company when ask about locational decisions:

> "Why Guangzhou? Simple: the industrial chain is in Guangzhou. For example, within a radius of fifty kilometers, we can collect all of the components for the products we produce. But in the north, there is no condition like that. Does Shanghai have a complete industrial chain for electronics production? No, it does not! The entire Chinese electronics production chain is in Guangdong, Shenzhen, and especially Dongguan— not the north" (authors' interview).

This clustered environment is highly conducive to opening of new firms and suppliers in the PRD. Both necessary sub-suppliers and market opportunities abound which help lower the risk in establishing a new business. Local leaders in Dongguan, for example, pride themselves on their locale's "complete" production chains as they see these as the region's source of sustained economic growth and competitive advantage:

> "Why is the [ICT] industry able to operate like this? It is because the production chain is complete. Why is Qingxi able to make computer cases, LCD screens, mice, keyboards, and entire IT systems or lines? It is because Qingxi's production chain is very complete. Our full industrial chain is our greatest advantage in stimulating growth and attracting new investment" (authors' interview).

The tight, dense network of related suppliers allows individual companies to focus on a narrow set of activities in which they can excel and constantly improve. Such specialization can be seen in one power supply firm which spun off its battery division as an independent company, allowing both to concentrate even more on their respective niches. Even high-end components are typically sourced within the PRD, although sophisticated software and integrated circuits frequently come from the local branch companies of foreign MNCs rather than indigenous companies. Up to ninety percent of the necessary components for most ICT hardware, such as uninterruptible power supplies, are sourced from other companies in the region rather than produced in-house. That companies source so many of their components locally, testifies to the degree of completeness of the local industrial chain and the extent of specialized firms' local integration.

Finally, we found that while ICT SMEs in the PRD have been excluded from the formal banking and financial system, they have found alternative means of securing access to necessary capital. The formal banking system remains largely closed to small firms; in interviews managers and owners noted this problem had only grown worse in recent years:

> "Financing is a problem for the entire non-state sector. Minying enterprises cannot get loans. In the PRD, you could before, but not now. The national banks keep themselves really tight when making loans to minying enterprises" (authors' interview).

Isolated from the formal lending system, the industry has developed two separate but complementary means of securing growth and development capital: rotating financing and local state support.[12] Rotating financing are agreements among suppliers, producers and customers to ensure smooth production, working and start-up capital, incentivize cooperation, and sanction cheating, without the need for formal regulation or even the need to utilize the legal system (Geertz, 1962; Putnam, 1993; Uzzi, 1996).

An example of such an informal financing institution is intercompany credit. Under such agreements, "credit" from suppliers is used to finance expansion. A typical arrangement involves obtaining necessary components for one's products based on a commitment to pay for them once the finished products are sold. In turn, these same companies extend credit to their resellers or final clients. The system is based on unofficial promissory notes made between enterprises, often without formal legal contracts. Such a system is highly susceptible to cheating since there is no formal legal enforcement mechanism. However, tight spatial concentration and tight networking

[12] Researchers have been increasingly noting that China's financial system privileges large and state owned enterprises and largely neglects small and medium sized private or minying enterprises. In the 1980s and 1990s, this was attributed to lack of reform in the official banking system and the resulting lack of knowledge for how to evaluate loan applications, as well as unspoken understanding that loans to state enterprises, even if they went bad, would be forgiven, while bad loans to private companies would not. More recent scholarship has found that loan patterns continue to favor large and established enterprises. Even ostensibly venture capital firms do not provide early stage investment to research intensive enterprises. Finally, much of the national research funding goes to megaprojects, and those conducted by well-connected enterprises or institutes, leaving small companies out in the cold (authors' interviews; Breznitz & Murphree, 2011; Economist, 2009; Fuller, 2010; Tsai, 2002).

of industry acts as a deterrent. A firm which fails to make good on its debts, particularly if done willfully, will be blacklisted. A blacklisting excludes the firm, and its owners, not only from lines of credit but also from the local industry as a whole. Since the necessary components for nearly any ICT hardware are all produced in Dongguan, falling from favor would result in an enterprise and individuals being forced out of business. A manager from an enterprise involved in one such credit network explained how it works:

> "The whole operation is based on trust. If you cannot be trusted, you will be kicked out of the business. In ancient China, total costs were calculated once per year. So people would trade and keep track of their balance sheets. At the end of the year, each merchant would collect their credits and pay their debts. This is traditional trust. When we first set up this company, I invested my money first. Suppliers helped me, since my own capital was insufficient. They provided me with the needed capital goods and first components, assuming I would pay once I sold the final products. We didn't borrow any money from the government. In the end, it was even better than having a loan from a bank, because had I had a loan, I would have to pay interest; now I don't. The entire business is based on trust to this day. For example, if my company needs $500,000 worth of inputs, but I only have $50,000 dollars in cash, all my suppliers support me. And I support my customers too. It's a trust cycle from beginning to end" (authors' interview).

Constant and repeated interactions within the manufacturing-based ICT hardware cluster of Dongguan enable enterprises to conduct transactions based on trust. Trusted firms can access credit when needed, thus partially relieving the need to rely on banks, which are quite hesitant to loan, especially to small hardware manufacturers. This informal financial system also extends to the creation of new enterprises. Since the start-up phase for a manufacturing facility involves a large capital investment and a time-lag before any revenue is generated, such an up-front investment would be difficult to sustain without credit. In Dongguan, trust-based pooled credit among enterprises enables start-ups to commence operations and secure orders in advance by purchasing capital equipment and parts on credit. The firm need only promise to repay once a revenue stream is established. However, such a system only encourages investment in proven business models that are well understood by all participants in the network. Further, to remain

viable, revenue streams must quickly be established. This pushes would-be entrepreneurs into manufacturing ventures which can secure orders in advance of, or very shortly after, commencing operations. It is thus not conducive to radically new business concepts or long-term R&D-intensive efforts.

The second major source of capital, and one more specifically focused on improving innovative and R&D capabilities, is local and provincial government investment. As the national government and the centrally run banking system have not expressed interest in or support for further development and growth of the sector, the local government can and does act as an alternative.[13] Local governments throughout the PRD have been an important source of research and development capital. Local governments subsidize expansion and capital-equipment upgrading through subsidies and tax rebates. The belief is that savings on capital-goods imports encourage companies to buy more-advanced equipment and train the local workforce in its use, further enhancing the region's competitive advantage in having an increasingly high skilled manufacturing workforce.

The idea that successful innovation depends on raising the skill levels of manufacturing laborers is entrenched in local government policies. In some sectors, such as power supplies, leading companies draw a large part of their R&D financing from local-government grants. Dongguan's Municipal Science and Technology Commission annually earmarks funds for projects designed to improve the R&D capabilities and technology quality of Dongguan's SMEs. In 2008, the city established a new fund of one billion RMB to help with the R&D activities of SMEs and newly established enterprises (NanfangRibao, 2008; Zhao, 2008). These grants go

[13] This pattern held true even for early adapters which have since become national champions. Both Huawei and ZTE were largely ignored by the central state in their early formative years. Only after they had achieved success did they begin to get central government funding and loans. In their formative years, they were outside the plan (Harwit, 2007).

directly to companies, in the amount of millions of RMB per year to each firm. While these are small numbers in terms of their absolute value, since other sources of financing are limited, the importance of local-government aid for the viability of the cluster should not be underestimated.

ICT hardware firms in the PRD have mostly successfully adapted to take advantage of new spaces in the global production chain – offering highly competitive flexible manufacturing and increasingly sophisticated design and development capabilities for domestic and overseas clients. They have also effectively navigated around the constraints imposed by structured uncertainty and shown considerable resilience, devising means of mitigating official capriciousness, the unreliable property rights system and even developing alternative means of financing their activities.

Discussion and Conclusion

Although it is clear China has established itself as an innovator and critical node in global production of ICT hardware, are the same forces that have enabled it emergence as an ICT powerhouse at work in other sectors? In a variety of industries, the answer appears to be affirmative. In the automobile industry, for example, the same forces of fragmentation and adaptations to structured uncertainty have shaped the performance of the Chinese auto industry. While the degree of fragmentation is much less than in ICT (since many car makers still have unique parts, making it difficult for component suppliers to specialize in providing a single high quality good to multiple buyers), China's auto industry itself is highly fragmented. Chinese auto makers are willing to purchase and integrate components from a variety of sources and brands before integrating them into a final product. High end design services are also purchased off the shelf. Chinese companies heavily utilize foreign design and engineering consulting firms from

Italy, Germany, Britain and Austria. This helps them rapidly generate high quality new models without having to develop the capabilities in-house. Rather they can concentrate on ever-improving their integration and manufacturing capabilities. These designs and technologies were bought outright as an outsourced service, thus giving the Chinese companies full rights and the ability to improve or alter them in the future, further building on incremental capabilities.

Further, recent trends may encourage even greater successes in China's auto industry. Thun's study of the automobile industry found very different institutional arrangements shaping the development of the auto industry in different parts of China (Thun 2006). Since his research, however, there has been the emergence of private or local-state owned automobile companies which rely even more heavily on outsourcing and modularization. Furthermore, such automobile firms' greatest advantages may come as a result of the skills in design and production of electronics and power sources – skills learned through fierce competition in the electronics and ICT industries. Firms such as BYD are leading China in development of hybrid and particularly wholly electric vehicles by relying on existing skills in production of inexpensive but reliable batteries. The same specialization that facilitated the development of a wide array of ICT firms, each with its own component niche, is supporting development of new types of automobiles by allowing for the use of commoditized and inexpensive power sources.

China should be seen as an innovative economic giant, one that has specialized in different stages of innovation. There is a precedent for emphasizing production and incremental improvements. Japan's most famous industries: consumer electronics and automobiles were neither invented nor commercialized nor mass produced first in Japan. Rather, the country successfully built its industry and long-term innovative capacity from the bottom-up. Japan's ability to produce novel innovations arose from the factory floor, just as appears to be happening

in China. Thus, we fully expect to find similar capabilities evolving in China over time. However, as the current innovation system is the product of a very specific political economic institutional environment, attempting to force a rapid move toward novel product innovation in China would likely be highly counterproductive. It would waste resources and harm otherwise highly successful and competitive business models.

China's rise was enabled by the global fragmentation of production. The ability to modularize production processes continues to benefit China in a wide array of industries. China's particular political economic institutional environment shapes the innovative skills of companies in very specific and recognizable patterns. These patterns stand in contrast to the declared goals of China's central government, which has long desired for China to become a global leader in the development of new technologies and products. Chinese enterprises, through skill and necessity, have successfully adapted to this environment. They innovate by entering niches enabled by the global fragmentation of production and specializing intensively in all innovation activities apart from novel product. In the ICT industry, manufacturing skills and tightly integrated production clusters have enabled firms to develop innovative capacities for ease, speed and cost of production and design. Thus even as costs rise, China will be able to remain competitive and profitable in many ICT niches from assembly to design and applied R&D. Despite wide divergence from central plans, China's enterprises – through their successful adaptation to the limits and risks of structured uncertainty – have developed an array of innovative capabilities.

For the developed West, China poses a unique challenge. China's industries are not competing with Western ones to lead at the cusp of novel-product innovation. Rather they are competing by successfully mastering all other stages of innovation and production. In so doing, although the largest shares of profits continue to be reaped overseas, the Chinese gain greater

broad-based employment and economic growth. They also gain an intimate understanding of a wide variety of technologies, exactly the sort of understanding necessary for an eventual leap into "higher" forms of innovation. Thus the China challenge is whether or not the modern economic model in the developed West which relies on specialization at only the top of the innovation pyramid is sustainable when the remainder of the pyramid, with its skills and jobs has moved elsewhere.

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