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**INNOVATION SUCCESS IN CHINESE ELECTRONICS INDUSTRY:
AN ANALYSIS OF THE EFFECT OF EXTERNAL INTERACTION**

by

Siying Ren, B.A. (Accounting)

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of
Master of Management Studies

School of Business
Carleton University
Ottawa, Ontario

January 18, 1996

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AN ANALYSIS OF THE EFFECT OF EXTERNAL INTERACTION**

submitted by Siying Ren, B.A. (Accounting)
in partial fulfillment of the requirements for
the degree of Master of Management Studies

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ACKNOWLEDGEMENTS

This thesis was made possible through the support of many people. I would like to express my profound gratitude to my thesis supervisor, Professor Vinod Kumar for his guidance, encouragement, endless patience and support throughout this study. I would like to thank my committee members, Professor David Cray and Professor Uma Kumar for their helpful advice. I am grateful to Aditha Persaud for reading my thesis draft and providing generous and expert guidance, my friend Gary Craigs for editing my thesis, Jean Blair for her helping me with several administrative matters and all the faculty and support staff of School of Business for their assistance over the years.

The financial support provided by the Faculty of Graduate Studies and Research and the Research and Publications Committee of School of Business for thesis-related work is greatly appreciated. Financial support in the form of scholarship and teaching assistantship provided by Carleton University which made it able for me to remain in the MMS program is acknowledged. My sincere gratitude is also extended to the companies that willingly participated in my study. Without their participation this study would not have been possible.

Very special thanks go to my father. Without his assistance in introducing me and setting up the appointments with his colleagues and friends - presidents, vice presidents, general managers of many Chinese electronics companies, the data collection of this study would not have been successful. Also his ingenious advice, encouragement and support throughout this study are greatly appreciated. Last but not least, I am indebted to my mother, brother and sister-in-law for their love and encouragement over the period of my study in Canada.

ABSTRACT

This study presents an empirical analysis of how the interaction between Chinese electronics companies and their external environment influences innovation success. Based on 48 electronics firms located in the cities of Beijing and Tianjin, four modes of interaction are examined in this study, namely contact with customers, contact/cooperation with research institutes and universities, contact/cooperation with other companies (domestic and/or foreign companies) and government support. Four internal organizational factors are also taken into account in the analysis: firm size, R&D intensity, firm age and ownership of the firm.

Pearson correlation and logistic regression techniques are employed to examine the effect of the interaction and internal organizational factors on innovation success. This study shows that the mobilization of external resources through a firm's interaction with its external environment plays a crucial role in achieving innovation success in the Chinese electronics industry. Meanwhile a firm's internal characteristics also determine the potential of its innovation success.

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I. INTRODUCTION

It is nowadays a truism to say that technology is the key to economic development. The impact of new technologies in particular is having and will increasingly have a profound effect on all economies, whether or not individual countries participate in any way in their generation (Conroy, 1990). China, since the inception of economic reform in the late 1970s, has started tentatively to integrate itself more into the global economy and to gain greater access to technology to improve its currently poor international competitiveness. One of its "Four Modernization" - the policy program for development - was to raise the level of Science and Technology (S&T). To do this China has realized that she must concentrate on technological innovation which will bring out maximum economic results. Thus, the task of promoting scientific advances and technological innovation has been of paramount importance in China.

However, for many years in China, there has been little attention paid to introducing new products and processes or even improving old products. Although since 1980 China has shifted her strategy of economic development and has begun to emphasize the technological innovation of existing enterprises, the shift, as Ye (1987) described, for various reasons, has been plagued by difficulty at every step, every turn, and has been very slow. This implicitly affects the competitiveness of Chinese industries in the new more challenging market environment. Consequently, to understand the innovation process and how innovation activities are affected become critical issues for Chinese firms trying to achieve innovation success.

Many factors influencing the innovation process have been identified in the literature (e.g. Kruus and Dawe, 1985; Jelinek and Schoonhoven, 1990). These factors can be mainly classified into two categories - internal organizational factors (characteristics of organization, marketing,

management, etc.) and external organizational factors (government intervention, economic condition, etc.). In addition the interaction between a company's internal environment and its external environment influences a firm's innovation process. For example, a company can not acquire all the resources which are needed in the process of innovation exclusively through its internal environment. The mobilization of external resources through a firm's interaction with its external environment, such as research institutes, universities, other companies and government, could play an important role in achieving innovation success. Thus, the purpose of this study is to analyze how the interaction between a Chinese firm and its external environment affects innovation success.

The electronics industry is selected as the focus industry of this study due to its unique characteristics. Jelinek and Schoonhoven stated (1990) that electronics is fundamental both to the world we live in and to the future of commerce and industry. The electronics industry shapes modern life, profoundly affecting every aspect of our culture and society. During the last several years, the development aspects of regional high-tech (mostly in electronics) economies have been a topic of great interest in the West. Since the 1978 "open door" policy, Chinese government has increasingly turned their attention to developing high technology, which holds out the hope of rapid economic development. Especially in the electronics industry, the state has, through a number of central directives, attempted to promote the production and commercialization of electronic products (Segal, 1993). According to Wang (1993), the Post-Mao leadership had identified electronics as the "hallmark of a country's level of modernization". For example, since 1983 the Chinese government has expanded the sum of funds allocated to the electronics industry for plant modernization and acquisition of key equipment. Meanwhile electronics has been again

selected to be one of the seven key development areas by the Chinese government in 1994 (CND Global, July 1994). By choosing the electronics industry, this study can gain important insights into the working of the current Chinese system and the degree to which Chinese industries are experiencing bottlenecks - organizational, technological, and economic - in their move to revitalize the electronics industry.

This study is divided into eight sections. The next section investigates the literature in innovation process and innovation success, as well as the interaction between a company and its external environment. The research objective is stated in Section III. Section IV describes the theoretical framework developed in this study, i.e. the theoretical model, hypotheses and measurement of variables. The fifth section provides the description of the methodology used in research design, sample, data collection, and data analysis. The results and discussions are presented in Section VI. Section VII provides the conclusion of this thesis. Finally, the benefits and limitations of the study are discussed in Section VIII.

II. LITERATURE REVIEW

This section first examines the literature on innovation and innovation success in order to develop a clear understanding of these concepts as employed in this study. Then four aspects of the interaction between the company and its external environment, namely, the role of the market and contact with customers, cooperation with research institutes and universities, cooperation with other companies, and government's effect on the innovation process are reviewed in order to develop the theoretical basis for the hypotheses in this study.

2.1 Innovation and Innovation Success:

Various definitions of innovation have been proposed in different studies. For example, in Berry and Taggart's view (1994), innovation is the total process from the inception of an idea through to the manufacture of a product and finally to its ultimate sale. Innovation therefore includes invention and the many stages of implementation such as research, development, production and marketing. However, for the purpose of this study, the definition given by Kruus and Dawe (1985) appropriately expresses the basic idea. According to them, innovation is the process of the development and commercialization of new and improved products, processes, and the means of delivering a good or service.

Generally, innovation can be divided into process and product innovation. Process innovation is the improvement of the production process which leads to increased efficiency and reduced cost of production. Product innovation is defined as the development and launching of new or improved products. Product innovation is chosen to be the focus of this study for the following reasons.

First, product innovation is one of the most important tasks in manufacturing firms which compete in fast-changing markets. Roman and Puett observed (1983) that manufacturing companies in the United States are spending billions of dollars each year for research and development of new products and improvement of existing products to extend their marketing life. Other developed nations, such as Japan and Germany, are also expending vast sums in a unending race for technological leadership and international market dominance. The aim of product innovation is to offer customers radically new or incrementally improved new products based on technological advances. Thus product innovation is arguably the most important process

in the long run because it can ensure survival in terms of rapid changes in technology and markets (Johne, 1985).

Second, as the introduction of market driven mechanisms of economic reforms in China began to take hold in industrial enterprises, competition between enterprises has driven Chinese companies to be more active in product innovation than in process innovation. According to Simon and Goldman (1989), process innovation, specifically in breakthrough technology, usually takes more time and requires considerable cost and advanced technology. It is hardly feasible for most Chinese companies to undertake process innovation individually due to the insufficiency of capital and technological resources. Also because of its high risk and uncertainty, there is a reluctance in Chinese firms to invest heavily in long-term process innovation. The major channel to obtain advanced manufacturing process technology is through technology transfer from Western developed countries or research institutes and universities.

Product innovation, however, is relatively inexpensive and needs less capital or advanced technological resources than process innovation, the investment payoff is shorter and it usually has higher rate of return on investment. Thus product innovation is observed to be much more popular and active than process innovation among manufacturing companies in China (Fischer, 1989).

Advancing competitiveness by innovation activity, however, gives no assurance that new products will always be successful. On the contrary, most new products fail. A study by Cooper and Kleinschmidt (1990) showed that more than 50% of new products are unsuccessful. Thus, it is imperative for a company to understand the innovation process in order to find a better strategy to achieve innovation success.

Innovation success can be achieved either at the technological level or the commercial level (Figure 1 explicitly outlines this path - process of innovation). The technological innovation process normally involves four stages¹. Stage 1 = "initial screening" which includes preliminary marketing assessment, preliminary financial assessment and preliminary technical assessment of a new product. Stage 2 = "commercial evaluation" which includes detailed marketing assessment, detailed financial assessment and detailed technical assessment. Stage 3 = "development" which includes the specification and design of a new product, prototype development and prototype testing. Stage 4 = "manufacturing/marketing launch" which includes tooling and documentation, preproduction, testing and redesign, and initial marketing test.

Various definitions for commercial innovation success have been proposed in the literature. For example, Pinto and Slevin (1988) measured success with an average of 13 items, including user acceptance and usage of the product, and user benefits from the project. Cooper and Kleinschmidt (1990) proposed that an innovation is regarded as commercially successful when product profit exceeds the firm's acceptable profitability criteria for new product investment. However, these definitions, to a large extent, are specific to particular firms and are subjective measures of commercial innovation success. For instance, by Cooper and Kleinschmidt's definition, 25% profitability could be considered both a success and a failure in different companies. To avoid this problem, a simple but explicit definition given by Rothwell and Zegveld (1985) is adopted in this study. They stated that, "Commercial innovation success is the one which attained significant market potential and/or made a profit".

¹. The division of each stage of the innovation process in technological level is based on the "Activity-Decision Stage Model of the Innovation Process" developed by Kumar, et al., 1993.

Figure 1: Process of Innovation

Many factors influencing innovation success have been identified in the literature. Table 1 summarizes major internal and external factors influencing innovation success. The most frequently discussed internal factor on innovation success is a company's internal characteristics (e.g. Hekman, 1985, Dorfman, 1987, Conroy, 1990), such as firm size, R&D intensity, firm age, ownership of firm, etc., which may determine the potentiality of its innovation success. Some other factors are also important when analyzing a firm's innovation success, such as management skills, organizational culture, understanding user's need, etc. However, due to the potential difficulty of measuring these factors in a consistent and an objective way, in existing literature these factors are usually still limited to theoretical discussion rather than being taken into account in empirical studies. Meanwhile, the external factors, such as a country's current economic condition (boom or stagnant), and science and technology level (high or low) could either facilitate or hinder the performance of a company's innovation process. Due to the same measuring problem, these factors are not considered in this study.

Table 1: Summary of Major Factors Influencing Innovation Success

Factors	Author and Year*
<u>Internal Factors:</u>	
<i>1. Management:</i>	
* management skill (education/experience)	4, 8, 10, 11, 24, 25
* management support	2, 11, 24
* interdepartmental cooperation	5, 8, 9, 11
* exchange of information	2, 5, 25
* management strategy	2, 8, 9, 11, 21, 24
* planning and control	5, 10, 11, 24, 25
<i>2. Characteristics of organization:</i>	
* firm size	1, 2, 5, 8, 9, 10, 11, 21
* firm location	6, 9, 10, 12, 21
* firm age (new/old)	1, 21
* R&D intensity	9, 10, 12
* organizational structure	1, 5, 9, 10, 11, 21
* organizational culture	9, 11, 21, 24
* availability of financial resources	2, 8, 9, 10, 15, 24
* availability of technological resources	2, 8, 9, 10, 15, 24
* ownership of company ²	10
* sector of industry ³	1, 5, 8, 9, 10
<i>3. Marketing:</i>	
* marketing skill	10, 11, 13
* understanding user's need	5, 11, 12, 13, 14, 15
* advertising	1
* sales promotion	1
* after sales/auxiliary service	1, 5
* user's education	5
* efforts of selling	1

². In China, companies are divided, based on ownership, into state-owned, collective, private, joint ventures (mostly refer to joint ventures with foreign companies), foreign companies and others.

³. Such as electronics, chemicals, transportation industry, etc.

Factors

Author and Year*

Internal Factors:***4. Design and Engineering:***

* technical skill	2, 9, 10
* expertise	1, 2, 5, 11
* efficient development	5, 8, 10, 24
* production techniques	1, 8, 10, 25
* cost of product	1, 2, 10
* roots of idea generation	4, 9, 11, 20

External Factors:***1. Government intervention:***

* regulations and laws	1, 2, 3, 4, 5, 22
* subsidy	1, 2, 4, 5, 8, 10, 23
* tax incentives	2, 4, 5, 7, 8, 10, 21
* in-house government performed R&D	1, 3, 4, 23
* training/education program	3, 4, 5, 10
* technology procurement	1, 2, 4, 5, 8, 10, 22
* information support/transfer	2, 3, 5, 21
* infrastructure support	2, 5, 23

2. Competition:

* technology competition (technology push)	2, 4
* market competition (market pull)	2, 4

3. Others:

* economic condition (boom/stagnant)	2, 15, 21
* level of science & technology	8, 10

*** Author and Year:**

1. Dorfman (1987)	2. Rothwell & Zegveld (1985)	3. Horning (1984)
4. Kruus and Dawe (1985)	5. Johne (1985)	6. Hekman (1985)
7. Collins (1986)	8. Ye (1987)	9. Simon and Rehn (1988)
10. Conroy (1990)	11. Jelinek & Schoonhoven (1990)	12. Gemunden (1992)
13. Parkinson (1982)	14. Foxall & Tierney (1984)	15. Stankiewicz (1985)
16. Combs (1993)	17. Robinson (1985)	18. Muller (1984)
19. Gray (1986)	20. Shao (1990)	21. Sweeney (1985)
22. Houttun (1985)	23. Wang (1993)	24. Gobeli & Brown (1993)
25. Bruijin & Jia (1993)		

However, innovation success is not simply determined by either internal or external factors. "No business is an island" (Hakansson and Snehota, 1989), there is always an interaction between an organization and its external environment, which can result in a multicompetence-effect on the development of innovation (Gemunden, et al., 1992). The major forms of interaction discussed in the literature include contact with customers, contact/cooperation with research institutes and universities, contact/cooperation with other companies and government support. Table 2 summarizes the major modes of interaction between a company and its external environment based on the literature. Further detailed discussion is provided in the following sections.

Table 2: Interaction Between Company and External Environment

External Contact	Author and Year^a
* Contact with customers	11, 12, 13, 14, 24
* Contact/Cooperation with research institutes and universities	10, 12, 15, 16, 17, 18, 19
* Contact/Cooperation with other companies	10, 12, 20, 25
* Government support	1, 2, 3, 4, 5, 7, 8, 10, 23

a. Refers to the number of "Author and Year" in Table 1.

2.2 Technological Interweaving with External Environment:

2.2.1 The Role of Market and Contact with Customers in Innovation Process:

Under a market economy, competition between enterprises pushes manufacturing firms to innovate in order to provide better and more appropriate products into the market in response to the customers' needs. A study by Foxall (1989) demonstrated that every stage of new product development should be sensitive to the requirements of potential buyers and users. Failure of industrial innovation is often associated with lack of attention to users' needs. In fact, contact with customers in advanced technology innovation is not only taken for granted by most companies in Western countries, it is widely identified as necessary (Jelinek and Schoonhoven, 1990). Especially in high-technology, for example, in the electronics industry, close customer contact is regarded as essential to success and as a source of enduring strategic advantage for the technical firm that builds such service into its repertoire. An early empirical study done by Hippel (1978) has shown that the level of the manufacturer's "understanding of user's need" is strongly correlated with the level of commercial success attained by an innovative industrial product. Also, a recent study (Gemunden, et al., 1992) disclosed that the companies which regard and use their customers as important sources of innovation have a higher level of technological and commercial innovation success.

However, unlike in the West, historically, the innovation process in China is not embedded in a web of market-type relationships. Simon and Rehn (1988) have described that in planned systems, innovation tends to be part of a larger administrative hierarchy whose R&D efforts are more the product of highly directed resource mobilization than a response to market signals. Meanwhile, all products of enterprises were monopolized in purchase and marketing by

the State. Therefore, the companies had been isolated from the market and their customers for years until economic reform was initiated in the late 1970s. One of the Chinese government's policies of economic reform was the significant introduction of market influences into economic decision making, which represented an abrupt change from the strong reliance on central planning that had characterized China for much of its existence. Since the implementation of market mechanisms into China's economy, though the steps for changing from a planned economy to a market economy proceeded in an orderly and slow way, the initiating mechanism for encouraging innovation in industry seems clear enough. Based on a study by two Chinese scholars (Tang and Xu, 1990), recognition of market demand was ranked as the second important factor for achieving innovation success among Chinese enterprises. This result explicitly demonstrates that the demand-pull factor driven by market demands has been perceived as critical factor in innovation success among Chinese companies.

Furthermore, Chinese companies have started paying more attention to establishing relationships with customers. One of the World Bank studies of Chinese industries indicated that enterprises' annual output, product variety, and specification were to be determined by the market and users' needs (Zhang, et al., 1991). The introduction of market influences into the enterprises' planning environment leads to the formation, in some industries, of user-service teams that visit customers to solicit ideas about desirable product innovation. This has explicitly indicated that Chinese enterprises are becoming more aware of the importance of the role of the market and contact with customers which could significantly affect innovation process.

2.2.2 Cooperation with Research Institutes and Universities:

Innovation is the process of transforming the achievements in scientific research into production, commercializing the achievements and realizing the economic value of achievements in R&D. However, with the growing complexity of technological change, this process of transfer of knowledge has become more complex. More and more of the emerging technologies require highly diversified knowledge inputs from a large number of scientific and technological disciplines. Even the large companies may find it difficult to maintain sufficiently diversified internal R&D resources to stay self-sufficient. Therefore, to establish contacts or cooperation with research institutes and universities could be one of the alternatives for dealing with this problem.

Research institutes and universities are increasingly looked upon as natural integrator of the multifaceted and rapidly growing knowledge industry. They are the natural diverse specialized members of the knowledge industry cluster. They are viewed as pools of technical expertise and creativity to be tapped directly through the involvement of academic scientists and engineers in the process of industrial innovation (Stankiewicz, 1985). By cooperating with research institutes and universities, a company can obtain complementary external know-how and the necessary technical and highly qualified personnel support. For example, consultancy by academic scientists and engineers is the most frequently occurring means of linking a company with universities. This is a relatively inexpensive, rapid and selective way of transferring information and solving technical problems of companies. According to one study (Marver and Patton, 1976), about one third of the faculty at American universities have been engaged in various forms of consultancy.

Meanwhile, research institutes and universities are also willing to engage in various forms of service to industry, which, at least partially, can be attributed to budgetary constraints imposed

on the research institutes and universities. Since all research institutes, universities and companies can benefit from such cooperation, there is a growing demand for the engagement of links between these two sectors. Some studies have tested the results of such cooperation. Combs (1993) developed and tested a model in which R&D cooperation between companies and research institutes and universities enables firms to increase the probability of discovering a new product by sharing information about strategies and outcomes. Numerical computations of equilibrium showed that cooperation tends to increase the underlying probability of research success. Meanwhile, when the probability of an innovation's success is relatively low, no cooperation occurs, nor will it be socially desired. This result explicitly reflects the positive effects of such cooperation on innovation success.

However, China, since the early 1950s, has replicated the Soviet R&D system in the planned economy model which imposed a set of constraints on China's innovation capabilities. According to Simon and Rehn (1988), the majority of China's research institutes were neither physically nor administratively linked to production enterprises. Most medium and large enterprises did have internal "engineering or design" departments, but as their name implies, these were not traditional research entities. Aside from the military, end user involvement in the structuring of an institute's research portfolio or selection of research priorities was extremely limited. Similarly, research institutes hardly ever consulted with factory managers regarding their research agenda or possible collaboration. This situation prevailed not only because of the vertical and highly compartmental character of the system, but also because of the ways funds for R&D were allocated to institutes and factories and because of the incentive structure that drove enterprise behavior. For example, the funding for R&D in support of innovation activities was

basically allocated in a highly centralized and planned fashion by government. Research institutes dispersed the various budgetary allocations they received in the form of grants, without any consideration for group performance, individual scientific and technological achievement, or even whether the results of their labor could be translated into production. As a result, the rate of research taken up by production enterprises is rather low. According to Tong (1984), in China today, applied research is reckoned to absorb 90 per cent of civilian science funds, yet a mere 10 per cent of research results can be utilized promptly in production, as opposed to 80 per cent in the U.S.A.. Apparently, the link between formal R&D sectors and production enterprises is quite weak.

However, China, especially since the Cultural Revolution in the late 1970s, has realized this problem and instituted unusual arrangements to bridge the gap from laboratory to production, such as the incorporation of pilot factories with science centers and university departments. For example, beginning March 1983, the Chinese Scientific and Technical Association set up a subsidiary called the Science and Technology Consultancy Service, to function as the umbrella organization for user-oriented research units. Some factories themselves host "technology development centers" with temporary staff from outside. Statistics indicate that by the end of 1987 in China, over half of the R&D units in the formal R&D sectors had established some type of collaboration with production enterprises (Zhang, et al., 1991). In this kind of cooperation, research institutes and universities can employ their technical superiority to the fullest. This can complement the company's resources with highly diversified sources of knowledge and R&D resources. Therefore, contact or cooperation between research institutes, universities and companies may contribute positively to a company's innovation success.

2.2.3 Cooperation with Other Companies:

Innovation processes often require interdisciplinary know-how, which may lie in a totally different field compared to a company's previous R&D expertise. A single company may find it difficult to obtain all the necessary knowledge and technologies for innovation processes. Consequently, the company tends to acquire such knowledge and competence from external partners.

Conroy (1990) proposed that the most common form of collaboration has been the ad hoc joint development of specific technologies or products with one or more production enterprises. This is because more appropriate and complementary technology is acquired through these channels than through research institutes and universities, whose results often need a lot more investment and work before they can be applied in production. However, such cooperation between competitors requires a wholly complete system of patent laws. In the absence of complete patent laws, a company would be reluctant to undertake the R&D cooperation despite the potential benefits that would accrue to it and to society, because the resulting invention may be exploited by other companies. In China, patent and trademark laws are relatively new. They were first enacted in March 1984 (Bruijin and Jia, 1993). Although a lot of work has been done in strengthening these laws, the current system of protection is still only "fairly complete" (CND Global, January, 1994). As Dorfman (1987) stated, when patents do not afford protection for inventors, the sale of licensing or production rights rarely offers an inventor much promise of a return on its R&D investment. Therefore, the conflict concerning the ownership of patents or trademarks between the Chinese partners is still the main constraint to R&D cooperation among Chinese companies. However China has realized this problem, according to a report in CND

Global (July 1994), the President of China, Jiang Zeming, urged in July 1994 that China will make every effort to strengthen the implementation of patent, trademark and copyright laws. With the improvement in the patent law system, the cooperation between companies is expected to increase since such cooperation can complement the company's financial and technical resources, which can facilitate innovation process and increase the probability of innovation success.

Besides cooperation with other domestic companies, there is an inclination among Chinese companies to cooperate with foreign companies. The most common form of cooperation with foreign companies is transferring technology or acquiring licenses from foreign companies with most of the cost being borne by the state (central ministries or local governments) (Wang, 1993). Thus, Chinese companies have more interest in cooperating with foreign companies. Meanwhile many Chinese enterprises are still confronting financial difficulties. By cooperating with foreign companies, not only can they gain access to advanced technology and modern management skills but also can obtain the necessary financial resources. This will explicitly facilitate the innovation process. Furthermore, foreign companies, through their equity participation, have a vast interest in ensuring innovation success.

2.2.4 Government Effect on Innovation Process:

A country's political environment, financial system and the nature of social and economic incentives can have a great effect on innovation processes. Government, as described by Houttuin (1985), is inevitably one of the major actors in the industrial innovation process. It is deeply involved in creating a framework in which industry operates as well as being a customer in large parts of the market. Therefore, the government in its triple-barrelled role of customer, supporter of R&D, and regulator has an important effect on the direction and speed of developments in the innovation process (Dorfman, 1987).

In most developed and developing countries government is the largest employer, dispenses the largest funds, and in its hands primarily lies the creation of the environment in which entrepreneurship can flourish (Sweeney, 1985). While many analysts are of the opinion that government action in supporting research and advanced training as well as providing backup services is essential to the innovation process, the greatest impact of government comes through its general social and economic programs. For example, government procurement policy may have an effect on innovation processes. Houttuin (1985) suggested that substantial government demand can be used to stimulate innovation in industry (demand pull) or government itself may need innovative products or services (technology push).

However, some researchers argue that government can only play a limited and indirect role in technological innovation since technological innovation is only indirectly responsive to economic and policy levers. Capital investment and regulatory policy do not automatically yield technological innovation; One can not buy innovation. However, one can manage better and increase the rate of product and process innovation (Solomon and Tornatzky, 1986). Government

effects on innovation could be significantly enhanced by identifying areas that have the greatest leverage and exploring organizational options that might strengthen the government's role in innovation. According to existing literature, there are a variety of direct and indirect means by which a government might affect the industrial innovation process. Table 3 summarizes the mechanisms through which government can influence the innovation process.

Table 3: Government Influences on Innovation Process

Means	Influence	Author & Year^a
<i>Financial Assistance/Incentive:</i>		
* low interest rate loans	indirect	1, 2
* subsidy on R&D projects	direct	1, 6, 9, 11
* direct funding on R&D project	direct	1, 11
* technology procurement	indirect	2, 6, 7, 8, 10
<i>Technical Assistance:</i>		
* government consultancy service	indirect	1, 3, 9
* transfer of technology from government laboratories	indirect	2, 9
* technical infrastructure support	indirect	2, 7, 8, 9
* transfer of information	indirect	2, 4
* personnel training/education	indirect	2, 5, 10
<i>Regulations and Laws:</i>		
* environmental health and safety regulation	indirect	2, 7
* patent, trademark and copyright laws	indirect	2, 7, 8, 9
* antitrust laws	indirect	2
* tax laws	indirect	2, 6, 7, 10
* accounting regulation (e.g. depreciation method)	indirect	6
<u>a. Author and Year:</u>		
1. Kruus & Dawe (1985)	2. Horning (1984)	3. Houttuin (1985)
4. Solomon & Tomatzky (1986)	5. Stankiewicz (1985)	6. Ye (1987)
7. Dorfman (1987)	8. Rothwell & Zegveld (1985)	9. Wang (1993)
10. Conroy (1990)	11. Shao (1992)	

China, as a communist country has been under the control of the central government since its establishment in 1949. Although the central government has transferred some of its power to lower levels, and increased managerial autonomy of companies since the early 1980s, the Chinese government still directly involves itself in stimulating and supporting industrial technological innovation through a number of mechanisms: creation of financial incentives (i.e. subsidies for R&D projects, direct funding of R&D projects, low interest rate loans, etc.), technical assistance (i.e. technology transfer from government laboratories, technical infrastructure support, personnel training, etc.), regulations and laws (patent, trademark and copyright laws, tax incentives, accounting regulation, etc.).

Many researchers have been involved in studying the issues of the role of government in industrial innovation processes, and most agree that some degree of government intervention encourages innovation and technical change. However, few empirical studies have been done to analyze how a country's government influences industrial innovation processes through its program and innovation policies. Especially for China, since the economic reform in the late 1970s, the Chinese central government has released its control of production and product price in most fields except for some products, such as rice and cotton which are tightly controlled by the central government due to shortages. It would be interesting to study whether the Chinese central government still plays an important role in Chinese industry's innovation success and how it influences innovation processes in Chinese companies after the changes regarding government control over companies since economic reform in the late 1970s.

III. RESEARCH OBJECTIVE

The review of the existing literature in the previous section clearly indicates that the interaction between a company and its external environment plays an important role in innovation success. The objective of this research is to analyze how the Chinese electronics industry's innovation success is affected by its interaction with the external environment.

IV. THEORETICAL FRAMEWORK

4.1 Theoretical Model:

The main purpose of this study is to analyze how innovation success in the Chinese electronics industry is affected by the firms' interactions with the external environment. The interactions to be tested in this study are the followings:

- (1) Contact with customers
- (2) Contact/cooperation with research institutes and universities
- (3) Contact/cooperation with other companies
 - domestic companies
 - foreign companies
- (4) Support from the government

Apart from the interactions with the external environment, internal organizational characteristics can also have impacts on a company's innovation success. Many researchers have proposed that internal organizational factors, such as firm size, R&D intensity, firm age, field of industry, location of industry, etc, (a detailed list of the "characteristics of organization" can be found in Table 1 under "Internal Factors"), could have effects on innovation success (Rothwell and Zegveld, 1985, Dorfman, 1987, Conroy, 1990, etc.). Four internal organizational characteristics, namely, firm size, R&D intensity, firm age and ownership of the company are included in the analysis.

With regard to firm size, a popular theoretical argument in the existing literature is that large firms are significantly more innovative than small ones. This can be derived from the following principal premises: (1) the large firm's presumed greater incentive to innovate, (2) its

more adequate financial resources with which to do so, (3) its ability to spread the risk of R&D, and (4) its ability to exploit economies of scale in R&D (Dorfman, 1987). Large firms are also more powerful than small ones. For instance, large firms may tie their suppliers to them without being dependent on their suppliers and force their partners to hand over their know-how to them or even put it at the disposal of other suppliers, which often means providing competitors with know-how (Gemunden, et al., 1992). Meanwhile, large firms usually have greater political and economic impacts and therefore receive more attention and support from government. Thus large companies have more chances to achieve innovation success.

Another important factor that may affect innovation success is R&D intensity. According to Roberts (1987) R&D intensity can be viewed as a measure of the innovativeness of a company. R&D activity is crucial to bringing out new products. A company not only has to be able to understand external input but also to develop it further and adjust it to its own needs. Furthermore, in order to be attractive a company must have its own technological competence, which it can offer its potential partners. Thus companies with a strong internal competence get easier access to external know-how.

The age of firms is also important when analyzing the effects on innovation process. After many years' experience in R&D activities, older companies may have established strong and formal management systems for R&D projects. They may also have accumulated more experience in dealing with the problems which occur in the new product development process (Dorfman, 1987). Furthermore, having existed in the market for years, older companies have already obtained large market shares and established more connections with their customers and partners, such as suppliers, research institutes and universities, etc.. Thus, older companies may be better

placed to achieve innovation success than younger companies.

The ownership of the company is another internal factor which could potentially have a large degree of impact on innovation success. The state-owned companies in China are still influenced by the Chinese government in almost every aspect though the government control has been reduced since its economic reform in the late 1970s. Meanwhile, government gives more support to state-owned companies than any other kind of companies. Furthermore, since the existence of private and foreign companies was only allowed after China's economic reform, and these types of companies are normally perceived as having more freedom and flexibility in their innovation process than state-owned companies, the impact of state-owned companies on innovation success therefore may be different compared to other ownerships of firms.

Thus, these factors, firm size, R&D intensity, firm age and ownership of the company are taken into account when analyzing the effects of interactions on innovation success. Innovation success is analyzed at both technological and commercial levels. Figure 2 illustrates the theoretical framework of this study.

Figure 2: Schematic Diagram of the Theoretical Framework

4.2 Hypotheses:

Hypothesis 1: Companies which maintain contact with their customers have higher innovation success than other companies.

Since the implementation of market mechanisms into China's economy, the demand-pull factor has been perceived as critical in the innovation process among Chinese companies (Tang and Xu, 1990). Most innovations are pulled by market demand. Since contact with customers can help a company know what their customers' needs are, the product therefore will be likely to meet targeted customers' requirements and thus the market receptivity will be high.

Hypothesis 2: Companies which cooperate with research institutes and universities have higher innovation success than those which do not engage in cooperative activities.

Due to the growing complexity of innovation processes and the pressure of competition in the market since economic reform in China, more and more Chinese companies find it difficult to maintain sufficiently diversified internal R&D resources to stay competitive and therefore are becoming interested in cooperating with research institutes and universities. By doing this, the company can explore external know-how (Wang, 1993). Furthermore, cooperation with research institutes and universities is usually developed and maintained in order to solve technical problems and to secure access to bottleneck resources for many innovation processes such as highly qualified personnel. Thus, it is assumed that innovation success is strongly and directly influenced by cooperative activities with research institutions and universities.

Hypothesis 3: Companies which have established arrangements for R&D cooperation with other companies (either domestic or foreign companies) have higher innovation success than companies which do not.

According to Gemunden et al., (1992), for companies with compatible goals and complementary resources, R&D cooperation appears to be an appropriate means to cultivate the synergy potential in the innovation process. Because the creation of knowledge and competence often lies in a different field, the development of internal competence in totally new fields of technology is very often protracted and combined with high costs. By cooperating with other partners, the company can split the risk of failure and cost among the partners. Through this division of risk and costs the partners gain the opportunity to diversify their innovation activities.

There is also a tendency in China that most companies are more willing to cooperate with foreign companies than with domestic companies. The level of existing technologies in Chinese industries is still fairly low, and many Chinese companies may not have enough financial resources for their R&D projects. Such cooperation can help Chinese companies acquire the necessary financial and technological resources from their foreign partners. This will explicitly facilitate the innovation process. Furthermore, foreign companies, through their equity participation, have a vast interest in ensuring innovation success. The innovation success therefore, is presumably positively correlated with cooperation with other companies (either domestic or foreign companies).

Hypothesis 4: Companies which get government support have higher innovation success than other companies.

The success of innovation can be greatly influenced by the intervention of government. The Chinese government has directly involved itself in the innovation process since the central government was established in 1949. Many state-owned enterprises can get direct funding or even technical professionals from the government to support their R&D projects. Also, through

regulations, laws and other financial incentives the Chinese government can vary its support in different areas and industries based on its technical priorities.

Although as economic reform has developed, China has switched from a planned economy to a more market-style system and the government's role in planning has been reduced, China's socialist characteristic of central planning has not been undermined. The Vice Minister of China reported in May 1994 (CND Global, May 1994), that in the development of the "socialist" market economy, the government would continue to give "guidance" to the industries. Most companies are still influenced by the government either directly or indirectly. Therefore, it is perceived that companies which get government support are more likely to achieve success than those companies which do not.

Hypothesis 5: Large companies show higher innovation success than small companies.

Large companies are usually viewed as being significantly more innovative than small ones since they have more adequate financial and technical resources. Large companies also have advantages in exploiting financial and technical resources when necessary. Moreover, large firms are in a better position than small ones to attract highly qualified personnel, not simply because of their greater financial resources but because they are able to offer better research facilities, greater job security and prospects of upward mobility (Dorfman, 1987). Therefore, it is usually noted that large firms fuel the engine of technological change.

In China, large companies have more advanced equipment and possess stronger technical forces, their technical levels therefore are in general far superior than those in small companies. Thus, large firms are seen as more likely to achieve innovation success than small ones.

Hypothesis 6: R&D intensive companies show higher innovation success than other

companies.

Though the cultivation of external technological resources is assumed to be vital for a firm's innovation success, internal R&D activities seem indispensable. Raelin and Balachandra (1985) have argued that R&D activity is critical to most firms interested in bringing out new products. R&D intensity can be viewed as the activeness of innovation and the ability of the company to initiate R&D projects by itself. Furthermore, companies with strong technological competence are likely to attract more companies to cooperate with them. Thus, internal R&D activities can be regarded as a necessary precondition for successful innovation.

Hypothesis 7: Older companies have higher innovation success.

Having existed in the competitive world for years, older companies have already obtained a large market share and established a relatively complete support system for the innovation process. Furthermore, these companies may also have established wider contacts with external partners than the younger companies, and thus are more advantageous to achieving innovation success than younger companies.

Hypothesis 8: State-owned companies have higher innovation success than other companies

State-owned companies have monopolized in Chinese industrial sectors since China's establishment in 1949. Although more and more types of ownership of companies have emerged in China since economic reform in the late 1970s, state-owned firms still dominate China in every sector. Meanwhile, the Chinese government gives more support to the state-owned companies than any other kind of companies. Furthermore, state-owned companies have more access and channels when dealing with public sectors or government bureau than other

companies. Thus, they may exploit external resources more easily during their innovation process and consequently may have higher innovation success than other companies.

4.3 Measurement of Variables:

(1). Innovation success:

Innovation success involves two levels of success. One is at the technological level and the other is at the commercial level.

There are two basic methods to measure technological innovation success. One way is to use the absolute number of new products that went into the manufacturing process in a company within the last five years. However, due to different technical scales of new products in each company, this method is not a reliable measurement. For example, the technical scale of new products, the degree of difficulty and the extent of financial and technical requirements for new product development in a computer firm are totally different than in a semiconductor element company. The absolute number of new products can not truly reflect the extent of technological innovation success of electronics firms in different fields. Therefore this method is not an appropriate measure for technological innovation success and is not considered in this study.

Technological innovation process normally involves four stages⁴. Stage 1 = "initial screening" which includes preliminary marketing assessment, preliminary financial assessment and preliminary technical assessment of a new product. Stage 2 = "commercial evaluation" which includes detailed marketing assessment, detailed financial assessment and detailed technical assessment. Stage 3 = "development" which includes the specification and design of a new product, prototype development and prototype testing. Stage 4 = "manufacturing/marketing launch" which includes tooling and documentation, preproduction, testing and redesign, initial

⁴. The division of each stage of the innovation process in technological level is based on the "Activity-Decision Stage Model of the Innovation Process" developed by Kumar, et al., 1993.

marketing test. The weighted average of the extent to which new products progressed through various stages of the innovation process is another measure of technological innovation success for a company. Respondents were therefore asked to indicate the proportion of their ideas of new products which normally passed each stage in the technological innovation process within the last five years. However, during the interview, some Chinese companies were not able to give the accurate proportion of ideas passed in every single stage except the last stage - "manufacturing/marketing launch" stage. Even though some companies came up with their estimates for the first three stages, they reminded the interviewer that the result may not be accurate since they did not keep track of the proportion of ideas passed in stage 1 - "initial screening", stage 2 - "commercial evaluation" and stage 3 - "development" in the technological innovation process. Therefore the measure of technological innovation success using the extent to which new products progressed through various stages in the technological innovation process could not be employed in the analysis due to the large extent of missing data and potential inaccuracy of the data. Consequently, the technological innovation success for a company in this study is measured by the percentage of ideas of new products⁵ that passed the "manufacturing/marketing launch" stage.

For this study, commercial innovation success is measured by the shares of companies' sales volume realized through new products which were introduced into the market during the last five years.

(2). Interactions with external environment:

⁵. New products include totally new product, a significant change in a product. Marginal improvement in a product will be explicitly excluded from this study.

Four types of interactions between the company and its external environment have been investigated in the literature. They are contact with customers, contact/cooperation with research institutes and universities, contact/cooperation with other companies, and support from government.

To measure contact with customers, the respondents were asked to indicate on a five-point rating scale (i.e. 1 = no contact, 3 = limited contact, 5 = considerable contact) to what extent their companies have contact with customers in their innovation process.

Contact or cooperation with research institutes and universities is measured by counting the number of the following types of contacts or cooperations that existed among the company and other research institutes or universities. The respondents were asked to indicate if they have maintained contact or cooperation with research institutes and universities by:

- * having joint new product development projects with research institutes or universities
- * demanding consultancy service to solve a technical problem from research institutes or universities
- * demanding consultancy service to market a new product
- * using their laboratories
- * providing new product trial program to research institutes or universities
- * transferring highly qualified personnel from research institutes or universities on a temporary basis
- * transferring/training technical personnel to/in research institutes or universities on a temporary basis
- * transferring technology or acquiring licenses from research institutes or universities

Contact or cooperation with other companies involves two modes of contact or cooperation, one is with domestic companies and the other is with foreign companies. To measure contact or cooperation with other companies, companies were asked to indicate if they have established contact or cooperation with either domestic or foreign companies by:

- * having joint new product development projects with other companies
- * transferring R&D personnel from/to other companies on a temporary basis
- * getting financial support for innovation activities from other companies
- * getting technical support for innovation activities from other companies
- * gathering information about new product development from other companies
- * transferring technology or acquiring licenses from other companies

For the measurement of government support, the respondents were asked not only to indicate which of the following types of support they received from government but also to provide the degree of importance of each type from their perspectives (i.e. 1 = not important, 3 = important, 5 = very important) since each support may have a different degree of impact on a company's innovation process. A weighted number (see Table 5 for detailed calculation) of supports is used to measure government influences. The types of government support given to the respondents are as follows:

- * subsidy for innovation activities
- * low or no interest loan for innovation activities
- * tax incentives for R&D expenditure
- * consultancy service to solve a technical problem
- * consultancy service to market a new product

- * information support/transfer on market study
- * information support for feasibility study of new product development
- * R&D personnel training in government training program
- * transfer of technology or acquiring licenses from government laboratory
- * support for exploring markets for new product launch

(3). Internal variables:

Four internal variables are considered in this study, namely, firm size, R&D intensity, firm age and ownership of the company.

There are many methods in the existing literature to measure firm size, such as number of employees, sales or assets. This study chooses the number of employees to measure the size of Chinese firms for the following reasons.

First, the number of employees in the company is a commonly used method to measure firm size in the literature. By using this method to measure firm size, it would be convenient to compare the results with other studies.

Second, the data of sales and assets provided by different companies may not have been calculated in a consistent manner. For example, due to different accounting systems (such as cash basis or accrual basis) and different depreciation methods (such as accelerated or straight-line method), the data of sales and assets of companies may not be comparable. Thus the study results may not have a high degree of consistency.

R&D intensity can be measured based on the share of R&D employees of the whole staff and the R&D expenditure as a percentage of sales. The latter one is used for the measurement of R&D intensity in this study. This is not only because this method can accurately reflect the

intensity of R&D activities but also because in most Chinese companies, it is hardly feasible to identify the R&D employees. Based on the interview results, engineers who normally work in the production line often get involved in R&D activities. For example, if a R&D project needs more technical personnel, an engineer working in the production line may be transferred to the R&D department for a short period. Therefore, the share of R&D employees as the percentage of the total number of employees in a company may not be a reliable measure of a company's R&D intensity.

The age of the firm is measured by the number of years since its establishment⁶. The ownership of the firm is divided into five categories: 1 = state-owned⁷, 2 = collective⁸, 3 = foreign-owned⁹, 4 = joint venture¹⁰, 5 = other.

⁶. The year of establishment for a company refers to the year when the company was registered under its current name and ownership.

⁷. State-owned companies refer to the units which are exclusively owned by the central government.

⁸. Collective companies mainly refer to units owned by township government.

⁹. Foreign-owned companies include units owned by foreign investors, overseas Chinese or investors from Hongkong or Taiwan.

¹⁰. Joint ventures include joint-owned units by: (1) state and collective, (2) state and individual(s), (3) collective and individual(s), (4) Chinese and foreign investors.

V. METHODOLOGY

5.1 Research Design:

Although a large number of innovation activities took place during the past decade in China, few public data bases are available. A questionnaire¹¹ is chosen as the research instrument to obviate the need for public data bases.

The questionnaire is designed for factual inquiry. It was first written in English, then translated into Chinese and customized to Chinese business terms and expressions to avoid confusion (Yin, 1992). The questionnaire is designed to be specific and operational enough to entice respondents¹² to answer these questions without revealing any privileged information. Personal interview is the main method used to collect data in order to ensure the correct understanding of the questions and the terminologies used in the questionnaire. Telephone interview is also used to gather data from certain companies due to the interviewer's time shortage and inconvenient transportation.

¹¹. The questionnaire (i.e. interview schedule) in English and Chinese is enclosed as Appendix A and B respectively.

¹². The respondents were the directors of R&D Departments, vice presidents who are in charge of the companies' technology development, or the persons who are in charge of R&D activities in the companies.

5.2 Sample:

For this study, cities of Beijing and Tianjin are chosen since these cities are two of the three largest cities in terms of population, industrialization level and economic scale in China. The firms selected from these two cities could represent most electronics companies in China, thus there is little threat to the reliability and validity of this study.

There are 345¹³ (Beijing 139¹³, Tianjin 206¹³) electronics companies in the cities of Beijing and Tianjin. For the purpose of this study, only companies which have both internal R&D activities and manufacturing activities could be included in the sample. Based on the list of electronics companies in Beijing Statistical Yearbook of Electronics Industry and Tianjin Statistical Yearbook of Electronics Industry, 234 (Beijing 86, Tianjin 148) companies satisfied this criterion. However due to the interviewer's time and financial constraints and the inconvenient location of some companies, only 65 companies were randomly selected to form the sample of this study.

¹³. Sources: China Statistical Yearbook of Mechanical & Electronic Industries (Volume of Electronics), National Statistical Bureau, 1994.

5.3 Data Collection:

Pretesting of the questionnaire was done in 3 companies in order to ensure the effectiveness and clarity of the questions. No unanticipated difficulties or problems were found in the pretesting regarding the questionnaire. The questionnaire was deemed to be valid and was used for the data collection. The three companies in the pretesting were included in the sample (i.e. total of 65 companies) since no modification was made for the questionnaire after the pretesting.

The 65 companies selected in the sample were first contacted by telephone to explain the objective of the study, and their participation in the study was sought. Forty-nine out of 65 firms agreed to participate in this study and have personal interviews. The main reasons for not participating given by non-responding firms were as follows:

Fourteen firms were afraid that participating in this study might affect their firms' profiles with the government and be subjected to retaliation from the government since the data and information are used for a study which could be exposed in a foreign country, though full confidentiality was assured.

one firm claimed that their top manager went on a business trip and they could not participate in this study without the top manager's permission.

one firm stated that they simply do not have time to participate in the study.

Out of the participating firms, 35 firms were personally interviewed. The other 14 firms were interviewed by telephone due to interviewer's time shortage or the inconvenient location of the company. Among 49 completed questionnaires, one could not be used in the final analysis since the responding company was set up only a year ago and was not able to answer some

important questions. Consequently 48 completed questionnaires were used in the final analysis of this study.

5.4 Data Analysis:

The objective of this study is to analyze how a Chinese electronics firm's innovation success is affected by its interactions with the external environment. But apart from the consideration of the effects from external interactions, four internal factors (i.e. firm size, R&D intensity, firm age and ownership of company) which could have impacts on innovation success are also taken into account in the analysis.

The innovation success is tested at two levels, namely technological innovation success and commercial innovation success. Both levels are differentiated between higher success and lower success based on the medians of collected technological and commercial innovation success data, the dependent variables were therefore deemed to be dichotomous variables.

5.4.1 Selection of Statistical Techniques:

A variety of multivariate statistical techniques can be used to predict a binary dependent variable from a set of independent variables. Multiple regression analysis and discriminant analysis are two related techniques that quickly come to mind. However, these techniques require certain assumptions for the prediction rule to be optimal, such as the multivariate normality of the independent variables, the linear relationship between the dependent and independent variables, as well as equal variance around the regression line in the multiple regression analysis (Tabachnick and Fidell, 1990, Alreck and Settle, 1985). The logistic regression technique requires far fewer assumptions than multiple regression and discriminant analysis, and even when the assumptions mentioned above are satisfied, logistic regression still performs well (Hosmer and Lemeshow, 1989). Furthermore, the researcher does not believe that innovation success is a linear

function of external interactions. Integrating external interactions in one way or the other certainly lengthens a company's innovation potential and stimulates innovation success but on the other hand it is assumed that there is a limit to positive effects of cooperation. The marginal utilities of increasing cooperation are positive but decreasing. Therefore, the logistic regression technique appears to be appropriate in this study.

5.4.2 Data Analysis Procedures:

The data is analyzed using the statistical package SPSS for Windows, version 6.0. First, a frequency distribution of each variable is plotted using the FREQUENCIES program of SPSS. It displays how the sample is distributed on various variables and helps the researcher to identify if there is any bias or unexpected result existed in the sample.

Second, the correlations among these variables are analyzed with a BIVARIATE program to examine the inter-correlation between independent variables and the effect of each independent variable on outcome variables in order to test the hypotheses. The Pearson correlation coefficient is used to determine the strength of association among these variables.

Third, stepwise logistic regression is performed since bivariate correlation analysis can only examine the separate association of each variable with one another without considering the effects from other variables. With the logistic regression technique, it can not only find out which of the analyzed variables contribute the greatest combined effects on innovation success but also can assess how well the model fits the data. The logistic regression model of an event occurring (i.e. having higher success) can be written as:

$$\text{Prob (higher success)} = \frac{1}{1 + e^{-Z}}$$

Where Z is the linear combination

$$Z = B_0 + B_1X_1 + B_2X_2 + \dots + B_pX_p$$

where

$X_1; X_2; \dots X_p$ = independent variable

$B_0; B_1; B_2; \dots B_p$ = coefficient estimated from the data

The probability of having lower success is estimated as

$$\text{Prob (lower success)} = 1 - \text{Prob (higher success)}$$

In logistic regression analysis, two dependent variables, i.e., technological innovation success (TIS) and commercial innovation success (CIS) are first recoded to dichotomous variables based on the median (median of TIS = 60%, median of CIS = 61.5%) of each variable. Both technological innovation success and commercial innovation success are coded as 0 = "lower success" and 1 = "higher success". The independent variables entered in each analysis are as following:

- * CUSTOMER (extent of contact with customers)
- * UNIVERSI (contact/cooperation with research institutes and universities)
- * DCOMPANY (contact/cooperation with domestic companies)
- * FCOMPANY (contact/cooperation with foreign companies)
- * GOVERN (support from government)
- * RDSALE (R&D intensity)
- * EMPLOYEE (firm size)

* AGE (firm age)

* OWNER (ownership of the company)

The Wald statistic is used as the criterion for removing variables from the equation. Hosmer and Lemeshow (1989) noted that the choice of an "alpha" level in stepwise logistic regression will determine how many variables will ultimately be included in the model. If the alpha level is too stringent, such as the generally used one - $\alpha = 0.05$, some important variables could be left out of the model. They recommended an alpha level of between 0.15 to 0.20. In this study, the entry α level was set at 0.1 and the removal criterion was set at 0.15.

Finally, the respondents' comments during the interview, i.e. qualitative data are also analyzed. The information is used to explain variables and support statistical results.

VI. RESULTS AND DISCUSSIONS

6.1 Firm Profiles:

As discussed in Section 5.3, forty-nine companies filled out the questionnaire, however one questionnaire could not be used due to some important missing data. Table 4 summarizes some of the general characteristics of the 48 participating firms.

Table 4: Profile of Participating Firms

Variable ^a	Mean	Median	Minimum	Maximum
Dependent Variables:				
TIS (%)	59.8	60	1.5 ^b	100 ^b
CIS (%)	54.7	61.5	2.1 ^c	100 ^c
Independent Variables:				
CUSTOMER (rating scale: 1-5)	4.29	5	3	5
UNIVERSI (# of contact)	3	4	0	7
DCOMPANY (# of contact)	3	3	0	5
FCOMPANY (# of contact)	2	2	0	7
GOVERN (weighted #)	16	16	0	29
RDSALE (%)	2.2	1.7	0.3	10
EMPLOYEE (#)	953	828	18	3536
AGE (# of year)	28	29	2 ^d	57
OWNER (category:1-4)	N/A	1	1	4

- a. See Table 5 for the description of variables.
- b. Among 48 companies, one company shows TIS as 1.5% and another company shows 100%. The range of TIS for the remaining 46 companies is from 20% to 90%. The presence of extreme case of 1.5% is because that the studied company is a newly established company and most of their innovative projects are still in process. For the extreme case of 100% of TIS, it is because that this company normally acquires new products mainly through buying licenses from research institutes or universities, and only modifies the new products when necessary. Thus, this company has not experienced any failure in its technological innovation process by the time of the interview.
- c. Among 48 companies, two companies show 2.1% and 6.8% of CIS respectively, one company shows 100% of CIS. The CIS of remaining 45 companies ranges from 12% to 86%. The reasons for the extreme cases of CIS are similar as given above.
- d. Among 48 companies, two companies were established 2 and 3 years ago respectively. The age of the remaining 46 companies ranges from 7 to 57 years.

Table 5: Description of Variables

Variable	Definition	Measurement
Dependent variables:		
TIS	technological innovation success	% of ideas passed "manufacturing/marketing launch stage"
CIS	commercial innovation success	% of sales realized through new products
Independent variables:		
CUSTOMER	extent of contact with customers	five-point rating scale: 1 = no contact 2 = few contact 3 = limited contact 4 = more contact 5 = considerable contact
UNIVERSI	contact/cooperation with research institutes and universities	total # of contacts/cooperations
DCOMPANY	contact/cooperation with domestic companies	total # of contacts/cooperations
FCOMPANY	cooperation with foreign companies	total # of contacts/cooperations
GOVERN	support from government	total weighted # of government support*
RDSALE	R&D intensity	R&D expenses as % of sales
EMPLOYEE	firm size	total # of employees
AGE	firm age	# of years since establishment
OWNER	ownership of firm	category: 1 = state-owned 2 = collective 3 = foreign-owned company 4 = joint venture with foreign company

* The importance of each government support was weighted by the respondents (1 = not important, 3 = important, 5 = very important). The total weighted # of government support was calculated in the following two steps:

(1). The average degree of importance of a specific government support:

$$A = \frac{\Sigma(\text{degree of importance assigned by each respondent for that support})}{48}$$

(2). Total weighted # of government support of a specific firm:

$$W = \Sigma(\text{the government support which a firm actually get} * \text{the corresponding A calculated in step (1)})$$

As seen from Table 4, the firms' average percentage of technological innovation success (TIS) is approximately 59.8%, with a range from 1.5% to 100%. The probability of commercial innovation success (CIS) is close to TIS, which ranges from 2.1% to 100% with an average of 54.7%. The firms' average number of contacts with customers (CUSTOMER) is 4.29, with a range from 3 to 5, and a median of 5, which indicates that more than 50% of firms in the sample have established "considerable contact" with customers (This result is discussed in further detail later in this section). The average number of contact/cooperation with research institutes and universities (UNIVERSI) is 3, with a range from 0 to 7. The number of contact/cooperation with domestic companies (DCOMPANY) and foreign companies (FCOMPANY) ranges from 0 to 5 and 0 to 7 respectively, the average number of contact/cooperation is 3 for domestic companies and 2 for foreign companies. The average weighted number of government support (GOVERN) is 16 and ranges from 0 to 29. The firms' average R&D expenses as percentage of sales (RDSALE) is approximately 2.2%, with a range from 0.3% to 10%. This figure reveals that the investment in R&D activities in Chinese electronics companies is still low compared to an average of 4% of R&D expenses as percent of sales in electronics companies in Western countries. It could result mainly from a common financial constraint in existing Chinese firms, and therefore cooperation with foreign companies in innovation process should be further encouraged. This will not only absorb financial resources but also explore advanced technical resources and stimulate innovation success. The number of employees (EMPLOYEE) ranges from 18 to 3536, with an average of 953. The age of firms (AGE) ranges from 2 to 57, with an average of 28. For the ownership of companies (OWNER), the sample consisted of 34 state-owned firms, 12 collective firms, 1 foreign firm and 1 joint venture with foreign company.

As shown in Table 4, there are no substantial systematic biases in the sample, but there is a bias in the case of ownership (OWNER) and an unexpected result in the extent of contact with customers (CUSTOMER). The FREQUENCY results for these two variables are shown in Table 6.

Table 6. Frequency of Two Biased Variables

Variable	Value Label	Value	Frequency	Percent	Cum.Percent
OWNER	state-owned	1	34	70.8	70.8
	collective	2	12	25.0	95.8
	foreign-owned	3	1	2.1	97.9
	joint venture	4	1	2.1	100.0
CUSTOMER	no contact	1	0	0	0
	few contacts	2	0	0	0
	limited contact	3	12	25.0	25.0
	more contact	4	10	20.8	45.8
	considerable contact	5	26	54.2	100.0

As seen from Table 6, among 48 participating firms, there are 34 state-owned companies or more than 70% of firms in the sample are state-owned. This is because state-owned companies still dominate China. According to the statistics¹⁴, only 10% of electronics companies are foreign companies or joint ventures with foreign companies in the cities of Beijing and Tianjin. Therefore the result of the effect of ownership on innovation success has to be interpreted cautiously due to presence of biased data.

For the contact with customers (CUSTOMER), the result showed that 54.2% companies have "considerable contact" and each company in the sample indicated at least "limited contact" with customers. This result reveals that the impact of the transition from a planned economy in

¹⁴. Source: China Statistical Yearbook of Mechanical & Electronic Industries (Volume of Electronics), National Statistical Bureau, 1994.

China is far greater than expected. The qualitative data gathered through the interviews also reveals that most companies have contact with customers in one way or the other. According to the information provided by the respondents, there are two common methods to maintain contact with customers in the Chinese electronics industry. One is direct methods, which the company uses its own channel, such as market surveys and direct requests from customers, to keep contact with their customers in order to meet customers' needs. The other one is an indirect method through associations. Most companies in related areas, such as computer, TV, and etc., form their own association called "Xiehui" in China. The objective of this association is to collect new product information from customers, such as what kind of new products they want and how many they need. Then the information will be passed to the companies during the members meetings. Both kinds of contact are counted as contact with customers in the study. Therefore, it is not surprising that every company in the sample indicated having at least "limited contact" with customers and more than half of the companies (i.e. 54.2%) indicated having "considerable contact" with customers (see Table 6 for detailed summary) since 47 out of 48 firms in the sample had joined such associations. As discussed in the literature, few contacts existed between companies and customers in planned economy before economic reform in the late 1970s. This study however shows that many Chinese companies have established considerable contacts with their customers, which implies that the transition from a planned economy to a market economy has a widespread and profound impact on a firm's interaction with its external environment in terms of contact with customers.

6.2 Correlation Between Independent Variables:

To test the inter-correlation between independent variables, the Pearson correlation coefficient is used to measure the strength of association. The criterion for defining multicollinearity is chosen as .70 (Tabachnick, et al. 1990). Table 7 displays the correlation matrix between the independent variables.

Table 7: Correlation Matrix Between Independent Variables

Independent Variables	Independent Variables				
	CUSTOMER	UNIVERSI	DCOMPANY	FCOMPANY	GOVERN
CUSTOMER	1				
UNIVERSI	.5010 ^a	1			
DCOMPANY	.4207 ^a	.5425 ^a	1		
FCOMPANY	.4167 ^a	.3437 ^b	.0898	1	
GOVERN	.2448	.4285 ^a	.4476 ^a	.0973	1
EMPLOYEE	.4092 ^a	.3634 ^b	.3315 ^b	.4172 ^a	.3908 ^a
RDSALE	.2307	.0583	.0825	.4576 ^a	-.3056 ^b
AGE	.0796	.1174	.2042	-.1658	.3457 ^b
OWNER	-.0772	-.3435 ^b	-.2550	.1500	-.2886 ^b

Continued:

Independent Variables	Independent Variable			
	EMPLOYEE	RDSALE	AGE	OWNER
EMPLOYEE	1			
RDSALE	.2125	1		
AGE	.4349 ^a	-.3060 ^b	1	
OWNER	.3123 ^b	.1695	-.4639 ^a	1

a. $p < .01$, b. $p < .05$

Based on the criterion of 0.7 for defining multicollinearity, no significant correlation is found between independent variables. However, moderate correlation is found between some variables. As shown in Table 7, 11 coefficients are positive at $p < .01$ and 1 coefficient is negative at $p < .01$. Moreover 5 coefficients are found positive at $p < .05$ and 4 coefficients are found negative at $p < .05$ (The moderate correlation coefficients are highlighted in Table 7).

For the interaction between a company and its external environment, the results show that contact with customers (CUSTOMER), contact or cooperation with research institutes and universities (UNIVERSI), contact or cooperation with other companies (DCOMPANY and FCOMPANY), and government support are all positively correlated except CUSTOMER and GOVERN, DCOMPANY and FCOMPANY, FCOMPANY and GOVERN. It seems that if a company which adopts a strategy for the external interaction, it normally tends to interact with all the external entities (i.e. $R = .5010$ between CUSTOMER and UNIVERSI, $R = .4207$ between CUSTOMER and DCOMPANY, $R = .4167$ between CUSTOMER and FCOMPANY, $R = .5425$ between UNIVERSI and DCOMPANY, $R = .3437$ between UNIVERSI and FCOMPANY, $R = .4285$ between UNIVERSI and GOVERN, $R = .4476$ between DCOMPANY and GOVERN).

With regard to the correlations between firm size (EMPLOYEE) and other independent variables, the results show that firm size has a positive correlation with all the other independent variables except R&D intensity (RDSALE) (i.e. $R = .4092$ between EMPLOYEE and CUSTOMER, $R = .3634$ between EMPLOYEE and UNIVERSI, $R = .3315$ between EMPLOYEE and DCOMPANY, $R = .4172$ between EMPLOYEE and FCOMPANY, $R = .3908$ between EMPLOYEE and GOVERN, $R = .4349$ between EMPLOYEE and AGE, $R = .3123$ between

EMPLOYEE and OWNER). This implies that large companies have more contacts or cooperations with its external environment and also receive more government support than small companies. Meanwhile, large firms are perceived as older and more likely to be state-owned.

Concerning the R&D intensity (RDSALE), the results show that RDSALE is only positively correlated with FCOMPANY ($R = .4576$) and negatively correlated with GOVERN ($R = -.3056$), which indicates that R&D intensive companies tend to cooperate more with foreign companies and get less support from government.

Firm age (AGE) is found having positive correlation with government support (GOVERN) ($R = .3457$) and firm size (EMPLOYEE) ($R = .4349$) and negative correlation with R&D intensity (RDSALE) ($R = -.3060$). This result shows that older firms get more support from government and their firm sizes are larger. However older firms seem to have lower R&D intensity.

The results for the ownership of the firm (OWNER) show that OWNER is negatively correlated with 3 variables, namely, UNIVERSI ($R = -.3435$), GOVERN ($R = -.2886$) and AGE ($R = -.4639$). This implies that foreign companies and joint venture with foreign companies show few contacts or cooperations with research institutes and universities and get less support from government. Meanwhile foreign companies and joint venture with foreign companies seem to have smaller firm size and to be younger than state-owned and collective companies. Also a positive correlation is found between OWNER and EMPLOYEE ($R = .3123$), which indicates that state-owned companies show large firm size than foreign companies and joint-ventures with foreign companies. However, due to the presence of biased data regarding the ownership of the

firm, this result is not reliable.

6.3 Findings versus Hypotheses:

The Pearson correlation matrix between dependent variables and independent variables is shown in Table 8.

Table 8: Correlation Matrix Between Dependent Variables and Independent Variables

Independent Variables	Dependent Variables	
	TIS	CIS
CUSTOMER	R=0.5424 (p=.000)	R=0.4212 (p=.003)
UNIVERSI	R=0.6304 (p=.000)	R=0.5126 (p=.000)
DCOMPANY	R=0.6619 (p=.000)	R=0.2341 (p=.109)
FCOMPANY	R=0.3594 (p=.012)	R=0.5943 (p=.000)
GOVERN	R=0.3287 (p=.023)	R=0.0719 (p=.627)
EMPLOYEE	R=0.4105 (p=.004)	R=0.3658 (p=.011)
RDSALE	R=0.3171 (p=.028)	R=0.3969 (p=.005)
AGE	R=0.1109 (p=.453)	R=-0.2570 (p=.078)
OWNER	R=-0.1224 (p=.407)	R=0.1822 (p=.215)

Hypothesis 1: Companies which maintain contact with their customers have higher innovation success than other companies

As seen from Table 8, the findings support hypothesis 1, contact with customers (CUSTOMER) is very strongly correlated with technological innovation success (TIS) ($R = 0.5424$ at $p < 0.0005$). The correlation with commercial innovation success (CIS) is also very strong but weaker than with technological innovation success ($R = 0.4212$ at $p < 0.005$). This result is consistent with other studies regarding the positive relationship between customer contact and innovation success. For example, an empirical study by Hippel (1978) shows that the level of the manufacturer's "understanding of user's need" is strongly correlated with the level of commercial success attained by a new product.

The result obtained from this study demonstrates the positive effect of contact with customers on innovation success in Chinese electronics companies. As discussed in Section 6.1, most Chinese companies maintain contact with customers either directly or indirectly, and their innovation tends to be more a response to market signals than to the State's exercise of its control in the planned economy. This finding illustrates that most Chinese companies have established contact with their customers and such contact plays a crucial role in achieving innovation success in Chinese electronics industry.

Hypothesis 2: Companies which cooperate with research institutes and universities have higher innovation success than those which do not engage in cooperative activities.

Hypothesis 2 is fully confirmed. The significant correlation is found with both technological innovation success (TIS) ($R = 0.6304$ at $p < 0.0005$) and commercial innovation success (CIS) ($R = 0.5126$ at $p < 0.0005$). This result is consistent with the literature. With the growing complexity of technological change in China, more and more of the emerging technologies require highly diversified knowledge inputs from a large number of scientific and technological disciplines. By cooperating with research institutes and universities, a company can obtain complementary external know-how.

The qualitative results also confirm this hypothesis. More than 50% of the companies in the sample stated that cooperating with research institutes and universities is a key success factor in innovation process. Due to the growing complexity of the innovation process it is hardly feasible for most Chinese companies to undertake innovative projects individually. The interview results indicate that a variety of relationships now exist between research institutes and Chinese

companies. These include consultancy services, joint R&D projects, long-term cooperation agreements, joint bidding for government projects, etc.. The most common contact between two actors is found to be the consultancy service primarily for technical problems. More than 80% of the companies in the sample indicated this form of contact with research institutes and universities. According to the respondents, consultancy services provided by research institutes and universities is a relatively inexpensive, rapid and selective way of transferring information and solving technical problems of companies compared to other modes of contact or cooperation. Especially for small and some medium-sized companies, which do not have strong R&D capacity, consultancy service is an easier way to obtain essential know-how for innovation processes.

Hypothesis 3: Companies which have established arrangements for R&D cooperation with other companies (either domestic or foreign companies) have higher innovation success than companies which do not.

Hypothesis 3 is confirmed. As shown in Table 8 there is a very strong correlation between technological innovation success (TIS) and cooperation with domestic companies (DCOMPANY) ($R = 0.6619$ at $p < 0.0005$). The correlation between commercial innovation success (CIS) and cooperation with domestic companies (DCOMPANY) is positive but very weak ($R = 0.2341$ at $p = 0.109$).

For cooperation with foreign companies (FCOMPANY), FCOMPANY shows a high correlation with commercial innovation success (CIS) ($R = 0.5943$ at $p < 0.0005$). The correlation with technological innovation success (TIS) is also significant ($R = 0.3594$ at $p < 0.05$) but

weaker than with CIS.

According to the literature, R&D cooperation with other companies, such as suppliers, competitors, etc., may constitute important sources of innovative know-how. The innovation process often requires interdisciplinary know-how which may lie in a totally different field compared to a company's previous R&D expertise (Gemunden, et al., 1992). By cooperating with other companies, a firm can obtain the necessary knowledge and technologies for innovation process and consequently increase the possibilities of achieving innovation success.

During the interview discussions, many respondents noted that both modes of cooperation with other companies (i.e. domestic and foreign) are important in the innovation process, however they are more interested in cooperating with foreign companies. The major motive behind such cooperation, as stated by 2 respondents, is that foreign companies are perceived as pools of financial and technical resources. By cooperating with foreign companies, Chinese firms can not only obtain necessary financial and technical resources, but also can gain access to advanced technologies, which may substantially facilitate innovation process. For example, one responding TV manufacturing company indicated that their sales volume had increased by 40% after acquiring new production equipment from a Japanese company. Meanwhile their new products have gained national awards twice since then. This is mainly because the quality of their products has been improved dramatically. Moreover by using the new production equipment, it enables the company to add more functions to their TV products and to change the design of their TVs. Thus the products can meet more of the customers' needs, making the company's new products very successful.

Hypothesis 4: Companies which get government support have higher innovation success than other companies.

There exist diverse opinions in the existing literature regarding the influences of government on the industrial innovation process . Some researchers (e.g. Houttuin, 1985; Sweeney, 1985) propose that government is one of the major actors in the innovation process. It can affect the direction and speed of developments in innovation processes through its financial incentives, policy, regulation and laws. However there is another group of researchers (e.g. Solomon & Tornatzky, 1986) who argue that government can only play a limited and indirect role. According to them the technological innovation is only indirectly responsive to economic and policy levers. Capital investment and regulatory policy can not automatically yield technological innovation.

The result of this study concerning hypothesis 4 is shown in Table 8. Technological innovation success (TIS) and support from government (GOVERN) are correlated ($R = 0.3287$ at $p < 0.05$). However as to commercial innovation success (CIS), no significant correlation is found ($R = 0.0719$ at $p = 0.627$). Thus hypothesis 4 is partially confirmed.

In order to determine the reason why government support is only correlated with technological innovation success, a further detailed analysis regarding each government support as displayed in Table 9 was done.

Table 9: Summary of Government Support

Government support	Freq.^a	Mean^b	Median^b	Min^b	Max^b
1. Subsidy for innovation activities	25	3.88	4	2	5
2. Low or no interest loan for innovation activities	42	3.98	4	2	5
3. Tax incentives for R&D expenditure	40	4.21	4	2	5
4. Consultancy service to solve a technical problem	14	2.38	2	1	4
5. Consultancy service to market a new product	7	1.92	2	1	4
6. Information support or transfer on market study	23	2.83	3	1	5
7. Information support for feasibility study of new product development	9	2.19	2	1	5
8. R&D personnel training in government training program	34	2	2	1	4
9. Transfer of technology or acquiring licenses from government laboratory	10	2.85	3	1	5
10. Support for exploring markets for new product launch	27	3.15	3	1	5

- a. The number of companies which get this support (N = 48)
- b. Rating scale of each government support: 1 = not important, 3 = important, 5 = very important

As shown in Table 9, government financial incentives, such as subsidy for innovation activities (mean = 3.88), low or no interest loan for innovation activities (mean = 3.98) and tax incentives for R&D expenditure (mean = 4.21) are perceived as important factors in achieving innovation success, which explicitly illustrates that financial support is still in great demand among Chinese electronics companies. Thus, Chinese government should still focus on financial support, such as subsidy or direct funding, low or no interest loan for innovation activities.

With regard to the frequency of government support that the company actually gets, Table

9 shows that the most frequent government support used by industry is low or no interest loan for developing new products. Forty-two out of forty-eight companies obtained this support. Tax incentives for R&D expenditure is ranked as the second most frequent support (40 out of 48). R&D personnel training in government training program is ranked as the third one. It is interesting to note that although many companies (i.e. 34 out of 48) received R&D personnel training from government, the average degree of importance regarding this support is only perceived as 2 (i.e. less important). This could be mainly because that many companies usually can "borrow" highly qualified personnel or experts from research institutes, universities or from other companies on a temporary basis. Thus even if they do not have qualified R&D personnel, they can always get the experts from external environment.

From the frequency result of government support for new product development, it is observed that most of the supports that Chinese companies obtained from government are at the technical level. According to the respondents, government low or no interest loans are only granted to innovative projects at the technical level. Tax incentives for R&D expenditure includes tax exemptions and tax credits for R&D expenses. Also the training program provided by government is only for technical personnel. Furthermore, as seen from Table 9, the frequencies of government support at the commercial level are low. For example, only 7 out of 48 firms received consultancy service to market a new product. And 9 out of 48 firms obtained information support for a feasibility study of new product development. These frequency rates are much lower than those for government support at the technological level. Thus it is recommended that while focusing the support on technological level, Chinese government should also develop some more appropriate support to facilitate the commercialization of new products.

Also as one respondent urged that government should provide assistance in searching cooperative partners for companies with compatible goals and complementary resources. This will explicitly facilitate the cooperation among companies and thus increase the possibilities of innovation success.

Hypothesis 5: Large companies show higher innovation success than small companies.

The findings support hypothesis 5. As seen in Table 8, firm size (EMPLOYEE) is strongly correlated with technological innovation success (TIS) ($R = 0.4105$ at $p < 0.005$). The significant correlation of firm size with commercial innovation success (CIS) is found at $R = 0.3658$ ($p < 0.05$). This result is consistent with a recent study (Gemunden, et al., 1992), which finds that large companies show higher technological and commercial innovation success. It is not surprising that the same holds true in China. As shown in Table 7, firm size (EMPLOYEE) is positively correlated with each variable regarding the interaction between a company and its external environment. This implies that large Chinese companies have more advantages in exploiting external resources than small firms.

Hypothesis 6: R&D intensive companies show higher innovation success than other companies.

Though the cultivation of external technological resources is vital for a firm's innovation success, internal R&D activities seem indispensable in new product development. A company can not only understand external input but also must have the ability to develop it further and adjust it to its own needs. Therefore R&D intensity is usually regarded as the prerequisite of achieving innovation success.

Again this hypothesis is confirmed. The correlation matrix in Table 8 shows that R&D intensity (RDSALE) is highly correlated with both commercial innovation success (CIS) ($R = 0.3969$ at $p = 0.005$) and technological innovation success (TIS) ($R = 0.3171$ at $p < 0.05$).

Hypothesis 7: Older companies have higher innovation success.

Older companies are normally perceived to have more advantages in achieving innovation success than younger companies. It is not only because older companies have accumulated more experience in managing R&D activities but also because they may have obtained large market share and established more connections with their customers and external partners.

However the results of this study seem to contradict the literature. As seen from Table 8, the correlation between firm age (AGE) and commercial innovation success (CIS) is strong but negative ($R = -0.2570$ at $p < 0.1$). Moreover no correlation is found between firm age (AGE) and technological innovation success (TIS) ($R = 0.1109$ at $p = 0.453$).

The result shows that younger companies in China have higher commercial innovation success than older companies. Qualitative data provides some support to this result. According to a comment from one of the respondents, "Many old companies in China have serious financial burden since they have to pay full amount of pension and health care expenses for all the people retired from their companies. For example, Zhang said, "There is a situation in our company, which on an average every 1 working employee is supporting 3 retired people, that is the profit brought from one employee has to pay pension and health care expenses for 3 retired people before it can be spend anywhere else." The older the companies are, the more retired people they have, and consequently the more financial burden they bear. This has become a common problem

among most aged companies in China. However younger companies do not have such financial burdens, they have more flexibility in exploiting their financial resources than older ones. Meanwhile bureaucracy or red tape is more common in older and larger companies, which may impede the pace of the innovation process. It is no wonder that younger companies show higher commercial innovation success than older ones in Chinese electronics industry.

Hypothesis 8: State-owned companies have higher innovation success than other companies.

Hypothesis 8 is not confirmed. No significant correlation is found between the ownership of a company (OWNER) and innovation success (TIS and CIS). This partially results from the bias in the distribution of the variable, OWNER, since 34 out of 48 companies in the sample are state-owned companies, and there is only 1 foreign company and 1 joint venture with foreign company in the sample. According to Alreck and Settle (1985), the presence of biased data may lead to inaccurate estimates and errors when making interpretations and drawing conclusions. Evidently, this result can not be accepted with a high degree of confidence due to biased data.

6.4 Logistic Regression Analysis:

In order to decide how well the model fits the data and which of the analyzed variables have a specific influence on innovation success, a stepwise logistic regression was performed. As mentioned in Section 5.4.2, the bivariate correlation analysis can not measure the combined effects of each variable on the outcome variables simultaneously. However with the stepwise logistic regression technique, the factors which have the most explanatory power enter the model sequentially, and only those variables having the greatest joint predictive power remain in the equation. This does not necessary imply that the variables which do not enter the equation are not important. The implication for omitted variables is that they do not contribute any additional information over and above that already contributed by the variables already included in the model (Hosmer and Lemeshow, 1989).

There are various ways to assess whether or not the model fits the data. "The classification table" is one way to assess how well the model fits the data. It compares the predictions to the observed outcomes. The higher the percentage of cases being correctly classified, the better the model fits. Another way of assessing the goodness of fit of the model is to examine how "likely" the sample results actually are, given the parameter estimates. A good model is one that results in a high likelihood of the observed results, namely the non-significant value of Chi-Square.

6.4.1 Results of Technological Innovation Success:

Figure 3 shows the logistic results for technological innovation success.

Figure 3. Logistic Results for Technological Innovation Success

2 Log Likelihood	42.612		
Goodness of Fit	52.074		
	Chi-Square	df	Significance
Model Chi-Square	22.593	3	.0000
Improvement	4.356	1	.0369

Classification Table for Technological Innovation Success (TIS)

PREDICTED

lower success higher success Percent Correct

OBSERVED

lower success	25	3	89.25%
higher success	6	14	<u>70.00%</u>
		Overall:	81.25%

Variables in the Equation

Variables	B	S.E.	Wald	df	Sig	R	Exp(B)
UNIVERSI	.4857	.2536	3.6687	1	.0554	.1600	1.6253
DCOMPANY	.8707	.4175	4.3487	1	.0370	.1898	2.3865
RDSALE	69.0857	31.4847	4.8148	1	.0282	.2078	1.01E+30
Constant	-6.0157	1.8990	10.0353	1	.0015		

From "Classification Table for Technological Innovation Success" in Figure 3, it is observed that the model correctly classified 89.25% of lower technological innovation success cases and 70% of higher technological innovation success cases. The overall percentage of cases

correctly classified is about 81.25%. The model for technological innovation success therefore fits fairly well. Also as shown from the "Variables in the Equation" in Figure 3, the key variables that influence technological innovation success based on the ranking of importance are:

- * RDSALE (R&D intensity) ($\text{Exp(B)} = 1.01\text{E} + 30$)
- * DCOMPANY (contact/cooperation with domestic companies) ($\text{Exp(B)} = 2.3865$)
- * UNIVERSI (contact/cooperation with research institutes and universities) ($\text{Exp(B)} = 1.6253$)

This result shows that when taking into account the effects from other variables on technological innovation success, contact/cooperation with research institutes and universities, contact/cooperation with other companies (specifically with domestic companies), and R&D intensity have the greatest joint predictive power over technological innovation success. As shown in "Variables in the Equation" of Figure 3, UNIVERSI ($R = 0.1600$), DCOMPANY ($R = 0.1898$) and RDSALE ($R = 0.2078$) show a positive contribution to the model, which confirms the bivariate results.

6.4.2 Results of Commercial Innovation Success:

The results for commercial innovation success in logistic regression analysis are shown in Figure 4. The results show that the model fits the data very well.

Figure 4. Logistic Results of Commercial Innovation Success

2 Log Likelihood	12.130		
Goodness of Fit	13.369		
	Chi-Square	df	Significance
Model Chi-Square	54.412	5	.0000
Improvement	-0.951	1	.3294

Classification Table for Commercial Innovation Success (CIS)

	PREDICTED		
	lower success	higher success	Percent Correct
OBSERVED			
lower success	23	1	95.83%
higher success	1	23	<u>95.83%</u>
	Overall:		95.83%

Variables in the Equation

Variables	B	S.E.	Wald	df	Sig	R	Exp(B)
UNIVERSI	4.0657	2.0457	3.9501	1	.0469	.1712	58.3042
FCOMPANY	1.6424	.8355	3.8625	1	.0494	.1673	5.1658
GOVERN	-.9042	.4451	4.1256	1	.0422	-.1787	.4049
EMPLOYEE	.0139	.0072	3.6820	1	.0550	.1590	1.0140
AGE	-.6698	.3970	2.8469	1	.0916	-.1128	.5118
Constant	2.2100	4.1309	.2862	1	.5927		

As seen from "Classification Table for Commercial Innovation Success" in Figure 4, the model correctly classified both lower commercial success and higher commercial innovation success at 95.83%. The overall percentage of cases correctly classified is 95.83%. As the "Variables in the Equation" shows that the key variables that influence commercial innovation success based on the ranking of important are:

- * UNIVERSI (contact/cooperation with research institutes and universities) ($\text{Exp(B)} = 58.3042$)
- * FCOMPANY (contact/cooperation with foreign companies) ($\text{Exp(B)} = 5.1658$)
- * EMPLOYEE (firm size) ($\text{Exp(B)} = 1.0140$)
- * AGE (firm age) ($\text{Exp(B)} = .5118$)
- * GOVERN (support from government) ($\text{Exp(B)} = .4049$)

This result shows that when taking into account the effects from other variables on commercial innovation success, contact/cooperation with research institutes and universities, contact/cooperation with foreign companies, government support, firm size and firm age have the greatest joint predictive power over commercial innovation success. As shown in "Variables in the Equation" of Figure 4, UNIVERSI ($R = 0.1712$) and FCOMPANY ($R = 0.1673$) show a positive contribution to the model, GOVERN ($R = -0.1787$) and AGE ($R = -0.1128$) have negative effects on the equation.

The logistic regression analysis confirms the bivariate results except for the effect of government support. In bivariate analysis, government support shows no significant correlation

to commercial innovation success ($R = 0.0719$ at $p = 0.627$), however a negative effect on commercial innovation success is found in logistic regression analysis, this may result from the inter-correlations between government support and other predictive variables, such as contact or cooperation with research institutes and universities ($R = .4285$ at $p < .01$), contact or cooperation with other domestic companies ($R = .4476$ at $p < .01$). A detailed inter-correlation between independent variables is show in Table 7.

VII. CONCLUSIONS

Based on the results of hypothesis testing, this study documents that the interaction between a company and its external environment plays a crucial role in achieving innovation success in the Chinese electronics industry. Except for government support, which shows a positive effect on innovation success only at the technological level, all the other modes of interactions (i.e. contact with customer, contact/cooperation with research institutes and universities, contact/cooperation with other companies) contribute positively to innovation success at both levels.

The analysis also takes into account relevant internal variables, namely firm size, R&D intensity, firm age and ownership of the company. The findings indicate that firm size and R&D intensity show positive influence on technological innovation success and commercial innovation success. Firm age, however, shows a negative effect on commercial innovation success. No correlation is found between firm age and technological innovation success. Also the ownership of the company seems have no effect on innovation success¹⁵.

Furthermore the results from the logistic regressions find that contact/cooperation with research institutes and universities (UNIVERSI), contact/cooperation with domestic companies (DCOMPANY) and R&D intensity (RDSALE) have the greatest predictive power in technological innovation success. At the level of commercial innovation success, variables of contact/cooperation with research institutes and universities (UNIVERSI), contact/cooperation

¹⁵. Due to the presence of biased data regarding ownership of the company, this result may not be accepted with a high degree of confidence.

with foreign companies (FCOMPANY), government support (GOVERN), firm size (EMPLOYEE) and firm age (AGE) contribute the greatest combined effects.

In summary, the interaction with the external environment is a strategic approach which could be used by the Chinese electronics industry to exploit external resources and know-how in the innovation process. This will facilitate the innovation process and contribute to innovation success.

VIII. BENEFITS AND LIMITATIONS

8.1 Benefits:

China, since the inception of economic reform in the late 1970s, has reduced government control over enterprises and encouraged more freedom and more interactions between companies and their external environment. This study provides an analysis of the effects of interaction between electronics companies and their external environment on innovation processes. Meanwhile, the results found in logistic regression analyses can help Chinese companies to identify the key variables in achieving innovation success and therefore pay more attention on these factors in order to design a better strategy to manage innovation process.

Electronics has been regarded as having strategic importance and has been selected as one of the major development areas by the Chinese government. By choosing the electronics industry, this study has provided important insights into the working of the current Chinese system and the degree to which Chinese industries are experiencing bottlenecks, financial, organizational, and technological, in their move to revitalize the electronics industry. Meanwhile, this study provides a good foundation for a more rigorous study in this area and it also opens up a number of issues for future research

8.2 Limitations:

Due to time and financial constraints, only the electronics companies in the cities of Beijing and Tianjin area are considered in this study. Although Beijing and Tianjin are two major industrial cities in north China, this may still pose threats to the generalizability of this study. For example, because Beijing and Tianjin are situated in the capital regions, companies in these two cities may have easier access to government for support. Companies in the cities of south China, such as Shanghai, Guangzhou and Shenzhen, on the other hand, may obtain less support from the government.

Furthermore, because of time constraints and the potential difficulty in obtaining all the necessary data, it was not possible to take into consideration too many internal organizational factors in this study. Only four internal factors, namely firm size, R&D intensity, firm age and ownership of the firm, were taken into account in the study, which may not be sufficient to fully analyze how the innovation success is affected by a company's interaction with its external environment. For example, firm location and sector of industry can also have effect on innovation success. Companies located in south China, such as Shenzhen, Guangzhou and Shanghai are usually perceived to have higher level of advanced technology and more highly qualified personnel than companies located in north China, such as Tianjin and Shenyang. Meanwhile the innovation pace of companies in different industrial sectors, such as electronics, chemicals and transportation, may also be different. Thus a more exhaustive study could be done by taking more internal factors into account when analyzing innovation success in Chinese companies.

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APPENDIX A

INTERVIEW SCHEDULE

I. Company Background:

1. Company name: _____
2. Type of business: _____
(e.g. manufacturing computer, electronic instrument, radio, video, domestic appliance, communication equipment and other electronic products)
3. Year of company's establishment: _____
4. Please indicate the following information for 1994, estimating where necessary:
 - (1). Number of employees (full-time): _____
 - (2). Number of employees working in your formal R&D department (if any): _____
 - (3). Number of employees other than R&D department involved in innovation activities (if any): _____
(please convert part-time employees involved into equivalent number of full-time employees based on their working hours if applicable)
 - (4). Normal R&D expenses as percentage of sales each year during the last five years (i.e. 1990-1994): _____%
 - (5). Ownership of the Company, please circle the appropriate term:
☐ state-owned ☐ collective ☐ domestic private
☐ foreign-owned ☐ joint venture
☐ other, please specify:

II. New Product Information:

(New products include totally new products or significantly changed products. Marginally improved products are excluded from this study)

1. Please indicate the proportion of your ideas for new products which passed each of the following stages during the last five years (i.e. 1990 - 1994 inclusive):

- (1). % of ideas which passed "initial screening" stage, including preliminary marketing assessment, preliminary financial assessment and preliminary technical assessment

_____ %

- (2). % of ideas which passed "commercial evaluation" stage, including detailed marketing assessment, detailed financial assessment and detailed technical assessment

_____ %

- (3). % of ideas which completed "development" stage, including specification and design of a new product, prototype development and prototype testing

_____ %

- (4). % of ideas which passed "manufacturing/marketing launch" stage, including tooling, documentation, preproduction, testing and redesign, initial marketing test

_____ %

2. How many new products went into the manufacturing process during the last five years (i.e. 1990 - 1994 inclusive)?

3. How many new products have been launched into the market during the last five years (i.e. 1990 - 1994 inclusive)?

4. What proportion of the sales was realized through these new products during the last five years (i.e. 1990 - 1994 inclusive)?

_____ %

III. Information of External Interactions:

1. To what extent did your company have contact with customers in your innovation processes during the last five years (i.e. 1990 - 1994)? Please indicate it on a five-point rating scale (1 = no contact, 3 = limited contact, 5 = considerable contact).

(innovation process is defined as the total process from the inception of an idea through to the manufacture of a product and finally to its ultimate sale)

No Contact

Limited Contact

Considerable Contact

1

2

3

4

5

2. Please mark at appropriate places the purpose of your company's formal or informal ongoing contact/cooperation with any research institute or university during the last five years (if any):

(Formal contact is defined as the contact made through a contract or a general agreement under written document.)

(Informal ongoing contact is defined as the current existing contact without any written document)

- () for joint new product development projects
- () for consultancy service to solve a technical problem
- () for consultancy service to market a new product
- () for using their laboratories
- () for new product trial
- () for temporary transfer of highly qualified personnel from a research institute or a university
- () for temporary transfer/training of your company's technical personnel to/in a research institute or a university
- () for transfer of technology or acquisition of licenses
- () other, please specify:

3. Please mark at appropriate places the purpose of your company's formal or informal ongoing contact/cooperation with other companies (domestic or foreign) during the last five years (if any):

(please check "Domestic" or "Foreign" to indicate with what kind of companies you have this kind of contact or cooperation)

() for joint new product development projects	Domestic	Foreign
() for temporary transfer of R&D personnel
from/to another company	Domestic	Foreign
() for getting financial support for innovation activities	Domestic	Foreign
() for getting technical support (i.e. technical consultancy,
equipment loan) for innovation activities	Domestic	Foreign
() for gathering information about new product development	Domestic	Foreign
() for transfer of technology or acquisition of licenses	Domestic	Foreign
() other, please specify:		

_____ Domestic Foreign

_____ Domestic Foreign

4. Listed below are a number of ways of getting government support in the innovation process. Please rate the importance of each kind of support and check the box on the left if that support applies to your company:

1 means not important

3 means important

5 means very important

() subsidy for innovation activities	1	2	3	4	5
() low or no interest loan for innovation activities	1	2	3	4	5
() tax incentives for R&D expenditure	1	2	3	4	5
() consultancy service to solve a technical problem	1	2	3	4	5
() consultancy service to market a new product	1	2	3	4	5
() information support/transfer on market study	1	2	3	4	5
() information support for feasibility study
of new product development	1	2	3	4	5

() R&D personnel training in government training program	1	2	3	4	5
() transfer of technology or acquisition of licenses
from government laboratory	1	2	3	4	5
() support for exploring markets for new product launch	1	2	3	4	5
() other, please specify:

_____ | 1 | 2 | 3 | 4 | 5 |
| _____ | 1 | 2 | 3 | 4 | 5 |

IV. Information About Respondent (Optional):

1. Name: _____
2. Position: _____
3. Years in service with this company: _____

THANK YOU VERY MUCH FOR YOUR SUPPORT AND COOPERATION!

2 of /de 2

PM-1 3 1/2"x4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

PRECISIONSM RESOLUTION TARGETS

一. 公司背景:

1. 公司名称: _____

2. 企业类型: _____

(如: 制造电脑, 电子仪器, 收音机, 摄相机, 家用电器, 通讯器材或者其它电子产品)

3. 公司设立时间: _____

4. 请注明下列一九九四年情况, 如果必要可以估计:

(1). 职工人数 (全日制职工): _____

(2). 正式的科研部门人数 (如果有): _____

(3). 除正式科研部门人员以外, 其它部门人员参与科研项目的人数 (如果有): _____

(如果有非全日制职工, 请根据他们工作时间的长短转换为相当数量的全日制职工)

(4). 在过去五年里 (1990 - 1994年) 平均每年科研费用占销售收入的百分比: _____%

(5). 公司持有人所属:

☐ 国营企业☐ 集体企业☐ 国内私有企业☐ 外国企业☐ 中外合资企业☐ 其它类型, 请注明:

二. 新产品信息:

(新产品包括全新产品, 经过加工改造的新产品, 其中边缘改造的新产品将不包括在此项调查中)

1. 请注明在过去五年内(1990 - 1994 年)你公司的新产品构思在每个革新过程中完成的百分比:

(1). 新产品通过'最初的审查阶段'的百分比。此阶段包括初步的市场评估, 初步的资金评估, 初步的技术评估: _____%

(2). 新产品通过'商业性的评估阶段'的百分比。此阶段包括详细的市场评估, 详细的资金评估, 详细的技术评估: _____%

(3). 新产品通过'开发阶段'的百分比。此阶段包括新产品的定型与设计, 新产品的原型开发与测试: _____%

(4). 新产品通过'生产/推销阶段'的百分比。此阶段包括试前生产, 测试与重新设计, 初始的推销测试: _____%

2. 在过去五年(1990 - 1994 年)内有多少新产品进入生产试制过程: _____

3. 在过去五年(1990 - 1994 年)内有多少新产品已被投入市场: _____

4. 在过去五年(1990 - 1994 年)内这些新产品销售收入占总销售收入的百分比: _____%

三. 与外部的合作情况:

1. 请在合适的数字上划勾用来表明你公司过去五年在革新过程中与顾客联系的程度 (1 = 没有联系, 3 = 有限的联系, 5 = 大量的联系):

没有联系

有限的联系

大量的联系

1

2

3

4

5

2. 请在合适的地方划勾如果你们公司在过去五年内与研究所或大专院校有下列正式或者非正式的联系/合作情况:

(正式的/合作是指双方通过合同或者书面证明而达成的一致协议)

(非正式的联系/合作是指没有任何书面证明的已经存在的联系或合作)

() 有合作的研究项目

() 向研究所或大专院校寻求技术咨询

() 向研究所或大专院校寻求新产品推销咨询服务

() 向研究所或大专院校借用实验室

() 为研究所或大专院校提供新产品试制服务

() 从研究所或大专院校暂借人才

() 将科技人员暂时转入或送入研究所或大专院校进行短期培训

() 从研究所或大专院校引进新产品或购买专利权

() 其它的联系, 请注明: _____

3. 请在合适的地方划勾如果你们公司在过去五年内与其它企业(国内的或者国外的)有下列正式或者非正式的联系/合作情况:

(请在“国内的”或者“国外的”上划勾用来表明与你公司进行合作的企业的所有)

() 有合作的研究项目

国内的

国外的

() 向其它公司暂时转入或借出技术人才

国内的

国外的

() 从其它公司得到科研资金的援助	国内的	国外的
() 从其它公司得到技术方面的支持
(如: 技术咨询, 借用机械设备)	国内的	国外的
() 从其它公司得到新产品开发信息	国内的	国外的
() 从其它公司引进技术或购买专利权	国内的	国外的
() 其它的联系, 请注明:		

_____	国内的	国外的
_____	国内的	国外的
_____	国内的	国外的

4. 以下是一些在革新过程中政府给予的援助, 请注明每项援助的重要性并且在合适的地方划勾用来表明你们公司获得此项援助:

"1" 代表 "不重要的"

"3" 代表 "重要的"

"5" 代表 "非常重要的"

() 对革新或科研项目提供补助金援助	1	2	3	4	5
() 对革新或科研项目提供低息或无息贷款	1	2	3	4	5
() 对科研项目实行税收鼓励政策	1	2	3	4	5
() 提供技术咨询服务	1	2	3	4	5
() 提供新产品推销咨询服务	1	2	3	4	5
() 提供市场行情信息	1	2	3	4	5

() 提供新产品可行性开发研究的服务 1 2 3 4 5

() 政府对科技人员提供技术培训 1 2 3 4 5

() 从政府研究机构引进技术或购买专利权 1 2 3 4 5

() 对新产品初步投放市场提供支持 1 2 3 4 5

() 其它的鼓励措施。请详细注明:

_____ 1 2 3 4 5

_____ 1 2 3 4 5

_____ 1 2 3 4 5

四. 回答者情况(任选的):

1. 姓名: _____

2. 职称: _____

3. 在此公司服务年限: _____

感谢你们的合作与支持!

END

0 5-0 6-9|6

FIN