A Model For Technology Adoption In China: Extending Caselli And Coleman

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ABSTRACT

Focusing on China, a country pushing toward a more market-oriented system at warped speed, we suggest that previous models of technology adoption and/or diffusion may not be suitable for countries migrating from centralized control. We support the work of Au and Yeung (2007), who suggest that China may suffer from a risk avoidance attitude at the firm level based on previous attitudes of "control." Relying on the literature and supported by an in-depth analysis of the Chinese machine tool industry we extend the work of Caselli and Coleman (2001, 2002) and advance an expanded model of technology adoption specific to emerging markets, such as China, experiencing a transformation from centrally controlled economy toward a market one.

Keywords: technology adoption; international strategy; empirical studies; decision making; Chinese economy

INTRODUCTION

The technical efficiency of a nation has long been associated with a growing sustainable economy. Most strong economies (high income) focus attention on research and development while weaker (low income) countries find efficiency gains by adopting technologies developed by stronger, technologically savvy countries (Caselli and Coleman, 2001). Yet, little is known about the determinants of technology adoption, nor is it clear if those determinants are common to all countries, and, specifically countries transitioning from a centrally planned economy, with strong central or segmented control, to a market-oriented system. One stream of research on technology diffusion points to the proliferation of information sharing at the firm level for successful adoption (Stoneman and Toivanen, 1997; Stoneman, 2002), , while others argue government level influences and incentives are necessary determinants of adoption (Cusumano and Elenkov,1994; Chen, 1995). Based on these bodies of work and their own in-depth field research Caselli and Coleman (2001) advanced a model of technology adoption typical of market oriented economies.

In this research we focus on China, a country pushing toward a more market-oriented system at a rapid pace, and suggest that previous models of technology adoption and/or diffusion may not be suitable for countries migrating from centralized control. We support the work of Au and Yeung (2007), who suggest that countries, and in particular China, may suffer from a risk avoidance attitude at the firm level based on previously encouraged attitudes of "control." Based on the literature and supported by an in-depth analysis of the Chinese machine tool industry, a dominant industry in China, we extend the work of Caselli and Coleman (2001, 2002) and advance an expanded model of technology adoption specific to markets, such as China, experiencing a transformation toward a market economy.

THEORETICAL FOUNDATION: THEORIES OF TECHNOLOGY ADOPTION

Theories of technology adoption have been characterized by how potential adopters process or gain access to information (Sarkar, 1998). Specifically, previous work suggests that it is the ability to gain this access that motivates the advancement of technology within a county. Using the early work of Shumpeter (1942) as a foundation, later empirical studies of technology diffusion patterns focused on information asymmetries and

resource requirements (Griliches,1957; Mansfield,1975), examples of which included studies of mobile telephony (Massini, 2004), of process innovations (Baptista, 1999), and of multiple design and manufacturing technologies (Stoneman and Toivanen, 1997; Stoneman, 2002). Each study hinged on the notion that information sharing makes technology adoption "contagious" thus explaining its proliferation. Cusumano and Elenkov (1994), and later Chen (1995) argued that governmental influences were often pivotal determinants of technology adoption patterns, suggesting that firm level technology adoption would increase with greater government incentives.

Caselli and Coleman (2001) conducted a muli-year empirical study of computer adoption in search of specific determinants of technology adoption. Equipped with the knowledge gained through their field research they advanced a general model of technology adoption. To accomplish this, they were required to make initial assumptions. Specifically, they assumed a roughly symmetric macro-environmental context and perfect competition. They suggested that technology adoption decisions would be a function of the abundance of either skilled or less-skilled labor within the subject economy. This assumption was confirmed by their adoption of the constant-elasticity-of-substitution production function advanced by Krusell et al (2000). Using extensive data gleaned from the computer industry, they identified determinants of technology adoption using the following model specification:

$$\log(I_c^{it}) = \alpha + \delta^t \beta + \mathrm{X}^{it}\gamma + \eta^i + u^{it}$$

where I_c^{it} is computer imports worker (in current U.S. dollars) in country *i* and year *t* . X^{it} is the set of explanatory variables, δ^t is a set of year dummies, η^i is a country effect and u^{it} is independently and identically distributed among countries and years. Each of the variables included in the vector X^{it} were measured by Caselli and Coleman annually. The vector X^{it} was expected to be orthogonal to η^i to clearly distinguish random from fixed effects. The vector was treated as exogenous for *I.*

Caselli and Coleman's results suggested a negative role for the size of government, indicating government control impeded adoption, a finding contrary to Cusumano and Elenkov (1994). On the other hand, they found that the government's openness to imports was a positive determinant. At the firm level, both human capital (skilled or non-skill labor), and educational attainment were found to be significant determinants of technology adoption. In addition, they found evidence that computer adoption was enhanced by good property-rights protection and high rates of investment per worker.

Looking specifically at Chinese manufacturers, Au and Yeung (2007) took a behavioral perspective in their model of technology adoption by combining the approaches of two well know antecedents. Their International Model for Technology Adoption (IMTA) is built upon Ajzen (1985; 1991)'s Theory of Planned Behavior (TPB) and Davis et al. (1989)'s Technology Acceptance Model (TAM). TPB suggests that any given action is determined by an attitude which is, in turn, a function of perceived behavioral control**,** attitude toward behavior and subjective norms. Specifically, Ajzen (1985;1991) contends any given action is a contingent on an individual's belief regarding the difficulty of adopting a given behavior (perceived behavioral control), an individual's general feeling, toward the acceptability or unacceptability of a given behavior (attitude), an individual's perceptions of how referent others (e.g., society, co-workers, family, friends) will respond to a given behavior (subjective norms) .

TAM, an adaptation of Fishbein and Ajzen's (1975) theory of reasoned action (TRA) to the information technology field identifies perceived usefulness and perceived ease of use as key determinants of attitude towards use of technology (Davis et al., 1989). Specifically, TAM suggests that an individual's intention to use a system is directly correlated with the perceived ease of use. Consequently IMTA suggests that controlled attitudes (such as centralized decision-making) would generally inhibit the adoption of new technologies. Au and Yeung (2007) further suggest that Chinese manufacturers may be particularly susceptible to risk avoiding behavior. This same argument can be applied to any formerly planned economy such as the former Soviet Union (Douglas and Wildavsky, 1982).

Au and Yeung's (2007) conclusion that formerly planned economies, and particularly China, may have other impediments to technology adoption at the firm level raises questions as to the generalizability of Caselli and Coleman's (2001) model of technology adoption and to its specific application to the Chinese context. Thus, we looked for further evidence. Taking the lead from Caselli and Coleman (2001) .we conducted a thorough field study of the Chinese machine tool industry in an attempt to confirm or deny Au and Yeung's (2007) belief that additional determinants of technology diffusion and adoption existed at the firm level in China. (A full account of the field research can be found in Appendix A.).

CONTEXTUAL BACKGROUND

Our research involved extensive field studies of a very large machine tool firm located in the heart of Beijing. Beijing No.1 Machine Tool Plant (BYJC) is a large computer numerical control (CNC) machine tool manufacturing firm in China. Since the firm was founded in June, 1949, it has provided its customers with over 100,000 milling machines in over 450 varieties, including small and medium-sized, heavy-duty and super-heavy-duty milling machines. The firm is ISO 9001 certified, employs engineers and technicians and occupies an area of 710,000 square meters that includes a building area of 430,000 square meters in the capital of China. Its production facility includes a modern 4000-square-meter air-conditioned assembly workshop, a 2000-square-meter Flexible Manufacturing System (FMS) workshop, advanced machining equipment along with precision measuring instrumentation, and a high-rack storehouse with 4896 storage positions.

Products

The main products produced by BYJC are CNC milling machines, CNC lathes, vertical machining centers, horizontal machining centers and CNC plano-type milling & boring machines. In addition, 20,000 geological rigs in more than 20 varieties have been manufactured and sold over the past ten years. Products bearing the "Beiyi" brand enjoy a good reputation and are in use in over 50 countries. The recent establishment of an advanced information system on their computer network has contributed to optimization of the enterprise's resources. BYJC designs and manufactures small and medium-sized, heavy-duty and super-heavy-duty numerical control (NC) and computer numerical control (CNC) plano-type milling and machines, machining center, bed-type milling machines, knee-type milling machines, CNC lathes, special purpose milling machines etc. The products are used in metallurgy, mining, railway, power generation, aerospace and aircraft and mold manufacturing. The plant also produces geological rigs that are widely used in mine prospecting and development of water resources.

Services

Founded in 1988, a subsidiary of BYJC, The Import & Export Corporation (IEC) conducts business to import and export on behalf of BYJC. It seeks out trades on the principle of mutual benefits and seeks co-developments worldwide. This Corporation was awarded "Customs Worthy Enterprise" by customs. The main business activities of IEC are:

- Import and export business of machine tools, such as machining centers, plano milling machines, CNC milling machines, conventional milling machines, and other electric and machinery products; Indirect export business through professional import and export corporations
- Cooperative production projects
- Machining according to drawings, samples, materials, Castings projects
- Technical maintenance and services
- Labor export and engineering contracting

Since the beginning, the products have been sold by direct export or indirect export through professional import and export corporations and now reach more than 50 countries and regions, including the US, Germany, Japan, Iran, and Russia, and the products are widely acclaimed by users and traders worldwide. In recent years, Beijing No. 1 Machine Tool Plant imported and adopted advanced technologies from developed countries through the IEC with the manufacturers and traders of Japan, the U.S.A., and Germany to co-produce CNC Lathe and CNC

milling machine (including CNC super heavy-duty plano-type milling & boring machines) to meet needs of overseas customers. And at the same time, BYJC undertook projects for machining to drawings, samples, and materials, and to provide castings and machined parts for domestic and international customers.

FIELD RESEARCH RESULTS AND MODEL JUSTIFICATION

The first moderating variable (γ) in the Caselli and Coleman (2001) model is the availability of expansion capital to the rate of new technology adoption. Understanding this variable and its behavior is crucial since it is a cornerstone of technology adoption. Our field research found this to be a major issue in China where the struggle between competing demands for expansion capital is acute. The availability of capital is asymmetric (the diametric opposite of the assumptions of Caselli and Coleman) because the national government gives state-owned enterprises (SOEs) preferential access to capital irrespective of industry. Such preferential treatment was not uncommon during the transformation of other formerly planned economies (see, for example: Russia, See Brandt and Zhu, 1997 for a description of alternative approaches to SOE funding and the approach of the former Soviet Union). Constraints of this nature keep the inefficient firms in business and prevent efficient firms from entering the market and/or competing successfully (Parente, 2008). In China, for example, private firms encounter limited access to investment capital, and where such funds have been made available, were subject to significantly above-market interest rates (Linton, 2006). The work of Overholt (2005) suggests that a politically motivated banking system can be seen as at least partially at fault. Linton (2006) added credence to Overholt's assertions noting that although small and medium size enterprises (SMEs) produce more value to the economy in general, more funding is provided to SOEs by lenders and government appointees based on national development plans rather than on risk assessments or expected return on investments. Similar asymmetries were observed by Oswald (2000) in the Czech Republic during the early days of its transitional economy.

Today, debt capital in China is further restricted at the national level by an increase in banking reserve requirements and interest rate hikes (Forbes, 2007). As summarized by Perkins (2006), in order to sustain the pattern of expansion in China, it will be necessary for the government to make the appropriate capital allocation decisions and assure that investments meet the collective interest.

Another pressing government concern in China is employment levels. Labor remains abundant and our research supports the belief that overexpansion of unproductive SOEs has helped to keep the lower skilled workforce employed. Thus, there is political pressure to allocate resources based on employment needs rather than on productivity as would be the case in a truly competitive market. On the other hand, a change in capital allocation to SMEs in search of new technologies would likely lead to efficiencies but lower levels of employment in the short run. Such was experienced in China's machine tool industry during earlier periods. Today China is the world's largest consumer of machine tools, buying at more than twice the rate of the U.S. Foreign manufactured machines have traditionally captured a large portion of the Chinese market. After experiencing a surge in the demand for imported machine tools from 1990-1996, the following year saw a deep decline because the Chinese Government cancelled tariff exemptions on imported capital equipment. Predictably, demand for foreign-produced machine tools slowed drastically. Then, at the start of 1998, the Chinese Government resumed tariff incentives and preferential treatment of imports of high technology and machine tools for foreign-funded projects. China imported $688 M USD worth of machine tools in the first six months of 1998, up 9.77 percent from the previous year. Today, China's consumption is nearly $13 billion US dollars.

Proposition 1: The likelihood of the technology adoption increases with the availability of expansion capital.

Thus, unlike the assumptions advanced by Caselli and Coleman, in the Chinese marketplace, we can assume neither symmetric macro-environmental contexts nor perfect competition, but suspect that technology adoption decisions would generally follow the abundance of either skilled or less-skilled labor within the industry., As investment in human capital continues to increase at a rapid rate in China, the addition of skilled labor will likely bring with it an expansion of technology adoption. As Perkins (op cit) observes: "the significance of this rapid expansion in education depends in part on what model of the relationship between education and economic growth

that you choose". Conventional growth accounting[1] assumes that the contribution of an educated person can be measured by the difference between the wage of the educated person and the wage of an uneducated person. The assumption is that wage equals the marginal product of that laborer and, hence, the contribution of that laborer to GDP. If one accepts these assumptions, then the contribution of China's massive increase in the educational levels of its population likely contributed 1% or less to the growth rate of GDP in the past and will make a comparable or lesser contribution in the future as the rate of increase diminishes.

An alternative model of the contribution of education to economic growth assumes that agglomeration effects result from the expansion of education (Dalmazzo & De Blasio, 2007). Specifically, the assumption is that people learn from each other. An educated population provides for increased learning both inside and outside the formal education system. This relationship has long been recognized in the connection between the education of children and the educational level of their parents. It also is present in the schools because a population with a large number of educated people is more likely to have qualified teachers than a population where most adults have had little more than a primary school education if that. Agglomeration effects are likewise present in everyday life. For example, an engineer working in isolation in a factory is likely to be much less effective than if that engineer was interacting with other engineers with similar or different experiences. Clearly stated, it is the "knowledge spillover" that is created by the clustering of educated individuals. Consequently, there appears to be good reason to think that the standard method used to account for education's contribution to economic growth seriously understates that contribution particularly in developing countries such as China. The previous argument suggests that China's vast investment in human capital would correlated with increased technology adoption, thus, we posit the following:

Proposition 2: The technology adoption increases with the availability of skilled workers in the manufacturing industry.

Another influence important to the technological expansion in the Chinese market (ε) is the alignment of regional/local investment decisions with the national priorities. Specifically, Chinese municipalities and regions have significant influence over factory managers with regard to staffing adjustments and can likewise impose constraints that may not be in the best interest of the national priorities. For example, even is situations were the demand for goods is high and national government policy supports expansion, the priorities of municipal decision makers may impede the adoption decision making process. As pointed out above, the pressure to retain or absorb a constant or growing workforce may work at odds with the pressure to improve methods and productivity through the acquisition of new capital assets. Further, significant obstacles can emerge with respect to the access to capital since firms under the direct influence of local governments typically receive preferential access to equity markets to the detriment of those without powerful, local, connections (Green 2003). At the national level, counter-market impacts have resulted in asymmetric availability of capital, concomitant with and deteriorating confidence in the capital markets. Consequently, capital alternatives are impacted (and often limited) at the firm level. Finally, as seen in other transitional economies (Oswald, 2000), municipalities or districts may control not only firm assets, and authority for new acquisitions, but may , hand out management responsibilities to "cronies" in return for political favors. Given this, we posit:

Proposition 3: The likelihood of the technology adoption increases with the alignment of local/regional priorities to those of the central government.

Our final moderating variable (Ψ) captures the notion of the extent of management autonomy within firms. Autonomy here is defined as the right to prepare and execute capital and operating budgets, to employ and terminate staff, to adjust compensation, and to change working conditions consistent with market forces. Such autonomy is generally representative of free markets, and, based on a cursory view of the technology adoption process in China tends to be the same. However, particular to China is the concept of guanxi, the network of relationships between various parties that cooperate and support one another (exchange of favors), that flows through Chinese culture and influences decisions (Park and Luo, 2001). In China business success is a function of aligning with the right guanxi.

[1] Growth accounting is a procedure used in economics to measure the contribution of various factors to the economic growth . It is indirectly used to compute the rate of technological progress. For more information, see Robert Solow 1957 Technical change and the aggregate production function Review of Economics and Statistics, Vol. 39, No. 3 (Aug., 1957), pp. 312-320

The correct guanxi can minimize risks, barriers, and start-up problems, and, if the guanxi has relevant authorities, can determine the long term competitive standing of an organization. Consequently, the guanxi is essential to successful business practices. As Alston (1989, pg 26) notes: "Guanxi is one of the major dynamics in Chinese society." The term refers to special relationships two persons have with each other. It can be best translated as friendship with overtones of unlimited exchange of favors and commitment to one another (Pye 1982), Whenever scarce resources exist in China, they are allocated by Guanxi rather than official or bureaucratic dictates. Within this context, Guanxi bonds two persons through the exchange of favors rather than through sentiment. Instead, the relationship is basically utilitarian rather than emotional. The moral dimension operating here is that a person who does not follow a rule of equity and refuses to return favor for favor loses face and becomes defined as untrustworthy." Therefore, moderated by guanxi, managerial autonomy is assumed to be the variable most closely linking technology decisions to market forces. Since the shift to uniform managerial autonomy has not occurred in China, we propose its inclusion in the model and posit:

Proposition 4: The likelihood of the technology adoption increases with the level of autonomy wielded by the firm's management.

Given the previous rationale we advance the following model for technology adoption (adapted from Caselli and Coleman (2001)), for the Chinese market,

$$\log(I_m^{it}) = \alpha + \delta^t \beta + \mathrm{X}^{\mathrm{it}} + u^{it}$$

where I_m^{it} is machine tool imports per worker (in current U.S. dollars) in region i and year t . X^{it} is the set of explanatory variables, δ^t is a set of year dummies, and u^{it} is independently and identically distributed among regions and years. All the variables included in the vector X^{it} are measured annually. The vector X^{it} is expected to conform to

$$X^{it} = \alpha + \gamma + \acute{\varepsilon} + \Psi$$

where γ is the availability of expansion capital in light of the competitive demand from other industries deemed strategic for the region.

So, $\acute{\varepsilon}$ is the alignment.

Solutions to expand the manufacturing base are short term in nature and not sustainable, consequently employment is a pressing concern yet labor is abundant. As a quick fix, there has occurred a rapid overexpansion of local/regional versus national priorities on investment decisions. And, Ψ is the extent of management autonomy in directing the produce and investment decisions of the firm.

SUMMARY AND CONCLUSIONS

While SOEs still dominate the business landscape in China, many have changed their ownership structure through joint ventures or privatization. This phenomenon, coupled with the rapid growth in FDI, has profoundly changed the face of the Chinese economy. Beginning in1978, the Chinese central leadership began to carve a path toward a more market-oriented system, and by 2003,China stood (on a PPP basis) as the second-largest economy in the world behind the US (Congressional Research Service, 2008). The observed process of an industrial giant migrating from a centrally planned economy with its inherent inefficiencies vis-à-vis a market economy is a dynamic one that has not yet been sufficiently described or evaluated by the existing literature.

Beginning with the dominant emergent models of technology adoption and specifically the model advanced by Caselli and Coleman (2001), and supported by an in-depth study of the Chinese tool industry, this research provided evidence as to why existing models of technology adoption do not accurately fit the Chinese marketplace. Specifically, within a market economy, a firm naturally seeks efficiencies and in so doing acquires new technologies

to enhance its market position. Such has not been the case in all industries in China. Despite its unprecedented transformation including a move away from a centrally planned economy, and despite its encouragement of FDI, China's national policies have served as impediments to market driven technology adoption. In the present research we show, by example, that China's technology adoption process does not conform to that observed in mature market-based economies. We advanced the work of Caselli and Coleman's (2001) by including three moderating variables to their model representative of the Chinese market. These moderating variables are: firm-level decision makers; municipal and regional-level decision makers, and state policymakers. As evidence from central and eastern Europe (Oswald, 2000) transformation to a market-based economy does not occur overnight, nor does technology adoption come without its own share of problems (eg: Russia, Czech Republic). We add to the literature by recognizing these differences in technology adoption and posit a separate model which suitably addresses these issues. Further research should look at empirically testing the propositions and model advanced in this work. In additional, further research should test the model on other countries that have or are transforming from a centrally planned economy.

AUTHOR INFORMATION

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REFERENCES

1. Alston, Jon P. 1989. Wa, Guanxi, and Inhwa: Managerial Principles in Japan, China, and Korea. *Business Horizons*, 32: 2, 26 - 32.
2. Au, Alan K.M. & Yeung, Matthew C.H. 2007. Modeling Chinese Manufacturers' Technology Adoption Behavior. *Organizational Transformation and Social Change*. 4: 2, 131-147.
3. Ajzen, I. 1985, From Intentions to Actions: A Theory of Planned Behavior, In J. Kuhl and J. Beckman (eds.), *Action-Control: From Cognition to Behavior*, Heidelberg: Springer, pp. 11–39.
4. Ajzen, I., 1991. The theory of planned behavior, *Organizational Behavior and Human Decision Processes*, 50, pp. 179–211.
5. Baptista, R. 1999. The Diffusion of Process Innovations: A Selective Review, *International Journal of the Economics of Business*, 6:107-129.
6. Brandt, L., Zhu, X., Decentralization and the Macroeconomic Consequences of Commitment to State-Owned Firms, University of Michigan, William Davidson Institute (WDI) - Working Papers, 1-Jun-1997, RePEc:wdi:papers:1997-54
7. Caselli, F., & Coleman, W. J., 2001. Cross-country Technology Diffusion: The Case of Computers, *AEA Papers and Proceedings*, May.
8. Chen, M., 1995. Technological Transfer to China: Major Rules and Issues, *International Journal of Technology Management*, 10:8, pp. 747–756.
9. Congressional Research Service , CRS Report for Congress., How Large is China's Economy? Does it Matter?, Wayne M. Morrison and Michael F. Martin, *Foreign Affairs, Defense, and Trade Division*, RS22808 February 13, 2008

10. Cusumano, M., & Elenkov, D., 1994. Linking International Technology Transfer with Strategy and Management: A Literature Commentary, *Research Policy*, 232: 195–215.
11. Dalmazzo, A. & DeBlasio, G. Skilled Based Agglomeration Effects and Amenities: Theory with an Application to Italian Cities, *Quaderni del Departimento DiEconomia Politica*. 503, April., 2007.
12. Davis, F. D. 1989. Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, 13:3, 319-340.
13. Douglas, M., & Wildavsky, A., 1982. *Risk and Culture: An Essay On The Selection Of Technical And Environmental Dangers.* Berkeley, CA: University of California Press.
14. Fishbein, M., & Ajzen, I. (1975). Belief, attitude, intention, and behavior: An introduction to theory and research. Reading, Mass.: Addison Wesley.
15. Forbes, September 9, 2007, China's Bank of Beijing says Macro Tightening will not affect Loan Growth, *AFX News Limited* 2007.
16. Freshfields, Bruckhaus Deringer, September 2007, *China finally enacts Anti-monopoly Law*, Briefing Document to clients, 4p.
17. Green, Stephen. 2003. *China's Stock Market, A Guide to its Progress, Players and Prospects***.** Bury St. Edmunds: St. Edmundsbury Press, 2003.
18. Griliches, Z., 1957. Hybrid Corn: An Exploration of the Economics of Technological Change. *Econometrica*, 48, 501–522.
19. Linton, K. C., 2006. Access to Capital in China: Competitive Conditions for Foreign and Domestic Firms, *Journal of International Commerce and Economics*, December.
20. Mansfield, E. (1975). International Technology Transfer: Forms, Resource Requirements, and Policies. *American Economic Review*, 65:2, 372-376
21. Middleton, B., 2005. Achieving U.S. Health Information Technology Adoption: The Need for a Third Hand, *Health Affairs*, 24: 1269 – 1272.
22. Oswald, S.L. 2000. Economic Transition in the Czech Republic: Attempts to Privatize the Health System, *Administration and Society***,** 32:3, 227-254.
23. Overholt, W. H., Director of the Center for Asia – Pacific Policy, The Rand Corporation, Statement before the US – China Economic and Security Review Commission, May 19, 2005,
24. Parente, S.L. 2008. Narrowing the Economic Gap in the 21st Century. In *The Index for Economic Freedom***,** a product of the Heritage Institute and the Wall Street Journal.
25. Park, S. H., & Luo, Y., 2001., Guanxi and Organizational Dynamics: Organizational Networking in Chinese Firms, *Strategic Management Journal*, 22: 455–477.
26. Perkins, D. H., 2006. China's Recent Economic Performance and Future Prospects, *Asian Economic Policy Review*, 1: 15–40.
27. Lucien Pye, Chinese Commercial Negotiating Style (Cambridge, Mass.: Oelgeschlager, Gunn & Hain, 1982).
28. Sarkar, J., 1998. Technological Diffusion: Alternative Theories and Historical Evidence, *Journal of Economic Surveys*, 12: 131 – 176.
29. Schumpeter, J., 1942. *Capitalism, Socialism, and Democracy*. New York: Harper.
30. Stoneman, P. and Toivanen O., 1997. The Diffusion of Multiple Technologies: an Empirical Study. *Economics of Innovation and New Technology*, 5: 1–17.
31. Stoneman, P., 2002. *The Economics of Technological Diffusion*. Oxford: Blackwell.

APPENDIX A

Field Research Summary

Our research involved extensive field studies of a very large machine tool firm located in the heart of Beijing, China. Beijing No.1 Machine Tool Plant (BYJC) is a large computer numerical control (CNC) machine tool manufacturing firm. Since its founding in June, 1949, BYJC provided its customers with over 100,000 milling machines in over 450 varieties, including small and medium-sized, heavy-duty and super-heavy-duty. ISO 9001 certified, the firm employed both engineers and technicians and occupies an area of 710,000 sq meters, including a 430,000 sq. meter building area. Its production facility included a modern 4000-sq-meter air-conditioned assembly workshop, a 2000-sq-meter Flexible Manufacturing System (FMS) workshop, complete with advanced machining equipment, precision measuring instrumentation, and a 4896 position high-rack storehouse.

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Products

BYJC's products include:

- Knee-type milling machines, universal milling machines and swivel head milling machines.
- Bed-type milling machines and rotary table milling machines.
- Plano milling machines, plano milling & boring machines, single column milling machines as well as double column milling machines.
- CNC vertical milling machines. CNC plano milling machines and vertical or horizontal machining centers.
- Several kinds of special-purpose milling machines.
- Geological drills

These products are used in metallurgy, mining, railway, power generation, aerospace and aircraft and mold manufacturing. The plant also produces geological rigs that are widely used in mine prospecting and development of water resources.

Services

Founded in 1988, The Import & Export Corporation (IEC), a subsidiary of BYJC, handles imports and exports for BYJC. It seeks out mutual benefit trades and co-developments worldwide. IEC received the "Customs Worthy Enterprise" award for its business activities which include:

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Since the beginning, the products have been sold by direct or indirect export through professional import and export corporations to more than 50 countries and regions, including the US, Germany, Japan, Iran, and Russia, and the products are widely acclaimed by users and traders worldwide. In recent years, BYJC imported and adopted advanced technologies through the IEC from Japan, the U.S., and Germany to co-produce CNC Lathe and CNC milling machines (including CNC super heavy-duty plano-type milling & boring machines).

Challenges Observed

One of the challenges in the machine tool industry is globalization. Among China's SOEs the machine tool industry suffered most from operating losses. The state opened the machine tool industry to the global market as early as 1994. Prior to that time, products from SOEs accounted for more than 70 percent of the domestic supply of machine tools. Firms within China were immune to foreign competition. However, when the purchase of machine tools no longer required government approval, foreign products flooded the market. Many such products had superior features, functions and quality than domestic products. Further, foreign products were offered at lower prices than those of Chinese manufacturers. Since the Chinese government did not impose tariffs or taxes on imported machine tools, the domestic manufacturers found themselves without government protection and had to compete on equal ground with competitors from Japan, Germany, U.S., Korea and Taiwan. The flood of foreign technologies and products has dramatically changed the competitive terrain. All the firms in this industry have been impacted significantly by China's admission to the World Trade Organization (WTO Managers inside BYJC advocated adoption of many new technologies as an immediate response. Today BYJC operates in a highly competitive market.

Product Challenges

Although government officials acknowledge the machine tool industry, and machine tool manufacturing as core industries, from 1976 to 1997, no advanced systems were implemented (the government invested only $37 million in the industry) and there emerged a wide technology gap between China and the rest of the world. Since 1999, the government has established four numerical control machine production bases, which consists of BYJC, Shanghai Machine Tool Group, Shenyang Machine Tool Group and Jinan Machine Tool Group. However, these significant investments fall short of the amount necessary to keep pace. Another challenge for BYJC is its sales force, which has yet to grasp the concept of marketing. Under the former economic planning system, the state disposed of finished products and dictated production expectations. Thus, the sales force has no clear idea of how the product can be promoted and sold in the marketplace. High sales costs and long sales cycle times have turned many customers toward foreign competitors, not solely because of their dissatisfaction with the quality and price of the products, but also because the sales force lacks the requisite knowledge.

Another challenge for BYCJ centers on the necessary facilities and technology for producing advanced machine tools. For example, product development was severely constrained due to the lack of investment capital. Most of the production equipment in the BYJC's plant was purchased prior to 1970. The implication was that without significant new technology, the domestic supply of machine tools could permanently lag behind foreign competitors.

Challenges To Reorganization

SOEs are often characterized by awkward organizational structures. On one hand, the plant owns everything in its value chain, from casting, forging, and machining to assembly, which has resulted in compromised efficiency. On the other hand, plant management has broad authority over its workforce. BYJC provides a wide array of benefits to its employees including primary and secondary schools, and dining facilities. Of course, with this power come significant expectations limiting autonomy regarding the number of workers. Whatever control managers have over the workforce is overshadowed by their inability to upgrade technologically.

Challenges In Motivation

Employee retention and motivation was also a challenge. The annual turnover rate for junior technical staff was as high as 70 percent. The plant is an excellent learning facility for new graduates; however, within three years, most become experts and leave for the private sector and higher salaries (more than four times higher). There is a significant depletion of technical talent from joint venture competitors because SOEs can't pay market salaries. As is the case with most SOEs, BYCI was overstaffed, causing inefficiencies in production. These problems could be handled with the addition of new technologies by external forces have inhibited progress.

Control Challenges

Even though 100 percent of the plant assets belong to the state, there was a lack of clear indication as to who actually was in charge. The Beijing Machine and Electronic Holdings Co. (BMEHC) selected the plant's general manager and approved managerial appointments but often the directives came from the Beijing Municipality government. An example of unclear lines of authority occurred when a detailed modernization plan was proposed. The plan, which was to have cost $120.500 USD was rejected by the Beijing local authority because it lacked "Chinese characteristics". So, while the plant management had operating rights, but did not control its corporate property or investments, which limited their ability to compete effectively in the global marketplace.

Strategic Responses Observed

Property Rights Solution

In December of 2000, the Beijing local authority (as distinguished from the Chinese Government) changed property rights for all state-owned assets. BMEHC would be given the full authorization to take charge of the assets of BYJC. The restructuring plan was for BYJC to become the Machine Tool Group. The ownership for this group would be such that BMEHC would be the biggest shareholder representing the state assets, but the rest would be opened to private investors, other domestic firms and foreign investors.

The Machine Tool Group was to be run according to the Chinese Corporate Law. A board of directors was selected to oversee the group. While it was estimated that it would take several more years to complete a restructuring plan, the new ownership structure allowed BYJC to work toward competitiveness. Part of this was to change the internal organizational structure such that subsidiaries that were not strategically important to BYJC would be spun off.

Employee Obligations

Machine tool plants in the developed countries usually have around 200 people but can produce several thousand machines each year. Since 1993, the staff of BYJC has been reduced from 9,700 to 4,000. Reductions to 2,000 were planned as a part of the restructuring which was completed in 2007. BYJC paid for helping displaced workers by providing training and lump sum of benefits for their severance and resettlement. Under the newly restructured company, employees would work on contract basis and, the company would contribute for medical insurance and pension benefits. Most senior technical staff remained with the company. BYJC is negotiating salaries to improve the living conditions; yet pay for senior technical staff remained significantly below the going market price.

Product Developments

BYJC has worked to upgrade its machine tool products since high-tech manufacturing systems was still restricted from entering the Chinese market. For the last six years, regulatory restrictions have allowed BYJC to withstand fierce competitive pressure. The plant has heavily invested in development of new products. The plant has purchased advanced production systems and blueprints from Japan, Germany and the US in an attempt to use their advanced techniques to build dominance in the Chinese machine tool industry.

Training

BYJC has also expanded training for its technical staff. Several classes in cooperation with universities are underway to prepare for computer integrating manufacturing. The plant has a plan to send many of its key employees abroad to learn the rules of the internationally competitive game.

Product Development

BYJC has formed relationships with universities. For example, the plant has benefited from the computer integrating manufacturing system (CIMS) at Tsinghua University. BYJC constantly introduces and applies world advanced technology and has established cooperative relationships with manufacturers in Japan, the United States, and Germany to produce machine centers and CN super-heavy-duty plano-type milling machines.

Capital Investment

Before BYJC's stock could be publicly traded, the plant needed to maximize return on its property. BYJC had an offer of $204 million USD for its land, and planned to move the plant outside Beijing to an economic development zone. This money from a sale would be sufficient to finance the first phase of restructuring before its public offering.

Managerial Autonomy

In order to improve the management of the enterprise and meet the needs of a market economy, an enterprise management information system was installed. The enterprise management information system (EMIS) provided manufacturing resource planning including scheduling the production process from raw material, manufacturing, to assembly.

Product Developments

BYJC's product structure was changed to apply computer numerical control system (CNC) to compete effectively on the global market. A high-level computer numerical control horizontal machining center model HB 500, cooperatively produced by BYJC and HITACHI SEIKI Co., Ltd. of Japan, was introduced at the "China CNC Machine Tool Show" in Shanghai in August 2000. The CNC bed-type series milling machines developed by BYJC were introduced at "the 5th China Machine Tool Show" in Beijing in June 2000. The machine features high carrying capacity, high torque, high efficiency and high performance. It is designed for die & moulds machining and has a competitive price point.

