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INDIGENOUS INNOVATION AND ECONOMIC DEVELOPMENT: LESSONS FROM *CHINA'S LEAP INTO THE INFORMATION AGE*[1]

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INDIGENOUS INNOVATION

Economic development depends on the innovative capability of a society to generate goods and services that, at prevailing factor prices, are higher quality and lower cost than those that were previously available. So defined, innovation makes it possible, although by no means inevitable, to improve the economic positions of many different groups of people—workers, managers, financiers, consumers, and governments—who participate in the economy. Social institutions will determine how the gains from innovation are distributed among participants in the economy, while the distribution of the gains from innovation will influence the incentives of participants in the economy to contribute their skills and efforts to innovation. From this perspective, the process of economic development needs to be analyzed within a framework that captures the dynamic interaction between social institutions and the innovation process (Lazonick 2002).

The process of innovation entails learning about how to transform technologies and access markets, and what is learned in one innovative activity can be subsequently applied to other innovative activities. The cumulative character of the process of economic development poses a profound problem for less developed nations. Given the lead of the advanced economies, how can the less developed nations accumulate the innovative capability that will enable them to embark on a cumulative development path so that they can eventually join the ranks of the more advanced nations? Is it necessary for them to follow the learning path that the advanced economies took, and hence forever lag behind? Or, by choosing a different path, can they catch up and perhaps even forge ahead? Do they have to accept a permanently subservient role in the international division of labor? Or can they engage, as have all of the advanced economies at certain times and in certain sectors, in "indigenous innovation", a process of making use of technologies transferred from the advanced economies to develop superior technologies at home?

1 An earlier version of this paper was presented at the Annual Meeting of the Business History Conference, Lowell, Massachusetts, 28 June 2003, in a session, sponsored by UMass Lowell and INSEAD, on Indigenous Innovation and Economic Development in East Asia, to honor the memory of Qiwen Lu. Kazuo Wada of Tokyo University and Feng Lu of Beijing University also presented papers in the session, while Dic Lo of the University of London served as discussant. Yingying Deng provided research assistance.

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Put this way, it is obvious that less developed economies want to choose a strategy of indigenous innovation. But what does indigenous innovation entail and how, within a national environment, is such a process put in place? These are the larger questions that Qiwen Lu poses in his book, *China's Leap into the Information Age: Innovation and Organization in the Computer Industry* (Oxford University Press 2000). The book contains detailed business histories of four leading Chinese computer electronics enterprises from their founding in the mid-1980s to the late 1990s when Lu completed the manuscript. Lu shows how, through reform of the nation's science and technology (S&T) institutions and the organization of industrial enterprises related to them, China engaged in indigenous innovation in the computer industry. Based on in-depth, field-based analyses of strategy, finance, and organization in the four companies—Stone, Legend, Founder, and Great Wall—Lu shows how, in becoming self-sustaining enterprises, they emerged out of and drew upon the technological resources of China's S&T infrastructure, itself a legacy of the era of central planning. At critical points, these enterprises also absorbed technology from abroad through a variety of organizational arrangements. Lu demonstrates, however, that these enterprises did not merely engage in learning from the advanced economies. Rather they integrated foreign technology into their indigenous innovation strategies.

Lu did this work as part of a research project on indigenous innovation and economic development that I was directing during the mid-1990s. His research built upon and helped to inform a "theory of innovative enterprise" that Mary O'Sullivan (then, like Lu, a graduate student at Harvard University) and I were developing at the time, and which, individually and jointly, remains a central focus of our research (see Lazonick and O'Sullivan 2000b; O'Sullivan 2000, 2004; Lazonick 2004). Lu explicitly employed this theory, with its focus on what we would now call the "social conditions of innovative enterprise", as an analytical framework for the case studies in his book.

As is recounted in my Foreword to *China's Leap into the Information Age*, Lu started working with me on these issues almost immediately after he had come from China to Harvard University in 1990 to do a PhD in sociology. His research on the evolution of the Chinese computer industry, that formed the basis for his PhD dissertation completed in 1997, was funded by, and done in collaboration with me at, the UMass Lowell Center for Industrial Competitiveness. Upon completion of his PhD, Lu joined O'Sullivan and me at our new posts at INSEAD, the international business school located in France, and it was as an assistant professor of Asian Business that he completed the volume. Qiwen Lu submitted the finished manuscript to Oxford University Press in June 1999, with none of us suspecting that he would not live to see the actual publication of the book.

While Lu's particular research focus on the Chinese computer industry was very contemporary, he saw it as part of a much broader intellectual effort to construct a theory of economic development that drew on the comparative-historical experiences of not only the developing nations but also the advanced nations. My own research agenda, begun some two decades before I met Lu, has focused almost exclusively on the comparative-historical development experiences of the nations such as the USA, Japan, and Britain that are now among the ranks of the advanced economies. I have pursued this agenda with the view that an understanding of the processes through which the advanced economies of today grew wealthy constitutes an important, and even essential, prelude to formulating strategies and policies that can foster and support sustained economic development in the poorer nations of the world. The argument is not that all nations follow the same path to economic prosperity, but, to the contrary, that the comparative-historical analysis of the different paths that they have followed can provide insights into the common underlying principles of innovative enterprise discernible in the variety of development paths (see Lazonick 2002).

When I first met Lu, the logic of this approach to the integration of theory and history was already apparent to him, and with it the notion that we shared of the need to analyze the current challenges of the developing economies in relation to the comparative-historical experiences of the already advanced economies. In addition, both of us agreed that to contribute to the construction of a relevant theory of economic development, one had to engage in rigorous empirical analysis of leading industrial sectors, both because they were leading and because, even within the same national economy, one should not expect to find the same conditions of innovative enterprise prevailing across industrial activities that are differentiated by technological, market, and competitive conditions. We agreed that an understanding of indigenous innovation and its implications for economic development requires an accumulation of case studies across enterprises, industries, regions, nations, and eras.

The purpose of this paper is to distil the insights contained in Lu's four business histories, and to make use of them to inform theories of innovative enterprise, indigenous innovation, and economic development. In the body of this paper, I outline the "social conditions of innovative enterprise" framework as I currently conceive it, and then use it to summarize the roles of strategy, organization, and finance as conditions of innovative enterprise in each of Lu's four case studies.[2] The concluding section of the paper considers the lessons of *China's Leap* for understanding innovative enterprise, indigenous innovation, and economic development.

THE SOCIAL CONDITIONS FOR CHINA'S LEAP

Social conditions of innovative enterprise

Lu's case studies show that the S&T infrastructure that China had put in place during the era of central planning was important for providing technological capabilities to indigenous innovation in the 1980s and 1990s. He argued, however, that the innovation process itself had to be analyzed in terms of "a set of social institutions that influences the strategic allocation of resources and returns in business enterprises" (Lu 2000: 14). Specifically, building on work on the theory of innovative enterprise that O'Sullivan and I had done at the time (Lu 2000: 14–15), Lu focused his case study research on "who makes investment decisions, what types of investments they make, and how investment returns are distributed".

2 At the time of Qiwen's death, we had just finished a joint article (Lu and Lazonick 2001) that, using material from his case study of Founder, drew out the implications for the debates on the roles of business and government in China's transition from a centrally planned to a market-oriented economy. In a similar vein, we had planned to consider the contributions of his other case studies to larger debates on issues such as ownership and control, the finance of innovation, cross-functional integration, and the commercialization of technology. In a different form than we had anticipated, this paper is an attempt to do a piece of the joint work we were unable to complete together.

O'Sullivan and I have subsequently elaborated and articulated the framework for asking these three questions in terms of three "social conditions of innovative enterprise" that we call "strategic control", "organizational integration", and "financial commitment". This framework seeks to identify how business enterprises strategize, organize, and finance in order to transform productive resources into goods and services that customers want at prices they can afford. Firms strategize when they choose the product markets in which they want to compete and the technologies with which they hope to be competitive. Firms organize when they combine resources, including first and foremost human resources, in the attempt to transform them into saleable products. Firms finance when they make investments to transform technologies and access markets that can only be expected to generate revenues sometime in the future.

To strategize, organize, and finance is not necessarily to innovate. By definition, as Lu stressed in his work, innovation requires *learning* about how to transform technologies and access markets in ways that generate higher quality, lower cost products. Learning is a social activity that renders the innovation process *uncertain*, *collective*, and *cumulative*. The innovation process is uncertain because, by definition, what needs to be learned about transforming technologies and accessing markets can only become known through the process itself. By investing in learning, an innovative strategy confronts the uncertain character of the innovation process. The innovation process is collective when learning cannot be done alone; learning requires the collaboration of different people with different capabilities. Investments in collective learning, therefore, require the integration of the activities of these people into an organization. The innovation process is cumulative when learning cannot be done all at once; what is learned today provides a foundation for what can be learned tomorrow. Investments in cumulative learning, therefore, require sustained, committed finance.

The *types* of strategy, organization, and finance that support such learning processes are "social conditions of innovative enterprise" (Lazonick and O'Sullivan 2000b; O'Sullivan 2000; Lazonick 2004). The social condition that can transform strategy into innovation is *strategic control*: a set of relations that gives decision-makers the power to allocate the firm's resources to confront the technological, market, and competitive uncertainties that are inherent in the innovation process. For innovation to occur, those who occupy strategic decision-making positions must have both the abilities and incentives to allocate resources to innovative investment strategies. Their abilities to do so will depend on their knowledge of the current innovative capabilities of the organizations over which they exercise allocative control and how those capabilities can be enhanced by strategic investments in new, typically complementary, capabilities. Their incentives to do so will depend on the alignment of their personal interests with the interests of the business organization in attaining and sustaining its competitive advantage.

The social condition that can transform organization into innovation is *organizational integration*, defined as a set of relations that creates incentives for people to apply their skills and efforts to organizational objectives. The need for organizational integration derives from the developmental complexity of the innovation process—that is, the need for organizational learning—combined with the imperative to secure high levels of utilization of innovative investments if the high fixed costs of these developmental investments are to be transformed into low unit costs. Modes of compensation (in the forms of promotion, remuneration, and benefits) are key instruments for integrating individuals into the organization. To generate innovation, however, a mode of compensation cannot simply manage the labor market by attracting and retaining employees. It must be part of a reward system that manages the learning processes that are the essence of innovation; the compensation system must motivate employees as individuals to engage in collective learning.

The social condition that can transform finance into innovation is *financial commitment*: a set of relations that ensures the allocation of money to sustain the cumulative innovation process until it generates financial returns. What is often called "patient" capital enables the capabilities that derive from collective learning to cumulate over time, notwithstanding the inherent uncertainty that the innovation process entails.

These conditions of innovative enterprise are "social" because, in a particular time and place, the characteristics of strategy, organization, and finance that support innovation depend on relations among economic actors who make different contributions to the innovation process and may have different incentives to do so. Even if the firm were simply an individual actor—an innovative entrepreneur who makes strategy, mobilizes his own savings to finance it, and organizes himself to develop and utilize resources—one would still need to specify the abilities and incentives of that individual to assess his or her potential for transforming generic business activities into higher quality, lower cost products. The modern corporate enterprise cannot, however, be analyzed as if it were an individual actor; it employs people numbering in the hundreds, thousands, tens of thousands, or even in some cases hundreds of thousands who possess a vast array of specialized abilities that can contribute to company performance. Depending on their differing prospects for reaping returns from the firm, different groups of corporate participants may also have discernibly different interests in making productive contributions. The innovation process, moreover, often requires the interaction of people who are employed by different companies, and hence, innovation may require the integration of the activities of people across as well as within firms.

The "social conditions of innovative enterprise" perspective provides an analytical framework for researching the dynamic evolution of actual enterprises (for other empirical studies, see Carpenter *et al.* 2003; Lazonick and Prencipe 2004). In *China's Leap*, Lu employed a version of this framework to understand how four indigenous computer electronics companies that, by the mid-1990s had clearly been successful as innovative enterprises, combined strategy, organization, and finance in their efforts to accumulate innovative capability. While the following summaries of Lu's findings abstract, as they must, from important details of how the companies engaged in innovation,[3] they illustrate how Lu captured the essence of what it was that permitted these companies to innovative, compete, and grow.

3 In the following summaries, I have refrained from referencing each factual point, and have only done so in the case of direct quotes. Unless otherwise indicated, all of the factual material that is included in these four summaries can be found, fully referenced to their original sources, in the relevant chapters of Lu (2000).

Stone

In 1984 a group of alumni of Tsinghua University, China's premier engineering school, founded Stone in Beijing's Haidian District as a "collectively owned" enterprise. In doing so, they took advantage of unfolding government initiatives to transfer technological capabilities from the nation's S&T infrastructure to autonomous industrial enterprises that, to survive, would have to sell products on the market. At the time when they founded Stone, these engineers were working in government research labs and institutes as well as in state-owned computer enterprises. They decided, however, to give up their secure state jobs—or what the Chinese call "iron rice bowl"—in order to run a business enterprise.

While this group of engineers founded Stone, they did not own it. The company was set up as a rural enterprise township, under the jurisdiction of Evergreen Township, which was part of the Haidian District. Evergreen Township provided the new company with a "venture loan" of RMB20,000 to be paid back within a year as well as free office space and a telephone. In two sentences the Stone company charter articulated its general stance on strategic control, financial commitment, and organizational integration: "The corporation's organizational principles are independent management and financial self-reliance. The company will develop technology-intensive products by adopting a new organizational mode of integrating R&D, manufacturing, and trade" (Lu 2000: 22). As Lu goes on to show, over the ensuing years that is precisely what the company succeeded in doing as it engaged in indigenous innovation.

Stone's first product was a low-cost electronic printer capable of outputting Chinese characters. In the early 1980s, when the Chinese state was importing huge numbers of personal computers, the only printer capable of handling Chinese characters was a very expensive Toshiba model. Stone re-engineered a less expensive model from the Japanese company, Brother, so that it too would have Chinese-character capability. As the sole distributor of the machine in China, Stone generated substantial revenues over the next 2 years. These revenues enabled Stone to easily pay back its loan from Evergreen Township and fund its entry into the Chinese word processor market. This product was, in Lu's words, "an instant market hit . . . [that] became the company's cash cow for quite a long time" (Lu 2000: 24).

During Stone's first year of operation, the chairman of the company's board of directors was also the top government official in Evergreen Township, and a number of other township officials were involved in the affairs of the company. Indeed, the initial agreement with the township gave it a 60 per cent claim on Stone's profits. In 1985, however, an administrative order from the Chinese Communist Party decreed that government officials and Party members had to cease direct involvement in commercial ventures. Most of the township officials resigned from Stone, with the exception of two of them who opted to give up their township positions and become full-time Stone employees. Meanwhile, the general manager of Stone, Wan Runnan, a former computer engineer at the Chinese Academy of Sciences, became the chairman of the board.

In 1988 Stone agreed to pay the township a fixed annual amount of RMB526,000, a small fraction of its total revenues, but even then the township had no actual equity rights in the company. Stone's employees collectively owned the company, although as individuals they could not claim equity shares. Should the company be liquidated, the proceeds would be used to provide retirement and unemployment benefits as well as retraining for its employees. This ownership structure gave Stone's managers the decision-making autonomy—or strategic control—that enabled them to allocate the company's resources to innovative investment strategies. Firstly, Stone was financially independent of the state, paying only taxes at the low rate that the government had set to facilitate the growth of high-tech enterprises. This control over its revenues and earnings provided Stone's managers with a critical foundation of financial commitment. Secondly, Stone's management could choose which employees to recruit, and how to structure their remuneration—control over the allocation of resources that is essential for organizational integration.

In the early years, it appears that, to attract new recruits, Stone paid employees two to three times what they could earn in the state sector, and that by the 1990s the ratio was about double. Meanwhile employment at Stone grew substantially. To finance such growth while retaining its financial autonomy, the company had to generate new products that could be competitive on the market, which in turn required that the company possess the requisite technological capability. Two young computer experts employed by the Computing Centre of the Chinese Academy of Sciences, but moonlighting for Stone for a consulting fee, had re-engineered the Brother printer that became Stone's first successful product. Thereafter, the company was able to lure key technologists away from the state sector to become its full-time employees. Indeed the three employees who constituted the key members of the development team for the Chinese word processor had come from state employment, although one of the three waited until the product had achieved commercial success before abandoning his "iron rice bowl".

Stone's word processor was developed in collaboration with the Japanese. Mitsui & Company, which had been the distributor of the Brother printer, took charge of hardware design and manufacture while Stone developed the software. A trading company, Mitsui outsourced the hardware work to a Japanese contract manufacturer, Alps Electronics. Lu (2000: 43) argues that "without the Japanese designing and manufacturing the hardware, it would have been impossible to put the product onto the market in such a short time with reliable quality and at a reasonable price". Lu also shows that, in the process of collaboration with the Japanese, Stone's employees learned about product design as well as the relation between production costs and market demand. Explicitly recognizing the need to exercise control over, and to learn through, the process of new product development, Stone also insisted on developing its own test software on equipment available in China rather than leave testing in the hands of Alps.

This learning, alongside Stone's success in expanding the extent of the market—itself the result of investments that the company made in a nation-wide distribution network—subsequently enabled the company to enter into a manufacturing joint venture with Mitsui on terms very favorable to Stone; 40 per cent of Stone's 75 per cent stake in the joint venture was directly attributed to the company's "technology know-how". For its part, one of Mitsui's obligations under the joint venture was the training of Chinese managers and technicians, with Stone sending all types of employees ranging from managers to operators for training stints in Japan. By 1991, as it produced the next generation of its Chinese word processor, Stone had, in Lu's (2000: 50) words, "internalized almost all the key manufacturing technologies". These investments implemented Stone's charter of integrating R&D, manufacturing, and trade.

By the early 1990s Stone had become a substantial enterprise, but to continue to grow it had to innovate continuously. Investments in innovation required committed finance, especially to retain key employees at a time when many other high-tech enterprises, both indigenous companies and foreign multinationals with operations in China, were trying, at times successfully, to woo them away. Besides corporate retentions, a stock issue could be another possible source of committed finance. In 1986 the company had experimented with a small private stock issue, about half of which employees took up. It did not, however, supply significant funding. In early 1989 the company was set to do an initial public offering, in which current employees would, as founders of the new joint-stock company, receive 10 per cent of the shares. But the student movement in the spring of 1989 forced Stone to put the IPO on hold. The government's reaction that culminated in the Tiananmen massacre, also compelled Stone chairman, Wang Runnan, a supporter of the student movement, to flee China.

Eventually, however, Stone did go public. In August 1993 it listed on the Hong Kong Stock Exchange as Stone Electronic Technology Limited, issuing 25 per cent of its shares to the public, placing 17 per cent with corporate and institutional shareholders (including Mitsui), and retaining 58 per cent in Stone Group as the holding company. Through the IPO, the company raised HK$300 million, while maintaining insider control with Stone managers retaining their positions as strategic decision-makers. About one-quarter of the funds raised were earmarked for investments in manufacturing facilities, and another quarter for expanding the company's distribution and service outlets as well as regional managerial centers. The rest would be used as working capital.

These investments enabled Stone to enter the electronic cash register business at just the time when the introduction of a value-added tax in China helped to create a huge demand for these business machines. Subsequently Stone diversified into light equipment—another joint venture with the Japanese—and then, by acquiring a state-owned enterprise, into unrelated products such as the production of Vitamin C for export.

Legend

By 1996 Legend was China's largest information technology enterprise, with Legend Group (Hong Kong) as the world's fifth largest supplier of computer motherboards and add-on cards and Beijing Legend Computer Group as the largest domestic personal computer maker and number three in domestic market share after AST and Compaq. At that time, Legend was 12 years old with its origins in the Zhongguancun region of the Beijing Haidian District. Like Stone, which had been founded in the same year, Legend was able to draw on the resources of the research institutes of the Chinese Academy of Sciences (CAS) that were located in the Haidian District. Indeed, Legend had been set up by the Institute of Computing Technology of the CAS as an enterprise named "New Technology Development Company of the Research Institute of Computing Technology of CAS"—or ICT Co., for short—for the purpose of commercializing the Institute's knowledge. The 11 founders of the company were and initially remained Institute employees, and the Institute provided ICT Co. with a loan of RMB200,000 as well as office space and research facilities.

It was the direct emergence of the company from within a major government research institute that led to the depiction of Legend as the product of "one academy, two systems". In setting up ICT Co., it was agreed that it would have "full autonomy in managerial decision-making, financial budgeting, and employee recruitment", even while having full access to the Institute's S&T resources and the use of the Institute's brand name in marketing its products (Lu 2000: 65). Initially the new company had to scramble for income, even selling roller skates at one point, and it secured its first substantial revenues from a CAS service contract for the installation and operation of 500 imported computers. The product that launched the company on a growth path was a Chinese word-processing add-on card that bore the "Legend" brand name. This card could be used with existing IBM PCs and clones (in contrast to Stone's development of a stand-alone integrated Chinese word processor). ICT Co. hired the key state scientist who had developed this technology within the CAS. The add-on card was ICT Co.'s most important product during its early years, but the company also produced a wide array of computer-related products.

In April 1988, ICT Co. entered into a joint venture in Hong Kong, setting up Legend (Hong Kong) Co. for the purpose of marketing motherboards and add-on cards worldwide. In October of that year ICT Co. reorganized itself as Legend Computer Group Co., with Legend (Hong Kong) and Beijing Legend Computer Group Co. as its constituent subgroups. Legend remained a state-owned enterprise, but one in which, following the example of Stone, managerial autonomy over strategic decision-making was of central importance to its governance and growth. It maintained this autonomy notwithstanding its origins within ICT of CAS and its ongoing reliance on the Institute for technological resources. That autonomy was reflected in the fixed annual payment of RMB1.2 million that ICT Co. and then Legend paid to the Institute. In 1985, this sum was 40 per cent of ICT Co.'s revenues, but by 1988 it was less than 1 per cent and by 1991 less than 0.02 per cent. Meanwhile by 1986 ICT Co. had paid back its RMB200,000 loan to the Institute. In 1995 the relation between Legend and the Institute was brought full circle when CAS authorized Legend to take over the running of the Institute as the company's internal research organization!

Besides control over its revenue flow and access to state S&T resources, an essential determinant of Legend's success was the integration of, to quote Lu (2000: 71), "R&D, manufacturing, marketing, and services into a coherent business structure". Within this integrated structure, before-and-after sales services, available in all the major cities of China, played a central role in both accessing customers and learning from them. In the early years, potential customers had to be taught how to use computers; the company placed highly trained technical personnel in the field to help make sales and had 3,000–4,000 technicians available for after-sales instruction. Through the formation of Legend Chinese Word-Processing System Users' Association, the company turned its users into advocates of its products and provided feedback for product development. From 1985 the company also held two major technology fairs per year with more than 5,000 people attending annually. As the president of Legend recalled in a speech in 1995:

> What were our major competitive advantages? Other Chinese word-processing add-on cards were mostly developed by research institutes. These institutes did not have the kind of marketing capability that we had. I remember at a product contest in early 1986, there were at least several Chinese word-processing add-on cards, the quality and performance of which were as good as ours. Why did they lose? It was because they did not have the organizational capabilities to derive ideas from the market and act accordingly. We had an advantage in this regard. (Quoted in Lu 2000: 73)

ICT Co. entered into the personal computer business by becoming the sole distributor in China for AST, on whose machines it installed its Chinese word-processing system. ICT Co. and then Legend prospered immensely as AST became the leading PC brand in China. This relation took advantage of, and helped to build further, Legend's distribution channels, which in turn facilitated the development and marketing of scores of other computer-related products.

It was from this base, and with a view to eventually becoming a leading international vendor of PCs under it own brand name, that in 1988 the company launched a joint venture in Hong Kong with a company called China Technology that had ample financial resources and international legal expertise. By subsequently acquiring an 80 per cent share of a small Hong Kong manufacturing plant, Legend (Hong Kong) built up its international business in PC motherboards. The original owner-entrepreneur of the Hong Kong plant retained the other 20 per cent ownership and stayed on after the acquisition as the plant's general manager. When the output of the plant proved to be low quality, however, Legend bought the remaining 20 per cent, dispensed with the services of this general manager, and brought in production managers and engineers from Beijing to improve quality.

In 1990 Legend introduced its own brand-name computer in China. Legend Hong Kong had already tried to market such a computer internationally, but was unsuccessful mainly because Legend was not a global brand. In China, however, the brand was well known, and the company had a nation-wide sales and service network to support its products. Legend's sales of its PCs in the domestic market increased from 2,000 in 1990 to 100,000 5 years later. With this growth, Legend increased its commitment to R&D, establishing centers in not only Beijing, Shenzhen, and Hong Kong but also Silicon Valley. In the Chinese PC market, Legend became the high quality, low cost producer.

In 1994 Legend went public on the Hong Kong Stock Exchange as Legend Holdings, Ltd. Twenty-five per cent of the shares were issued to the public, while Beijing Legend retained almost 39 per cent. Four private Hong Kong individuals who had been associated with China Technology held another 32 per cent between them (two of them holding 12 per cent each). Beijing Legend's president became the chairman of Legend Holdings, Ltd, and Beijing Legend supplied three of the five of Legend Holdings executive directors. The IPO raised HK$200 million, much of which was used to permit Legend to expand its manufacturing capacity. In addition, Legend did a secondary rights offering of shares (which left the ownership structure essentially unchanged) to raise HK$108 specifically to build the Legend Science and Technology

Park in Huiyang, China, near Shenzhen, less than 50 miles from Hong Kong. The company also took a controlling interest in a Hong Kong semiconductor company.

In the conclusion of his chapter on Legend, Lu stressed the fact that whereas most previous studies of the China–Hong Kong industrial relationship have focused on Hong Kong's access to cheap Chinese labor in Guangdong (for example, Vogel 1989), the case of Legend was one of much greater complementarity of capabilities; China brought technology and managerial capability to Hong Kong as much if not more than vice versa. He also emphasized that, as of the time of writing, notwithstanding the listing of the company on the Hong Kong Stock Exchange and the minority shares held by private individuals in Hong Kong, majority ownership of Legend remained in collective hands—a somewhat vague combination of CAS, ICT, and Legend employees—and this ownership translated into Beijing remaining the locus of strategic control.

Great Wall

By the time of writing *China's Leap*, China Great Wall Computer Company (CGC) had become "a large-scale, fully integrated high-tech enterprise group engaging in a wide range of IT related businesses, including R&D, manufacturing, distribution, services, systems integration, foreign trade, and finance" (Lu 2000: 150). Its privileged position as not only a state-owned but also, unlike Stone and Legend, a state-run company enabled it to dominate the Chinese PC industry in the last half of the 1980s. When in the early 1990s it was challenged by multinationals and non-governmental enterprises such as Stone and Legend, CGC responded by forming strategic alliances with the world's leading information technology companies, including IBM, Intel, and Microsoft.

In the early 1980s China's state-run PC industry had pursued an import-substitution strategy of assembling computers from imported parts and components. The Computer Industry Administration wanted China to develop its own PC capability, and began to negotiate with IBM about joint ventures in China. The initiative ultimately failed because IBM did not want to make its advanced technologies available to the Chinese. Nevertheless, in the process of negotiation, the Chinese learned how IBM Japan organized its PC business. As recounted by Wang Zhi, who was at the time deputy bureau chief of the Computer Industry Association (CIA) of the Ministry of Electronics Industry (MEI), but later became president of Great Wall:

> We went to Japan. We learned that IBM (Japan) conducted business differently. Product development was done in-house. Production was outsourced to several Japanese companies. The company only controlled marketing and distribution. Such a model could still be successful. It was quite revealing. We thought that we could certainly copy this model. (Quoted in Lu 2000: 152)

In 1984 Wang set out to build this business model, under the jurisdiction of the CIA. He formed a product development team of about a dozen engineers and technicians (average age 24) and secured an allocation of RMB300,000 from the CIA R&D budget. As in the cases of Stone and Legend, the central task was to develop a PC that could do Chinese-language word processing. To get access to product development tools, the CIA sent one half of the development team to Hong Kong to work on high-resolution Chinese font display technology and the other half to Tokyo to work with IBM Japan on Chinese word-processing software (a technology in which IBM was deficient). By early 1985 the whole team was back in China with a computer that could generate Chinese fonts and that in other respects could match the IBM PC/XT, which was then the best-selling PC in China. In launching the product, the CIA decided to make the development team a company, called Great Wall Microcomputer Development Co., with the head of the development team as the general manager. The Great Wall computer sold for 80 per cent of the price of competing domestic models, and about 65 per cent of that of the IBM PC/XT.

The Great Wall computer was an initial market success, and the company expanded production using the outsourcing (or OEM) model it had learned from IBM. The CIA set up another company, Longxing Electronics, to organize production for Great Wall computers by outsourcing assembly to 13 state-owned manufacturing enterprises, which in turn sourced components from 10 second-tier suppliers. Longxing also set up a national dealership system, with over 100 outlets by 1987. In China, this OEM model became known as the Great Wall Model.

To organize the further development of this business model, the MEI formed the China Computer Development Corporation (CCDC), with Wang Zhi as its general manager. CCDC took control of Great Wall and Longxing and included as well some other computer and electronics firms, training centers, and a finance company. Within this structure, CCDC invested in product development and manufacturing centers in Shenzhen, near Hong Kong. By the end of 1990 these plants produced over 80 per cent of Great Wall PCs; the OEM strategy had proved to be only a transitional model. Meanwhile, in late 1988, CCDC was renamed China Great Wall Computer Company (CGC). The company launched a new series of Great Wall PCs in April 1988, and new higher end models followed. Besides its domestic sales, CGC exported about US$35 million in PCs, monitors, and add-on cards from 1989 through 1991, partially offsetting some US$51 million in components that the company imported during this period.

In the last half of the 1980s, however, CCDC/CGC was not a high-growth company; it sold an annual average of about 15,500 PCs domestically from 1988 through 1991, failing to even reach its 1987 sales volume of over 16,300 units in any of these years. Its computers suffered from quality problems attributable to its initial OEM model. Increasingly, CGC faced superior domestic competition from Stone, Legend, and Founder as well as from cheap foreign imports.

To remedy this situation, CGC sought out strategic alliances with foreign firms. In 1994, in a sense picking up where it had left off about 10 years earlier, CGC entered into a joint venture with IBM, with (after long negotiations) IBM holding a 51 per cent stake. IBM was open to this venture because it had failed to make headway in the growing Chinese PC market. According to Lu (2000: 166), "the joint venture became a platform for CGC to learn product development, production, and marketing techniques from IBM". CGC used the joint venture to bring out a high-end PC, called Golden Great Wall, that was produced alongside IBM PCs. In 1996 the joint venture produced 200,000 PCs, of which 80,000 were sold under the Great Wall brand name. In 1998 a CGC manager told Lu (2000: 168): "We acquired the technical know-how, established our own brand name, and didn't give up our market."

In addition, by 1995 CGC had become "the largest OEM supplier of computer parts and components to both domestic and overseas PC makers in China" (Lu 2000: 168). In 1993 the company created Great Wall Software and Systems Inc., and in 1994 it had already become "the largest [software] systems integrator in China" (Lu 2000: 168). CGC built on its success with IBM to form a number of other strategic alliances both with IBM and other international IT companies. By the time Lu researched the company, it had become one of the largest IT conglomerates in China.

The only direct government financial subsidy of CCDC/CGC had been the original RMB300,000 research grant. The remaining funding came from the company's revenues, with the managers of CCDC/CGC controlling their allocation. The company was initially privileged in the foreign currency quotas that were granted to it, but these privileges were gradually reduced and ultimately eliminated. The company also received the tax concessions that the government accorded to all high-tech firms. When CGC's internally generated funds were insufficient for its expansion in the 1990s, it turned to loans from state-owned banks. Then in June 1997 CGC floated two joint-stock companies on the Shenzhen Stock Exchange, with CGC emerging with controlling shares in each of the new companies. CGC raised a total of RMB649 million from the two IPOs, and used the proceeds to pay off its bank debt and expand its productive capacity.

Founder

By 1997 Founder Group had emerged as the world leader in pictographic language electronic publishing systems (EPS), with the dominant position not only in China—where it had over 80 per cent of the market—but also in Hong Kong, Taiwan, Singapore, Malaysia, USA, and Europe. The company had also developed a series of high-resolution professional color EPS that enabled it to compete head-to-head in this market with leading companies such as Linotype-Hell of Germany and Adobe of the USA. In addition, in 1997 Founder was the fourth largest indigenous PC brand in China; indeed in the previous year 42 per cent of its sales came from PCs and peripherals and 39 per cent from EPS.

Like Legend, Founder is a non-governmental S&T enterprise subject to "whole people ownership", a non-traditional form of state ownership in which the enterprise is established outside central or local budgetary control. Whereas Legend sprung out of the Institute of Computer Technology of the Chinese Academy of Sciences, Founder was a commercial offshoot of Beijing University's Institute of Computer Science and Technology (ICST). From 1986 Beida New Tech—a company set up by Beijing University to commercialize technology—took control of the development of the EPS, and through a reorganization in 1993 created Founder Group around the EPS product.

In 1996, one of its former presidents explained the formal relation of Beida New Tech to Beijing University:

> Nominally, Beida New Tech is still a state-owned enterprise. However, it is different from the traditional state-owned enterprises, I mean the ones under the jurisdiction of ministries of industries. It is actually owned by Beijing University. Yet it is operated as if it were a private enterprise. The university does not interfere with the daily business activities of the company. None of its wages, welfare benefits, or bonuses are constrained by the regulations set for state enterprises. We are completely autonomous for doing business. However, because it is not a state-owned enterprise in the traditional sense, its

> risk-bearing capability is also very low. If it fails, no one would bail it out. This is part of the reason why the enterprises in Electronics Alley rise and fall so quickly. It puts a lot of pressure on management. (Quoted in Lu 2000: 125)

China's efforts to develop an EPS date back to an August 1974 project proposal, made by top bureaucrats from five government agencies and institutions to the State Planning Commission. At the time, China still relied on lead typesetting, which required workers to select individual fonts manually from a shelf of thousands of Chinese characters, an extremely laborious process. The State Planning Commission approved the proposal. The Fourth Ministry of Machine Industry (later renamed the Ministry of Electronics Industry), assumed the role of organizing and coordinating Project 748 (signifying the year and month that project was initiated).

The most advanced technology available at the time was a third-generation CRT-based photo-typesetting system, developed by the German company, Hell. The basic principle of the technology was to generate the page layout on the screen of a high-resolution computer monitor, then photograph the on-screen image of the page layout, and develop the film for offset printing. The fonts used to generate the on-screen page layout were stored in the computer memory in dot-matrix format. The CRT-based photo-typesetting technology was capable of storing and generating fonts for alphabetic languages, which have at most several dozen characters and other symbols. For a Chinese-language publishing system, however, one set of font type has at least 7,000 characters. To meet the minimal requirements for professional publications, a publishing system needs at least four different types of high-resolution fonts. The computer memory required to store these fonts in dot-matrix format is enormous (up to 20MB). At the time, the internal memory of a minicomputer was only 64KB and the domestically produced minicomputer only 640KB. Although secondary memory devices such as hard drives had larger memories, the capacity of such hard drives was also limited and the access time was too slow for industrial uses.

Given these limitations, therefore, the major technological challenges were to compress Chinese font information so that it could be stored in the very limited memory of the computers then available and to regenerate the fonts at a sufficiently high speed. Wang Xuan, a junior professor in the Computer Science Department of Beijing University, came up with an ingenious idea for compressing Chinese font information by mapping the contours of Chinese fonts into different shapes and parameters, thus reducing the required computer memory by a magnitude of several hundred times. In May 1976, after comprehensive testing, including a successful computer simulation, Wang's research proposal won the support of Office 748, which assigned to Beijing University the lead role in developing an EPS. The University's Institute of Computer Science and Technology (ICST) was born out of this research effort.

The project included many other participants. Industrial prototyping and manufacturing was assigned to Weifang Computer Company, a state-owned computer electronics enterprise under the MEI. Several other state research institutes and enterprises were allocated the tasks of developing complementary hardware. The task of developing the laser typesetter went to an enterprise under the Ministry of Posts and Telecommunications that made newspaper fax machines. Industrial testing for the system would be carried out at the Xinhua News Agency.

Wang had realized early on that the system would require the development of a laser typesetter. His solution for compressing fonts made it possible for ICST to develop the core technology of the laser typesetter, the raster image processor (RIP). The development of an EPS also required a large-scale software development project to generate a multi-user operating system and an on-screen newspaper editing system. Complicating the software development process was the poor quality and performance of domestically made computer hardware and peripherals. In February 1980 the State Import and Export Control Committee allocated US$200,000 in hard currency to import a minicomputer system as well as some electronics parts, including integrated circuit components. With the computer hardware problem to a large extent solved, the 748 team developed a second-generation system that by the end of 1982 was ready for industrial testing.

In 1983 the State approved the Program for the Renewal of the Printing Industry, with funding of RMB40 million per year for 3 years to upgrade the publishing and printing industries. Project 748 was incorporated into the new program, while Xinhua News Agency was designated as the industrial testing site at a newly constructed pilot print shop. In May 1985 a panel of 17 experts from 16 state units organized by the State Economic Commission approved the quality of the system's technology. At about the same time, the State Economic Commission made a new proposal to add RMB10 million per year for 5 years to renovate the equipment of major newspaper publishing houses, all of which were state run. The Project 748 development team installed its latest system at the state-owned newspaper, *Economic Daily*, for testing the publication of a daily newspaper. Testing went on for another 2 years before the reliability of the EPS was finally approved.

The question was then which company would control the commercialization of the technology. At the very beginning of Project 748, MEI had designated the state-owned Weifang Computer Co. as the systems integrator. Weifang had prototyped as well as made all the previous versions of the system, and had started to produce the latest version of the product. At Beijing University, however, ICST controlled the design and manufacture of the RIP chip that was the heart of the system. Moreover, Beida New Tech, a venture set up by Beijing University in 1985 to commercialize technologies developed in the University, had by 1987 decided to commercialize a high-resolution Chinese EPS. Under a technology transfer arrangement with Beijing University (on behalf of ICST), Weifang agreed to pay royalties to Beijing University of RMB10,000 for each high-end system and RMB5,000 for each low-end system sold, in addition to paying for the RIP chip from ICST.

From mid-1988, the two companies, Weifang and Beida New Tech, manufactured and marketed the same brand-name product—the HGIV Electronic Publishing System—with different physical designs. When Beida New Tech got into the EPS business in 1988, Weifang was already a well-established, state-owned computer electronics enterprise. It had been producing general-purpose minicomputers for years. To prepare for industrial production of the EPS, Weifang had been investing heavily in upgrading its R&D and manufacturing facilities. In contrast, Beida New Tech was a start-up company with very little initial capital and only several dozen employees. It did not have its own production facility. It outsourced the production of the system to a state-owned electronics enterprise in Beijing, which had one of the most up-to-date imported wave-soldering production lines. The handful of personnel in Beida New Tech's production department mainly focused on quality control.

By the end of 1990, however, with a better product design and high quality production, plus systematic marketing efforts, Beida New Tech had surpassed Weifang to become the leader in the Chinese electronics publishing market. In 1991 Beida New Tech registered its own trademark "Founder" to signify a new-generation system. The company was reorganized and, in February 1993, renamed Founder Group Co. By 1995, Founder Group Co. had a 75 per cent share of the Chinese domestic EPS market, while Weifang Computer Co. had only 25 per cent.

By late 1991 Founder also had developed an integrated desktop color publishing system for newspapers, but it was too low quality for color images in book publishing. By 1995, however, Founder completed a chip that placed it on the frontier of the new generation of color publishing technology. As had happened when the development of the HGIV system had displaced international producers from the Chinese electronic publishing market, the emergence of the Founder professional desktop color system ended the dominance of the Chinese market by the world's largest professional color systems equipment manufacturers, Hell, Dainippon Screen, Scitex, and Crossfield.

One of the most important organizational characteristics of the development of the Founder systems was the integration of postgraduate education into the technology development process; graduate students of ICST developed the majority of the dozen or so key technological breakthroughs underpinning the Founder systems. The integration of postgraduate education into research and development (R&D) was possible because of the close organizational tie between ICST and Founder. Founder's commercial activities provided financial support and product–market feedback for ICST's R&D activities, while ICST attracted and developed talented young graduate students who provided Founder with the critical resource for continuous technological innovation. What is more, as a public institution, ICST's position in China's S&T infrastructure gave Founder access to resources developed through the organizational reform of the S&T system, and specifically through the creation of National Key Laboratories and National Engineering Centers.

In the late 1980s the technocrats in the State Planning Commission, the State Science and Technology Commission, the State Educational Commission, and the Chinese Academy of Science had proposed that, by year 2000, China would build some 100 national key laboratories in selected fields where China was close to the frontier of basic scientific research. The World Bank agreed to provide a 30-year interest-free loan of US$130 million. In 1989 ICST was designated as a site for establishing a National Key Laboratory in the field of computer information processing technology.

The purpose of National Engineering Centers was to accelerate the process of translating lab results into commercial products. In April 1994 the State Planning Commission and the State Educational Commission jointly provided a RMB12 million preferential loan to ICST to establish the National Engineering Research Center for Electronic Publishing Systems. The mission of the center was the development of high-end professional color publishing systems, as well as integrated news report, transmission, editing and publishing systems.

In addition to these two organizational devices, in an effort to move industrial

R&D from state research institutions to enterprises, the State Economy and Trade Commission (formerly the State Economy Commission), the State Tax Bureau, and the State Bureau of Customs jointly initiated a plan for sponsoring 100 enterprise R&D centers in 1994. The sponsored enterprise R&D centers would get tax breaks with regards to R&D expenditures and exemption from import duties for R&D-related materials and equipment. ICST, as Founder's R&D center, was chosen as one of them.

This new organizational structure implied a fundamental change in the role of the government in organizing scientific research, particularly industrial R&D—a change from direct involvement in decision making and the financing and coordinating of scientific research to building institutional infrastructures to facilitate scientific research. One of the notable changes in this regard was a shift from grants to loans as the government's planning mechanism for allocating financial resources to industrial R&D. In the eighth 5-year plan period (1991–95), all government funding would be loans, albeit low interest preferential loans. The use of loans assumed that the borrower would have a revenue stream from the sale of its products with which, among other things, to service the debt. Summarizing the changing funding mechanisms of ICST, Wang wrote:

> In more than a decade from the mid-1970s to the late 1980s, ICST got a total of RMB10 million in government grants for research and development of the electronic publishing system. Today, we spend more than RMB15 million per year on R&D (not including industrial testing), all derived from the sales of our products in the market. (Quoted in Lu and Lazonick 2001: 70)

As for Beida New Tech/Founder, its growing revenues and profits enabled it to increase its R&D fees to ICST and its remittances to Beijing University while still retaining earnings to help fund its own growth. Its fees to ICST increased steadily from RMB0.7 million in 1988 to RMB11.0 million in 1994, or from 2.5 per cent to 10.9 per cent of profits, while over the same period its remittances to Beijing University increased steadily from RMB0.6 to RMB16.0, or from 2.1 per cent to 15.8 per cent of profits. But Beida New Tech retained the residual earnings, which amounted to RMB74 million in 1994, down from RMB181 million the previous year. In 1992 EPS represented almost 85 per cent of Founder's total business, but in 1995 only 40 per cent, as the company increased its revenues from RMB420 million to RMB2,500 million by diversifying into distribution of computer products (43 per cent of revenues in 1995) and systems integration for banks and retailers (14 per cent). By 1996 Founder had become China's fourth largest indigenous PC producer, after Legend, Great Wall, and Tongru.

To help fund its further growth, in December 1995 Founder went public on the Hong Kong Stock Exchange. In 1992, in collaboration with the owners of a small computer company in Hong Kong, Founder had established a private limited company in Hong Kong to serve as the company's overseas operations center. When Founder (Hong Kong) Ltd went public in 1995, it issued 27.5 per cent of its shares to the public to raise HK$277.3 million, of which HK$149 million was used to expand its existing businesses and the remainder for working capital. Founder Group Co. retained a 55.6 per cent share of Founder (Hong Kong) Ltd, as well as control over the management of the Hong Kong company.

LESSONS FROM *CHINA'S LEAP INTO THE INFORMATION AGE*

As already noted, in doing his case study research on innovative enterprise in the Chinese computer industry, Lu (drawing on O'Sullivan 1996) asked "who makes investment decisions, what types of investments they make, and how investment returns are distributed". His four case studies give fairly unambiguous answers to these questions of who, what, and how. In terms of "who makes investment decisions" that result in innovative outcomes, Lu's case studies tell us that it was scientists and engineers who had a deep understanding of the key technological disciplines involved and who were willing to take leadership positions to transform that knowledge into revenue-generating products. While they invariably started their careers as salaried (or "iron rice bowl") employees within the state S&T infrastructure, they were willing to play entrepreneurial roles when given a chance. China's economic reform process gave them that chance by making it possible for them to use the S&T infrastructure as a foundation for their entrepreneurial endeavors. As individuals, they did not have to be at odds with the system in order to succeed, although they often (but not always) had to give up the security of state employment to play the entrepreneurial role.

When they assumed this role, entrepreneur-managers of new ventures could exercise strategic control; while they were able to draw upon the state's S&T knowledge base, they had the autonomy to allocate enterprise resources as they saw fit. They did not have to wrest strategic control away from the S&T bureaucracy who ostensibly controlled the accumulation of knowledge on which these new enterprises, at least initially, relied. Rather it was a characteristic of the reform process that the institutions of collective ownership protected managerial autonomy in strategic decision-making. The most obvious manifestation of institutional support for managerial autonomy was the willingness of the S&T bodies to forego the extraction of significant "ownership" rents from the enterprises to which they had given birth. These governance institutions protected managerial autonomy in the early stages of innovative ventures, when ownership was entirely collective, as well as in the later stages when, in need of finance, these companies listed on the stock exchanges and private interests as minority shareholders entered the governance scene.

What investments did these autonomous managers make? Lu's case studies show that the critical investments that they made included R&D, manufacturing, and marketing, including before- and after-sales service. At critical junctures in the evolution of these investment strategies, their success demanded that the indigenous firms partner with Chinese state agencies and foreign companies, much more established and powerful than themselves, to gain access to technology. In doing so, however, the managers of these indigenous enterprises maintained control over strategic decisions that concerned the future of their companies, including the allocation of most of the revenues that they generated from these transferred technologies. In none of the cases was it a condition of these partnerships that the indigenous companies relinquish significant strategic control.

Lu shows in all of the cases that, on the basis of these investments, the development of innovative capabilities depended on the organizational integration of R&D, manufacturing, and marketing. Experienced engineers and scientists were sent into the field to find out what potential customers wanted. Distribution networks were not merely facilities for the sale of products but also for training customers to use the products and securing the feedback of information that affected the work done in manufacturing and R&D. The investments that resulted in innovative outcomes were not just the *combination* of R&D, manufacturing, and marketing resources under the control of one firm, but, more profoundly, an *integration* of capabilities so that people in different functional specialities engaged in the interactive learning that could generate higher quality, lower cost goods and services. In some cases, such learning was also inter-organizational, but, again, with the indigenous firms' investment strategies driving the development and utilization of this learning.

Investments in marketing were key to managerial autonomy because they enabled the companies to transform their technological capabilities into the stream of revenues that gave managers financial independence. Beyond relatively small initial financial grants (most of which were quickly repaid) from government bodies, strategic managers at Stone, Legend, Great Wall, and Founder did not have to go back to the state for more "equity" investments. Rather these companies quickly secured markets for their products, in large part because in the early stages of their development they found some easily producible goods and services that they could market quickly. The combination of managerial autonomy and financial independence—or what I have called strategic control and financial commitment—gave these enterprises the autonomy and the time to develop *innovative* capabilities that could give them a sustainable competitive advantage.

How then were the returns from investments distributed? One way was by sharing gains with employees who found themselves better remunerated (if less secure) when employed by these enterprises. The role of this enhanced remuneration can be considered in two ways, depending upon whether one views it *ex post* or *ex ante* to the innovation process. If one views it *ex post*, higher remuneration can be considered as a return to these employees on the investments that the individuals, the companies, and, even more so, the government had made in their capabilities in the past, now that the innovative potential of these capabilities had been unleashed. If one views it *ex ante*, the prospects of higher remuneration with an innovative enterprise can be considered as an incentive for these employees to contribute to the innovation process. It was not, however, just employees who gained from the success of the innovative enterprise. Customers, in this case government agencies, other business enterprises, as well as households who bought computers, got higher quality products at lower prices than previously.

Successful enterprises, moreover, still had financial resources to fund further investments that might possibly regenerate the innovation process. In each case, to help fund their further expansion, the companies went public, in three cases listing on the Hong Kong Stock Exchange and in one case (Great Wall) on the Shenzhen Stock Exchange. In every case, the companies raised substantial amounts of money without giving up majority ownership positions and while maintaining managerial control.

Lu did not investigate strategy, organization, and finance at unsuccessful enterprises, although at various points in his cases he mentioned that there were many firms that emerged from the S&T infrastructure that did not succeed. It would, of course, be interesting to have some accounts of the failures. Perhaps they were enterprises in which managerial autonomy led to agency problems, with managers using state resources opportunistically rather than for the sake of innovative investments. Or alternatively, perhaps the problem was a lack of managerial autonomy that undermined the allocation of resources to innovative investment strategies. Perhaps the failures were ones in which organizational integration did not occur, either because the necessary investments in complementary capabilities were not made or because, even if they were made, incentives were not created for participants in the enterprise to engage in interactive learning. Perhaps they were ones in which a failure to find markets in a timely manner led to a continued reliance on the state for finance and loss of financial independence and, ultimately, strategic control.

From this perspective, given the prevailing ideology that pervades academic thinking on corporate governance (see Lazonick and O'Sullivan 2000a), what is important about Lu's work is that he showed that not all enterprises that drew resources from the S&T infrastructure were beset by agency problems. Far from it, the four companies that he investigated were central to the creation in China of a successful indigenous computer industry. I would argue that one needs innovation theory, not agency theory, to explain such an outcome (see Lazonick 2002).

Lu shows, moreover, that it is an outcome that must be understood as *indigenous* innovation. In each of the four cases, China could have imported the products that Stone, Legend, Great Wall, and Founder created, and indeed to some extent did. True, in the mid-1980s, when these companies were founded, foreign computer companies had not yet mastered the problem of Chinese-language word processing. This particular problem provided all four firms with a dimension of computing in which they could become world leaders. To innovate on this basis, however, they also had to acquire capabilities from abroad. It is also highly likely that if these Chinese enterprises had not jumped into the fray when they did, in a few years Japanese companies would have mastered the Chinese-language problem for them. And if that had been the case, the Chinese might have lost a golden opportunity to master information technology more generally, and the nation would be that much further behind in the catch-up process.

The process of indigenous innovation is not unique to "late developing" economies. In comparative-historical perspective, indigenous innovation has been important in creating the wealth of the wealthiest nations. When in the USA from the 1820s the Boston Associates decided that they would not simply use existing British textile technology in their mills, but would invest in more high-throughput, less skill dependent machinery, they were engaging in indigenous innovation (see Jeremy 1981). Indeed, in their development of the Lowell mills, the most capital-intensive investment of their innovative strategy was the locks and canal system that was put in place to harness natural but unsteady water power and turn it into a steady flow of energy to an expanding number of mills. The engineer who was in charge of this project was James B. Francis, after whom the UMass Lowell College of Engineering is named. Francis's lasting claim to fame was the development of the water turbine, the key innovation in the Lowell water-power system and one that is mentioned in most histories of aircraft engine technology as an early invention that would become critical in the development of the modern turbojet (see, for example, Constant 1980).

Indigenous innovation in one time and place can have long-run implications for the development of a nation's innovative capability.

Closer to China in time and place is the case of indigenous innovation in the development of Japan. When the modern Japanese cotton textile industry emerged in the last decades of the 19th century, all of the "spinning" firms (which by the 1890s were integrating forward into weaving) bought all of their machinery from one British company, Platt Brothers. The spinning firms that became strongest employed university-educated engineers to determine a blend of cheaper Indian cotton and more expensive American cotton that could permit high productivity from the British machines while saving on cotton costs. Meanwhile, around the turn of the century, some Japanese machinery makers were producing power looms for use in the spinning mills.

Foremost among them was a company founded by Sakichi Toyoda, who in the 1890s had developed an all-wooden power loom for weavers who worked in their homes or small workshops. Toyoda then turned to the production of power looms for the spinning firms that could substitute for the Platt imports. Building on these successes, in 1903 Toyoda started experiments in producing an automatic loom that would be suitable for Japanese conditions. The loom had to be able to get high productivity with blended (and hence more break-prone) yarn and, for lack of precision machine tools, it could not replicate the bobbin-changing mechanism that characterized the Draper (or Northrop) automatic loom, which was the dominant design. Instead, after two decades of experimentation, Toyoda Automatic Loom Company created a shuttle-changing automatic loom that, when it became available in 1924, was an immediate success in Japan. In 1929 Toyoda licensed the technology to Platt Brothers, which, however, was never able to develop a successful automatic loom. The Toyoda Automatic Loom Company meanwhile built on its success at home to export machinery abroad, and used the profits from these sales, combined with capital infusions from other companies in the Toyoda group, to enter the auto industry as the Toyota Motor Company (Wada 2003). In launching itself on a long-run path to become one of the world's leading automobile companies, Toyota was able to draw directly on the organizational and technological capabilities that the Toyoda Automatic Loom Company had developed in the textile machinery industry (Mass and Robertson 1996; Wada and Yui 2002).

These cases of indigenous innovation in the US and Japanese textile and textile machinery industries and the transfer over time of capabilities accumulated in these industries to newer, more technologically and organizationally complex industries such as aircraft engines and automobiles raise the big question of why nations such as China and India, that had significant textile sectors in the late 19th and early 20th centuries were unable to embark on such a development path. Indeed, in earlier work that Qiwen Lu did on the Chinese textile industry as part of our indigenous innovation project, he documented the limited, yet potentially significant, extent to which China had developed an indigenous capability in textile machinery before the revolution of 1949 (see Lu and Mass 1999). This is not the place to go into this case, or its comparison with India, which coming into the post-World War II period had accumulated virtually no capabilities in textile machinery, not even spare parts (see Lazonick and Mass 1995). It is important to recognize, however, that, in addition to his need to understand China's prospects for economic development in the present and future, Lu recognized the importance of placing the current Chinese experience in comparative-historical experience.

As for the period of China's economic reform from the 1970s to the 1990s of which his story of the computer industry is an important part, Lu and I discussed at length the implications of his study for understanding the lessons to be learned from the Chinese transition process.[4] The case studies in *China's Leap* illustrate the role and operation of China's national innovation system in the nation's transition process from state resource allocation under the plan to a decentralized allocation system that is oriented toward market competition. China had developed considerable S&T capability under the central planning system that was in place at the onset of economic reforms in the late 1970s (Sigurdson 1980; Conroy 1992; Gu 1999). But, the evolution of the S&T system was driven exclusively by government demand, mostly for military purposes. A prime task of the reform process of the 1980s and 1990s was to develop national S&T resources that could enable China to innovate in production for consumer markets and in related capital-goods industries. In the economic transition process of the 1980s and 1990s, the Chinese government was highly proactive in putting in place an institutional and organizational infrastructure that could ensure that S&T activities supported the process of industrial development. The result was the emergence of a new "national innovation system" that integrated government S&T efforts with the business activities of industrial enterprises that exercised strategic control over the allocation of enterprise resources and returns.

Finally, *China's Leap into the Information Age* is a contribution to an important body of work on indigenous innovation in Asia that is changing the way in which we view the process of economic development (see in particular Hobday 1995; Kim 1997; Mathews and Cho 2000; Ernst 2002). This work focuses on the role of business organization in generating the learning that is the essence of innovation and, ultimately, economic development. It thus enables us to escape the narrow confines of the traditional "state versus market" debate that for decades has stifled an understanding of how economic development actually occurs—and not just in the "developing economies" (see Lazonick 1991). The new body of literature on indigenous innovation does not ignore the role of the state; rather it asks how government policy can support innovative enterprise. Nor does it ignore the role of the market; rather it asks how business organizations make use of, and possibly shape, factor markets and products markets in pursuit of their innovative strategies. As Mike Hobday (2000: 125) has put it in a recent summary of his own work on East Asian innovation:

> Much of the discussion of Asian-Pacific development has been conducted within what can be called the "market *vs.* state" debate.... Partly because of the dominance of this debate, there are few studies which derive "bottom-up" policy conclusions from firm-level studies. The activities and strategies of firms in engaging with international

4 Some of the results of those discussions were committed to print in the conclusion to a paper we co-authored and published in *Research Policy* (Lu and Lazonick 2001), which focused on the Founder case. In that paper, we situated the findings of Lu's research within the literatures on (a) technological learning in the process of economic development (for example, Ozawa 1974; Lall 1992; Bell and Pavitt 1993; Hobday 1995; Kim 1997; Kim and Nelson 2000 generally, and Suttmeier 1992; Ding 1997; Jiang 1997; Wall and Yin 1997; Sun 2000 on China in particular) and (b) the role of S&T in China's transition process (for example, Goldman and Simon 1989; Baark 1992; Zhou 1995; Naughton 1997).

production networks cannot be properly accounted for within theories of the developmental state, as latecomer firm behaviour tends to be treated (usually implicitly) as an automatic response to policy and economic circumstances, rather than as a shaping influence in its own right. Research on electronics confirms Nelson's (1991) view that variety and difference in corporate behaviour, strategy, capability, and performance play a key role in economic progress.

It would be rash, of course, to draw any policy conclusions from Qiwen Lu's study of the Chinese computer industry. What he showed, however, was that policy debates ignore at their peril the role of innovative enterprise in economic development. Lu also demonstrated the intelligent application of a framework for empirical research that captures the key social relations that determine whether a business enterprise is, or is not, innovative. For the sake of more relevant policy debates, one hopes that his example will inspire more empirical research that both delves inside the so-called "black box" known as the firm and situates the business enterprise in its larger social context.

REFERENCES

Baark, E. 1992: Fragmented innovation: China's science and technology policy reforms in retrospect, in Joint Economic Committee, Congress of the United States (eds) *China's Economic Dilemmas in the 1990s: The Problems of Reforms, Modernization and Interdependence*. Armonk, NY: M.E. Sharpe.

Bell, M. and Pavitt, K. 1993: Technological accumulation and industrial growth: contrasts between developed and developing countries, *Industrial and Corporate Change*, 2(2): 157–210.

Carpenter, M., Lazonick, W. and O'Sullivan, M. 2003: The stock market and innovative capability in the new economy: the optical networking industry, *Industrial and Corporate Change*, 12(5): 963–1034.

Conroy, R. 1992: *Technological Change in China*. Development Centre, OECD.

Constant, E. 1980: *The Origins of the Turbojet Revolution*. Baltimore, MD: John Hopkins University Press.

Ding, J. 1997: Using imported technology to transform existing enterprises in China, in C. Feinstein and C. Howe (eds), *Chinese Technology Transfer in the 1990s: Current Experience, Historical Problems, and International Perspectives*. Cheltenham: Edward Elgar.

Ernst, D. 2002: Global production networks and the changing geography of innovation systems: implications for developing countries, *Economics of Innovation and New Technology*, 11(6): 497–523.

Goldman, M. and Simon, D.F. (eds) 1989: *Science and Technology in Post-Mao China*. Cambridge, MA: Harvard University Press.

Gu, S. 1999: *China's Industrial Technology: Market Reform and Organizational Change*. UNU/INTECH Studies in New Technology and Development.

Hobday, M. 1995: *Innovation in East Asia: The Challenge to Japan*. Cheltenham: Edward Elgar.

Hobday, M. 2001: The electronics industries of the Asia-Pacific: exploiting international production networks for economic development, *Asian-Pacific Economic Literature*, 15(1): 13–29.

Jeremy, D. 1981: *Transatlantic Industrial Revolution: The Diffusion of Textile Technologies Between Britain and America, 1790–1830s*. Cambridge, MA: MIT Press.

Jiang, X. 1997: Chinese government policy towards science and technology and its influence on the technical development of industrial enterprises, in C. Feinstein and C. Howe (eds) *Chinese Technology Transfer in the 1990s: Current Experience, Historical Problems, and International Perspectives*. Cheltenham: Edward Elgar.

Kim, L. 1997: *Imitation to Innovation: The Dynamics of Korea's Technological Learning*. Cambridge, MA: Harvard Business School Press.

Kim, L. and Nelson, R. (eds) 2000: *Technology, Learning & Innovation: Experiences of Newly Industrializing Economies*. Cambridge: Cambridge University Press.

Lall, S. 1992: Technological capabilities and industrialization, *World Development*, 20: 165–186.

Lazonick, W. 1991: *Business Organization and the Myth of the Market Economy*. Cambridge: Cambridge University Press.

Lazonick, W. 2002: Innovative enterprise and historical transformation, *Enterprise & Society*, 3(1): 3–47.

Lazonick, W. 2004: The innovative firm, in J. Fagerberg, D. Mowery and R. Nelson (eds) *Oxford Handbook of Innovation*. Oxford: Oxford University Press.

Lazonick, W. and Mass, W. 1995: Indigenous innovation and industrialization: foundations of Japanese development and advantage, *Best Papers*. Association of Japanese Business Studies.

Lazonick, W. and O'Sullivan, M. 2000a: Maximizing shareholder value: a new ideology of corporate governance, *Economy and Society*, 29(1): 13–35.

Lazonick, W. and O'Sullivan, M. 2000b: Perspectives on corporate governance, innovation, and economic performance. Report prepared for the project on Corporate Governance, Innovation, and Economic Performance under the Targeted Socio-Economic Research Programme of the European Commission, INSEAD, June (www.insead.edu/cgep).

Lazonick, W. and Prencipe, A. 2004: The governance of innovation: the case of Rolls-Royce plc, in A. Grandori (ed.) *Corporate Governance and Firm Organization*. Oxford: Oxford University Press.

Lu, Q. 2000: *China's Leap into the Information Age: Innovation and Organization in the Computer Industry*. Oxford: Oxford University Press.

Lu, Q. and Lazonick, W. 2001: The organization of innovation in a transitional economy: business and government in Chinese electronic publishing, *Research Policy*, 30: 55–77.

Lu, Q. and Mass, W. 1999: Technology transfer and indigenous innovation in pre-revolution China: mechanical engineering capabilities and textile machinery enterprises, *Journal of Industrial History*, 1(2): 23–49.

Mass, W. and Robertson, A. 1996: From textiles to automobiles: mechanical and organizational innovation in the Toyoda enterprises, 1895–1933, *Business and Economic History*, 25(2): 1–37.

Mathews, J. and Cho, D.-S. 2000: *Tiger Technology: The Creation of a Semiconductor Industry in East Asia*. Cambridge: Cambridge University Press.

Naughton, B. (ed.) 1997: *The China Circle: Economics and Electronics in the PRC, Taiwan, and Hong Kong*. Washington, DC: Brookings Institution Press.

Nelson, R. 1991: Why do firms differ, and how does it matter?, *Strategic Management Journal*, 12(1): 61–74.

O'Sullivan, M. 1996: Innovation, industrial development, and corporate governance. PhD dissertation, Department of Economics, Harvard University.

O'Sullivan, M. 2000: The innovative enterprise and corporate governance, *Cambridge Journal of Economics*, 24(4): 393–416.

O'Sullivan, M. 2004: Finance and innovation, in J. Fagerberg, D. Mowery and R. Nelson (eds) *Oxford Handbook of Innovation*. Oxford: Oxford University Press.

Ozawa, T. 1974: *Japan's Technological Challenge to the West, 1950–1974*. Cambridge, MA: MIT Press.

Sigurdson, J. 1980: *Technology and Science in the People's Republic of China*. Oxford: Pergamon Press.

Sun, Y. 2000: Sources of innovation in China's manufacturing sector: imported or developed in-house?, *Environment and Planning*, 34(6): 1059-1072.

Suttmeier, R. 1992: China's high-technology programs: problems and prospects, in Joint Economic Committee, Congress of the United States (eds) *China's Economic Dilemmas in the 1990s: The Problems of Reforms, Modernization and Interdependence*. Armonk, NY: M.E. Sharpe.

Vogel, E. 1989: *One Step Ahead in China: Guangdong Under Economic Reform*. Cambridge, MA: Harvard University Press.

Wada, K. 2003: Kiichiro Toyoda and the birth of the Japanese automobile industry: reconsideration of Toyoda–Platt agreement. Paper presented at the Annual Meeting of the Business History Conference, Lowell, MA, 28 June.

Wada, K. and Yui, T. 2002: *Courage and Creativity: The Life of Kiichiro Toyoda*. Toyota Motor Company.

Wall, D. and Yin, X. 1997: Technology development and export performance: is China a frog of a goose?, in C. Feinstein and C. Howe (eds) *Chinese Technology Transfer in the 1990s: Current Experience, Historical Problems, and International Perspectives*. Cheltenham: Edward Elgar.

Zhou, Y. 1995: Reform and restructuring of China's science and technology system, in D.F. Simon (ed.) *The Emerging Technological Trajectory of the Pacific Rim*. Armonk, NY: M.E. Sharpe.