Corporate Governance and Technological Capability Development: Case Studies in China's Electronics Industry[1]

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Abstract

I. Executive Summary

In this paper we apply a recently-developed theory of the effects of corporate governance on technological capability to China's electronics industry. Through case studies, we examined the influence of corporate governance, in a broad sense, on a firm's choice of approaches to developing its technological capabilities. Four electronics companies, Longertek, South Electro, Smoke Detect, and Fire Sensor[2] were selected for case studies. A combination of archive researches, site observations and cascade interviews were employed in the empirical study. In each company we carried out 4 to 6 in-depth interviews, during which semi-structured questions were asked to: i) understand the firm's governance situation; ii) characterise the technology strategy; iii) assess the technological performance and iv) understand the interconnections among i), ii) and iii).

We confirmed that three aspects of corporate governance, *engagement*, *expertise* and *inclusion*, affect a firm's strategy and behaviour in technological capability development. Longertek and Smoke Detect had better governance – characterised by: high shareholder engagement and industrial expertise; and high employee inclusion (trust in, empowerment of, commitment by, lower-level managers and shop-floor workers) that caused them to seek, identify and implement the appropriate *unbundling* strategy to steadily build up their technological capabilities. By contrast, handicapped by the classic Chinese governance system, low in engagement, expertise and inclusion, South Electro and Fire Sensor chose a *bundling strategy*, and proved failures in both technological and market performance.

II. Theoretical frameworks

This study used two theoretical frameworks, one for evaluating the appropriateness of technology strategies in developing economies, the other for predicting the effects on this of corporate governance characteristics.

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[2] According to interviewees' requests, only Longertek kept its original name and all other three were disguised.

Framework one: To bundle or to unbundle – challenge of technology strategy facing Chinese firms.

Firms in China, as in other developing economies, view technology catch-up as the main challenge and technology transfer as the obvious means (Cai and Tylecote 2005, 2006). The typical transfer involves purchasing one "bundle" or package of turnkey elements, normally from overseas. Such process, although allowing a speedy rise in *static* technological capability (both product and process), is often expensive and restrictive due to licenses, patents and/or intellectual properties, therefore in the long-run will hinder the development of *dynamic* technological capability. By contrast, the unbundling strategy separates the technology to be acquired into elements, say, blueprints, machinery (separated into individual items), and components (likewise separated). It is then possible to reduce the dependence on overseas firms to a minimum, by identifying elements which can be sourced domestically and others which the firm itself can develop and produce. Such a strategy not only enhances a firm's market position for technology transfer but also gives it chances to carry out independent development, and hence is more beneficial for the development of sustainable, dynamic capability. Recent research undertaken in the Chinese auto industry (Liu and Tylecote 2006) has indicated that the more far-reaching unbundling a firm performs, the more it learns from doing so and hence the more dynamic its technological capabilities.

However, the *status quo* in China is that state firms in medium-high technology industries almost always opt for bundles and are dependent on passive technology transfer. This can be partly explained by policy constraints (Qian 2002; Lu and Feng 2004). We argue below, however, that what lies underneath is a flawed governance mechanism.

Framework two: Corporate Governance and Technological Capability Development - challenges for all, but particularly for China.

We understand 'corporate governance' very broadly, as *who controls firms, and how*. In this we follow Tylecote and Ramirez (2006), who set out a framework tracing the effects of corporate governance (and finance) on technological capability. They identify three features of corporate governance which are required (in varying measure depending on the situation) for successful technological development:

- *Engagement* – activities required for technological development may be low in visibility to outsiders and slow in pay-off; they cannot then be properly assessed and monitored without close *shareholder engagement*;
- *Industrial expertise* – to the extent that technologies and markets are *novel*, they cannot be properly monitored and governed without *industrial expertise*;
- *Stakeholder inclusion* – if technological learning and development requires substantial inputs from, employees and/or related firms, these stakeholders need to be well motivated and *included*.

Cai and Tylecote (2005, 2006) and Tylecote and Liu (2006) apply this framework to China. In most (but not all) Chinese state-owned enterprises, as they show, the system of governance has long been weak in the aforementioned aspects:

1) Managers report to officials who have low engagement (and expertise);

2) Managers *are* officials: short time horizon inside the firm (ca. 5 years);

3) Managers need to cultivate relationships (*guanxi*) with senior officials – therefore have little time for "stakeholder" relationship-building.

Privately-owned firms do not suffer from the first two difficulties, but they do suffer from the last one, since they need good relationships with officials as a defence against official obstruction of various kinds. They also have had serious financial constraints, not shared by state-owned firms. Firms which are partially state-owned tend to occupy an intermediate position.

The two frameworks in combination indicate that, in China, firms with similar histories and industrial context but different governance practice may choose different approaches to capability building and, as a result perform differently. Is it really so? Since the electronics industry satisfies the criteria of technology level and economic importance, it provides us with a good soil for field research.

III. Methodology and Data

Since capabilities are processes embedded in firms (Eisenhardt and Martin 2000), we assume an organisational and empirical stance, rather than an economic and formal modelling one (Barney 1991; Peteraf 1993). Case studies were used at this stage to facilitate in-depth, longitudinal examination of individual instances to gain a sharpened understanding of the subject matter, and to decide what might become important to look at more extensively in future research (Yin 2002; Flyvbjerg 2006).

Four Chinese electronics firms were selected for the case study research. They are respectively Longertek, South Electro, Smoke Detect and Fire Sensor. All firms had similar lines of products and had both development and manufacturing activities at the time of field work. From May to September 2006, a series of in-depth semi-structured interviews were carried out in these firms. Interviews started with CEO and descended along the hierarchy of Chief Operations Officer, Chief Engineer/R&D Director, line manager and one to two shop-floor/maintenance worker(s) (see Table 1: Number and type of interviews conducted in case studies). Such “top-down” interview technique helped to generate holistic maps of the cases in limited time periods and more importantly, to triangulate key issues of interest (Tylecote and Conesa 1999). In the interviews adjusted sets of questions were put to each informant according to his/her operational role. See Appendix I for a list of interview questions.

Face-to-face interviews were then followed by site visits, where the researcher gained observational insights into the firm’s organisational and daily routines that are often reflections of its capability dynamism (Zollo and Winter 1999; Winter 2003). In addition, historical and background information such as product technology, industry and policy evolution, company ownership structure and market performance were gathered from various sources from published books, journal articles, government websites, company websites, newspapers to anecdotal accounts of current and former employees.

Table 1: Number and type of interviews conducted in case studies

Company name / Number of person interviewed / Position	Longertek	South Electro	Smoke Detect	Fire Sensor
CEO	1	1	1	1
Senior managers in charge of technology or finance	2	2	1	1
Operation managers	1	1	1	1
Line managers	3	1	1	1
Shop floor operatives and maintenance workers	2	2	1	2

IV. 4 Case studies in the Chinese Electronics Industry

1. Company Profiles and Performance

a. Longertek

Situated in the coastal city of Tsingtao, Shandong province, Longertek Technology (Group) Co. Ltd (hereafter referred to as Longertek) is a private enterprise established in 2000. As of April 2006, Longertek Group's total (net) assets were 84.83 (22.80) million *yuan*, and it had 285 employees (60 are graduates, 55 technical staff). It has two subsidiaries, Tsingtao Longertek Co., Ltd (**TLL**) and Laiwu Sanhe Technology Co., Ltd (**Sanhe**). TLL specialises in the R&D and production of Intelligent Power Modules (IPM), Universal Intelligent Power Modules (UIPM) and Permanent Magnet Variable Refrigeration (PMRV) related products, and Sanhe mainly makes energy-efficient variable-frequency multiple-split system refrigerators and air-conditioners used on locomotives and passenger trains.

Longertek has been awarded 16 national patents and 2 of its products have been named "National Key New Products". PMRV is its latest energy-efficient control technology. Longertek is the only Chinese firm that has independently developed, patented and commercialised its own PMRV technology. Longertek's most recent achievement is the PMRV-UIPM (Digit DCBL Sine Wave Universal Intelligent Power Module) unit which was included in the State's "Electronic & Information Technology Promotion and Multiplication Plan". Combining PMRV and UIPM technologies, this product is going to be 1/3 cheaper than ordinary PMRV controllers and much easier to use. Moreover, the unique re-programmable feature means it can not only be used on air conditioners but also on any other electric and electronic appliances and devices.

Longertek's market performance is also impressive. It is the supplier of IPM-embedded controllers to most major Chinese air-conditioner producers, such as Haier, Hisense, Gree, Aucma, TCL, Midea, Galanz and hence dominates 60%-70% of the domestic market. It also sells to (or OEMs for) overseas customers, including O.Y.L (Malaysia), Sampo (Taiwan), Kolin (Taiwan), Semens (Germany), LG (South Korea) and companies in the US and Italy. In 2004 by introducing new technology and under-cutting unit price by 150% - 200%, Sanhe became the only firm outside of the Chinese railway system to supply air-conditioners to locomotives and passenger trains [3]. It also dominates 80%-90% of the air-conditioner market for other transportation sectors. Table 2 briefly summarises its sales over the last three years:

Year	**Total Sale (Thousand *Yuan*)**	**Gross Profit (Thousand *Yuan*)**	**Net Asset (Thousand *Yuan* as end of period)**
2004	41，929	2，741	15，943
2005	54，417	3，682	21，575
Jan – April 2006	19，666	1，235	22，810

Source: Longertek's Internal Document (May, 2006)

From only 5 employees when it started six years ago to the industry's technology and market leader, what lie underneath are not only technological superiority but also strong aspiration. Now Longertek is doing everything it can to prepare for its IPO at the end of 2007 on NASDAQ which will raise 12 million USD to facilitate more intensive R&Ds and mass production of UIPM.

b. South Electro

South Electro is one of the four affiliates of South (Group) S&T Co., Ltd, which is among China's first batch of shareholding companies（but all of its shares were state-owned in various forms）. South came into being in 1965 as one of the National Defence Electronics Industry Bases in inland China. Along with 6 other companies in its province, South Group has the privileged status of National Key Enterprise. In 1991 it became one of the first 57 'National Experimental Large-scale Enterprises/Groups'[4]. As of end of May 2006, 49.7% of South Group's shares were tradable and the rest 50.3% were non-tradable state shares: it is thus a 'majority-state-owned enterprise'

At the time of research in May 2006, South Electro had 570 staff, 400 directly engaged in daily operations; the figure is only half compared with its best time in the early 90s. The firm was suffering from severe losses and struggling to survive.

[3] Procurement of air-conditioners in the railway system is highly controlled and rationed by the corresponding ministry, in the past only three companies were short-listed as suppliers. They are: Shijiazhuang Guoxiang Transportation Equipments Co., Ltd (Taiwan Invested and Controlled); Shanghai Hakenuke Refrigeration Co., Ltd (Foreign-invested) and State-Controlled Guangzhou Refrigerator Co., Ltd.

[4] The purpose was to deepen internal reforms, improve the level of management, enhance competence of the firms and hence to set good examples for other enterprises, in 1998 another 63 large-scale companies were selected to join the list.

South Electro as one of the four subsidiaries of South Group specialises in the manufacturing of cathode-ray tubes (CRTs) for televisions and other generic electronic circuit boards. Its CRT production started in the late 80s when TV production was taking off in China and demand for CRTs was also soaring. South Electro started off by manufacturing CRTs and television remotes against specification for a Japanese company which supplied the technology and equipments. A few years later the collaboration came to an end but South Electro managed to understand the technology and continued production. By the end of 1992 its products ranged from 17'' B/W to 25'' colour CRTs. Annual sales reached over 1 million units with over 30% gross profit margin. From 1997 on, however, when the competition among Chinese TV set firms became white-hot and was mainly concentrated on cut-throat price wars, 70% of loss in margin was passed on to parts and components suppliers (Kang 2003). As one of the major suppliers to most brands in China, South Electro was then forced to cut its price by 40% compared to the mid 90s. In the 21st century major breakthroughs in TV display technology started to become the main stream, such as rear projection, LCD and plasma. South Electro was still only capable of producing traditional CRTs for a fast-shrinking market. Moreover, with market perspectives for CRT TVs being unclear, many TV set firms stopped putting in regular orders and demanded 'just-in-time' supplies, which again increased pressure on South Electro's inventory and cash-flow. From 2001 on, due to lack of investment, its research and development stagnated. In 2002 the senior management in South Electro found that its old-fashioned lifeline was no longer making money and the company was having constant difficulty paying wages, they then decided to resign collectively.

c. Smoke Detect

Smoke Detect is a medium-sized private firm with around 800 employees. Its main business includes manufacturing smoke detectors and electronic controllers for automatic fire alarm system (a system based on the technology of nuclear radiation, micro-electronics and optics). According to a survey conducted by the Association of Chinese automatic fire alarm manufacturers in 2006, Smoke Detect is by far the most successful and the only listed Chinese firm in this sector. (See appendix II for a brief review of the Chinese smoke detector and automatic fire alarms industry.)

Established in 1993, Smoke Detect was initiated by four postgraduates with around 100,000 *yuan* (£6,500) as start-up capital. It did not get any support from the local government. All its development depended completely on those four people. 60% of products are sold abroad. On 30th June 2005 Smoke Detect was listed on the Hong Kong market.

d. Fire Sensor

Fire Sensor is a medium state-owned enterprise (SOE), operating under the Ministry of Nuclear Industry. Its main businesses cover three areas: automatic fire alarm system, nuclear reactor and electronic medical devices. During the 1980s Fire Sensor was a major player in the local market and had a dominant position, and most of its revenue was generated by the fire alarm system. However since the mid 1990s it has gradually withdrawn from the fire alarm market and employment was reduced by 50%.

Fire Sensor had a glorious start, but what followed was dismal. It initially gained its competitive edge by combining its inherent strength in nuclear radiation technology with licensed production of fire detectors from a Swiss company in the early 80s in order to gain the necessary technology. The then engaged and motivated technical staff actively learned, digested, absorbed and assimilated the new optical technology, and in less than a year's time the R&D team successfully designed their own improved version of the product: the 732 series, which achieved higher accuracy in detecting causes of fire. These young researchers did not just stop there. From the mid-1980s they started to work on regional and central control panels and brought out a much more advanced new product: the 088 series. Compared to the original Sino-Swiss hybrid, the new system had several technical advantages: it had a self testing function which reported any malfunction of the system immediately. It used N+1-line control which made it easier to identify where the problem was. In addition, by using local and domestic components Fire Sensor managed to bring costs down, hence the attractive price became another merit of the product. In the early 1990s it held more than 50% of the Chinese market.

Unfortunately from then on the firm's history experienced a dramatic down-turn – with more and more smaller-sized private firms entering into the lucrative market, Fire Sensor not only suffered from sharp decrease in profit margin but more importantly large-scale brain-drain – according to the general government rules at that time, staff in SOEs were compensated in a rigid system. Although some 'brave' leaders were breaking such rigidity in response to increasing market pressure, managers at Fire Sensor were not among them. Their pay scheme could in no way compete with appealing offers from foreign joint ventures or even private firms. From 1992, within five years most experienced system developers left the company. Further, the organisation suffered from limited autonomy for the R&D department to hire and fire, lack of inter-departmental/intra-departmental communication and co-operation. Consequently, the firm's new product – the 4700 series – proved to be inferior in quality and the negative market response was not properly dealt with. By the mid 1990s Fire Sensor's major products no longer enjoyed a good reputation and the market share started to shrink. Now it has almost completely withdrawn from the fire alarm market. The so-called R&D department simply conducts some quality control activities or minor modifications in product design.

2. Corporate Governance

a. Longertek

1) External factors

As a private company, Longertek is controlled by its sole shareholder and founder, the CEO. There is thus no owner outside the firm; and the owner inside the firm is fully engaged, and highly expert in the industry. In China absence of a state shareholding does not necessarily mean that the state has no share in control. We were however informed that there is no excessive intervention from outside Longertek. 'We are subject to lots of authorities – the tax bureau, the bureau of industry and commerce, the bureau of science and technology, the bureau of social security, the bureau of environment, etc. But it only involves quite ordinary stuff: paying taxes/fees, renewing registration, handling routine checks. We are left to mind our own business…' commented company CEO Mr. Li. However, he also admitted '…in China, it is essential for an enterprise to build and maintain a good relationship with

local authorities, and, if your ambition is to become the biggest or most successful, a good relationship with the central government is especially important.' According to Mr Xu, who has been working with Li since the 90s, Li learned this lesson at quite a high price: 'Longertek was the first Chinese company to develop (air-conditioner) controllers; we were even not too far behind Japan in the 90s. Pity that we didn't realise how important it was to win government support and missed a very good opportunity to be included in the list for exclusive project funding and technical support …' Li spends 80%-90% of his time cultivating all sorts of relationships, a significant proportion of which were developed with government officials over the dinner table. ' I must do so for the benefit of the firm …the government controls a lot of key resources – think about tax policy, industrial policy and the use of land; on the other hand, government officials are themselves very resourceful too - think about the sales of product… ' (Li)

Longertek's belated smart moves finally took effect – it started to receive the treatment that it had long deserved, but on the other hand, seeing the firm's promising prospects some supervising bodies got over-excited. For example, in order to get (state) funding for a major project Longertek did a bit of 'posing' and the funding authority then set them an unrealistic target. '…actually they don't quite understand what we are doing and what our position is. In other words they just want to use us to showcase their political merits; this gives us some unnecessary pressure.' (Li)

2) Internal factors

a. Employee Inclusion

The advantage of owner-management is that close committed relationships can be developed between those who control the firm and those who work for it – employee inclusion - starting of course at the top. At Longertek the CEO is not the only one who is enthusiastic about his job – the R&D manager, company vice president and manufacturing manager work long hours both at the Tsingtao HQ office and on the production sites. 'I don't simply look on myself as *Dagong* (making a living) here, at Longertek I am building my career' is the comment made by 2 senior managers in 2 separate interviews. Miss Wang, aged 29, is operations manager of Longertek's Jimo factory 60 km outside Tsingtao. Her home is in Tsingtao but she lives with workers in the factory's dormitory. 'We moved to this new site this May (2006). I remember it was raining heavily on that day and the road outside of the factory became very muddy and our lorries got stuck. The young workers didn't know what to do. I dashed into the rain and picked up a box…they all followed suit…those days I slept in the office, and since there was no hot water I even couldn't wash my feet… '

The sense of employee inclusion is fostered by clearly defined policies in Longertek:

i. The company selects top-performing staff (mainly technical employees and managers) every year and pays the interest on their housing mortgage;
ii. The company pays all or part of the university tuition fees for outstanding staff's children;
iii. If any staff takes on part-time education that leads to degree or certificate qualifications, the fees can be reimbursed by the company.

An employee shareholding scheme was being drafted at the time of interviews.

Many experienced employees in Longertek previously worked for state firms. They admitted that if one only wants a comfortable life he should stay in the state firm. However, working in private firms, although much more stressful, provides one with much more space for career and ability development. 'I am exhausted every day, but I feel that my life is more fulfilled than before. The company always sets me challenging goals but it also always rewards me, not only financially, but with higher responsibility and trust…I work very hard, so do my colleagues, *because we believe that the company's prosperity means our own prosperity*', says 32-year-old Miss Zhan, director of PR department.

Technological contributions from the shop-floor are encouraged and rewarded. Mr Chen Chao, age 23, got his name on a poster and received financial reward after solving an abnormal vibration problem on one of the control circuits. In addition, highly 'included' young managers – such as Miss Wang mentioned in the previous section – did excellently in eliciting their staff's enthusiasm and contribution by demonstrating their own.

b. Finance

As a private company Longertek has always had to fight for financing. Due to the past discriminatory rules against small private firms, Li never managed to get a loan from the banks. 'not even a penny… the banks asked for physical collaterals and wouldn't accept intangible assets, and what we had at that time was nothing but ideas, patents and intellectual property rights.' (Li) The reason for choosing to float in the US rather than on the domestic market is similar. According to the current policy in China private firms have to go through a time consuming and painful process to get listed. ' It means life and death to us that our project be launched in a certain time frame, and I am afraid that by the time we finally got listed in Shanghai or Shenzhen the dinner would be cold already'. (Li)

b. South Electro

1) External Factors

South Electro is supervised by its own parent company South Group, whose state share belongs to the provincial office of SASAC (State Asset Supervision and Administration Commission). Being on the second layer of the hierarchy, South Electro often feels 'administratively isolated' (quoting the CEO). '…We used to be the 'star' company in the group; outstanding in all aspects – technology, sales revenue, profit rate, staff income, and tax contribution…we are very sad that it has become history. Now the problem is that we don't have good projects at hand. So even when the Group agrees to be our guarantor we still can't find money...' said the current CEO. Direct financial support from government is rare and limited. The latest injection dates back to 2004 when South Electro received 150,000 *yuan* (£10,000) from the Provincial Committee of Economy and Trade for its ERP (Enterprise Resource Planning) project and a few *wan* (a few thousand British Pounds,) for its product improvement project.

In 2002, seeing the dismal prospects of South Electro, its senior managers collectively resigned. The new management team mainly consists of young people (average age 33), and all the executives were assigned by South Group.

Performances are measured by South Group against uniform criteria with financial performance as a priority. It is required by the Group that there should be a 10%-15% annual increase to the net assets and according to the CEO: 'there is no way we can manage that given the current situation, but, you know, since the report determines how much funding we can get from the Group the next year, we must meet these targets. If there is a will, there is a way.' (Indicating that they could meet these targets through manipulation of the financial accounts). Irregular inspections from the Group are conducted. Normally it is the chief finance director and the chief accountant who come down to check the financial reports. Sometimes the executive in charge of production also comes to the workshops to inspect, but he normally does not stay there for more than 30 minutes. Afterwards, expensive 'souvenirs' and dinner at luxurious restaurants are part of the routine.

2).Internal factors

a. Management inclusion and commitment

No interviewee agreed to give specific comment on the top managers' engagement in innovation-related activities. However, one of the top managers expressed his reluctance to put in too much effort: 'I simply don't have the energy and time to go over all the details, and relationship management (with external officials) for our company is definitely of higher priority – otherwise we will have no money to pay and keep the workers, without workers how can we be innovative?'

b. Staff Inclusion

In South Electro there is no well-defined and implemented scheme that promotes staff inclusion. The relationship between lower-ranking managers and top managers is highly hierarchical. The CEO of South Electro, Mr Wang, refused to comment on the internal relationship. However, Mr Xie, the production manager had a lot to say: 'our managers definitely need a brain-wash; they are very stubborn and old fashioned. I started this job last year and I have submitted lots of technical improvement suggestions and proposals since then, but very few actually reached the decision makers. Don't ask me, it's very complicated and I don't understand why... I have something to say about the R&D department as well, I hope they can be more responsive and show some respect to the rules and regulations. For example, in the process of parts manufacturing, a lot of money can be saved if the processes at my workshop can be simplified. I noticed that and asked through the leaders for technical support from the R&D department, I waited and waited but it seems no one cared '.

Like many other SOEs, South Electric uses an apprenticeship system to train new workers. Each new worker is allocated to a *shifu* (master worker). Tacit experience is imparted through life-long apprenticeship relationship. Team members are highly devoted, disciplined and innovative. Once a job is allocated (e.g. a minor technological improvement), the master worker gathers all his apprentices to discuss solutions. Every one is encouraged to top up each other's ideas. If one gets stuck, other team members/the master worker are always helpful. Maintenance work force is also highly skilled. They know the machines/equipment very well and can play important roles in innovative activities. For example, Mr Sun, director of maintenance team found out that on three key equipments the boring bar and boring sheath does not match. This situation was reported to the CEO and a budget worked out. A set of matching bar/sheath costs at least 30,000 *Yuan*. Sun suggested that the cost could only

be around 5,000 *Yuan* for each machine if right changes can be made on site. At the time of site observation his team was experimenting on one of the equipments.

Site observations show that front-line operatives are mainly middle-aged skilled workers. 'They are well trained, responsible and loyal to the company, we are very grateful to them ' (Mr Xie and Mr Yang). However, with more and more of them retiring or leaving, South Electro found that newly-recruited young workers can hardly match the old employees in any respect. Managers describe young people as immature, badly disciplined, irresponsible, reluctant to learn, lazy and always complaining about the low wage and the heavy work load. Many measures were initiated to deal with the new problems. For example, the main gate is kept closed and guarded, and any one leaving the site during the day must have a signed note from the line manager.

c. Smoke Detect

1) External Factors

Like Longertek, and for the same reason, Smoke Detect does not feel much intervention and performance pressure from outside the organisation. However, unlike Longertek, it keeps a very low profile in spite of its commercial and technological success. For example, apart from executives in the headquarter office, all other staff including senior managers had no idea that the company was to get listed in Hong Kong until the day of IPO. The CEO Mr Zhang simply explained it as to prevent sabotage from competitors. Such strategy resembles another firm, Huawei, the biggest private firm as well as the most successful in the telecommunication industry, which also holds its tongue tightly about its development and success. Mr Zhang further commented that private firms need to be 'humble' otherwise they will get themselves 'troubles' and burdens. One example is that each year Smoke Detect is pressed by the authorities to help to reduce local unemployment and to hire the disabled.

2) Internal Factors

a. Manager-Shareholder Engagement

At Smoke Detect the executives and senior managers are all shareholders, and it is one of the incentives for their engagement. The CEO and other executives are actively involved in product research and development as well as market exploration. They talk to junior managers and workers to see what is going on and to ensure that an agreed plan is being carried out. The CEO also reads reports to check whether the overall performance has met the assigned targets.

b. Inclusion

- Shop-floor workers are offered the best local wage rate. The staff turnover rate therefore is extremely low. Also because of the good salary, workers are more motivated to improve process technology and to make changes. Key workers are highly trusted and empowered. 'We have five automatic production lines which are managed by only three key workers; and they also oversee equipment maintenance. Each of these lines produces a unit in every six seconds; therefore you can imagine how much responsibility they are given and how important their roles are'. The key workers are also consulted for strategic decisions related to production and equipment procurement. Moreover, both the CEO and the interviewed line manager believe that the relationship between the top and the bottom is horizontal and close.

Flow of information and creative ideas are deliberately encouraged. A weekly

meeting is held in every department in which employees brainstorm to solve problems, make decisions and set goals. The Executives also attend departmental meetings to get first-hand information. Recognising that their own well-being is closely attached to the firm's prosperity, employees are keen to contribute new ideas and appreciate well-justified changes.

c. Performance Measurement

Performance is measured by quota/ targets. Bonuses which account for most part of the annual income are decided by how well the target is met [group or individual?]. However, the firm does not punish its staff for risk-taking. 'Failure in Smoke Detect is OK because we are an opportunity- rather than problem-focused organisation', says the R&D manager.

d. Fire Sensor

1) External Factors

Fire Sensor is a provincially-owned SOE, located in a Chinese inland city where SOEs still dominate the local economy and working for SOEs is regarded as lucky and reputable. Fire Sensor has many characteristics of a typical old-fashioned SOE – it never experienced radical ownership reforms; top managers are hand-picked or approved by the local government; performance is measured in terms of revenue, market share, profits and employment which determines the management's remuneration, but 'there is always space for negotiation', says Mr Su, a former CEO who retired in 1992 and has been the firm's management consultant since then. Each year there is an annual inspection. A few officials come down for a few days to assess the firm's performance by talking to employees. According to Mr Su and an interviewed line manager, what these officials expect to hear is good news and what they expect to see are new buildings and machines. 'These officials are happy as long as Fire Sensor is still making profits…in fact profits or financial data can be manipulated by top managers…as long as it can pay its employees regularly and on time…' (Su). During the inspection only carefully-selected ('reliable' is the word used by the interviewee) mid/lower level managers and workers get to talk to the officials to ensure that nothing but achievements are reported.

But what if top managers perform really badly? In recent years, so that the officials could please their superiors with 'administrative merits', the local government encouraged SOEs to become conglomerates or industrial groups through mergers. Such decision was welcomed by company top managers since in China the influence of power grows with the size of the firm. In 2001 FS was affiliated to a conglomerate which merged 5 medium-sized SOEs. Two years later this group disbanded with a debt of over 80 million *yuan* (£5.5 million). The local government simply wrote off all debts, and reallocated the top managers to other governmental departments.

2. Internal factors

a. Management Inclusion and Commitment

Since top managers are selected by local officials the boardroom is split into camps representing different interest groups. It is common knowledge that the managers spend much of their time and energy fighting for influence, of course not through positive contributions to the company's development since it is not what the monitoring officials really care about. These top managers are highly 'respected' not

because of their charisma but because of their power. Top managers have absolute power to decide who benefits from Fire Sensor's subsidised accommodation, how much salary one receives and whether one gets to extend his employment contract. The interviewed line manager and shop-floor work felt that top managers were purposely distancing themselves from subordinates to create a sense of authority. For instance, in spite of making appointments in advance, staff who want to see the manager have to wait in a common room for at least 20-30 minutes.

b. Staff Inclusion

According to the operations manager, the level of inclusion of shop-floor workers has largely deteriorated compared to 30 years ago when workers were regarded as the 'pillar force' of the firm. However the average technical skill of workers in Fire Sensor is high. The maintenance work force is also highly skilled. However, skilled maintenance workers are highly sought after in the labour market, therefore some young workers are not happy with the pay and moonlight outside. The reason why they do not want to leave Fire Sensor is that their housing mortgage is subsidised by the company.

Communication within the organisation is mainly practised through a hierarchical reporting system: shop-floor workers report to their line managers; junior managers contact middle managers; a middle manager will then go to a carefully-selected top manager whom he believes will not be embarrassed by the nature of the report. Although occasionally an ordinary worker may request to speak to top managers if he finds it necessary, workers normally rather share views with friends or close colleagues than seek discussions with their supervisors.

- Performance measurement and management remuneration

Top managers are measured in terms of general performance such as sales revenue, profit and particularly increase in asset value. Assets value can be examined by fixed assets like buildings and machines and intangible assets like brand name, managerial skills, and technological potential. To increase value of intangible assets, it requires constant internal effort over time which might reduce profit in the short run. Although top managers are under pressure to strengthen Fire Sensor's competence in productivity and profitability, the management team in general failed to fulfil its responsibility in this respect. If top managers miss their targets, their bonus will be reduced. But bonus only takes a small proportion of their annual compensation, moreover, 'they are very good at coming up with various excuses to cover their misconducts' (Mr Su, the previous CEO). Middle managers are measured by the project they are in charge of. Assessment indicators include project progress and quality etc. Pressure on middle managers is higher because their performance is directly linked to their salaries. However they never need to worry about demotion or dismissal. Junior managers and workers are measured by more detailed indicators such as productivity, product quality and fault rate etc. Financial punishment is perceived to be harsh by shop-floor workers since their basic salaries are very low.

The salary gap between top managers and ordinary workers is obvious. The annual compensation of Fire Sensor's director is 15 to 20 times an ordinary worker's salary (£700). Top and middle managers also have more chance of subsidised accommodation (half the market price) and 'grey' income, such as gifts, and free entertainment.

3. Technological Development Strategies

a. Longertek

'To attack is the best way to defend, and that is what we have always been doing in Longertek'. says Mr HU, aged 32, chief engineer and director of R&D department .

Longertek's technology base can be traced back to the early 1990s. Mr Li, owner-founder of Longertek gained his experience in air-conditioning by imitating and modifying Japanese technology.

'At the beginning what I did was basically imitation – imitation of Japanese technology. But even that was by no means easy. In 1994 I bought a 2-unit split air-conditioner from Japan. When I first saw the inside I gasped: it was so complicated yet sophisticated, and so state-of-the-art! But I managed to disassemble it and understand the technology behind it, and finally made something even better than the original. 12 years later Longertek is producing its own branded 16-unit machines.' says Li.

Due to their technology backgrounds of most managers, the culture of 'if possible, do it by ourselves' is very distinctive in Longertek. Although not overtly recognised within the company, lots of unbundling activities have been practised over time and the level and complexity of unbundling has experienced significant progress.

The primary version of unbundling was undertaken before the firm's establishment. When Li and his colleagues worked as R&D contractors in the 90s, they bought sample products from Japan; disassembled the machine/device; understood the technology and manufacturing details; and then reassembled it – literally reverse engineering.

After benefiting from unbundling not only financially but also technologically, such strategy was confidently and skilfully implemented when Longertek officially came into being in 2000. Three examples illustrate three aspects of unbundling:

1) *Production.* Early in the company's development, due to lack of capital and expertise in production operations, and since the production of an air-conditioner controller only involves generic manufacturing process which can be managed by any electronic company, Longertek outsourced production to its local partners. By doing so it unpacked the bundle of product development and manufacturing and concentrated its limited resources on the areas where it has competitive advantage.

2) *Equipment and material.* In 2003 and 2005 Longertek decided to take more control over production and set up two factories. Rather than spending money on imported equipments, it went to local suppliers. In order to meet its modest budget, modest machines were bought when company experts ensured that they were good value for money. Then R&D staff worked closely with production and maintenance workers on fine-tuning and changes to the machines so as to meet production requirements.

As to parts and materials, Longertek always purchases from domestic or local suppliers if possible. However, for parts and components that are crucial to the products, supply was sought from the world's best makers.

3*) Product technology*. Although Mr Li is regarded as the driving force of innovation and is always well informed on product details, he did not and could not lead every R&D project by himself. In fact he delegated most jobs to the steadily-growing R&D team led by Mr Hu. Many members of the team previously worked for two other big and famous air-conditioner companies, and were head-hunted by Longertek for their expertise. For problems beyond their competence, friends and past classmates in research institutes and multinational companies are secretly consulted. In addition, Longertek pays executive-level salaries to three retired engineers for technical consultation. 2 experts from Panasonic and Sanyo are also constantly invited to provide training and trouble-shooting.

b. South Electro

South Electro's strategic failure in technological capability development can be attributed to the following:

Not understanding the firm's core competence and not being able to cultivate it, the management at South Electro was content with profit generated from its CRT division and never aimed at new projects that were compatible with the firm's traditional strength and long-term development. According to the director of the research institute Mr Yang, South Electro made a strategic mistake in the mid 90s. In 1993 China started mass production of wireless telecommunication devices such as pagers and later mobile phones. Chip resisters and inductors are one of the key electronic components. Although South Electro and its parent company had no experience or expertise in the related area, and desperate to have a come-back after suffering from falling profits in the CRT market, South Electro decided to invest heavily to produce surface placement machines used in chip device production. In naive hope of turning blue-prints into finished product as quickly as possible, complete sets of equipment such as digital-controlled lathes, milling machines and boring machines were bought in batches. However, making placement machines turned out to be completely new for South Electro. The products didn't meet the industrial standards in accuracy and reliability. The project started in haste, and came to an end with massive debts in 1998. Three years later, South Electro invited Samsung, the Korean company which makes one of the best placement machines to set up a joint venture. However, South Electro found it impossible to satisfy and keep its Korean guests. First of all, Samsung was not ready look after South Electro's over 500 retired employees, let alone its weakness in technology and poor governance practice.

'It has relied too heavily on reverse-engineering of prototype products and then copy-making its. Such strategy worked and paid off in the early years of the reform (from 1979 to 1989), but there was no growth from there, nowadays in the market economy, if you don't change and grow, you are doomed …' says a retired chief engineer.

South Electro's current director has his explanation: '… from 1995 many highly qualified and experienced R&D personnel started to leave for much more lucrative

jobs in the coastal regions[5] and the technology team shrank from over 100 people to around 30. South Electro was not capable of carrying out any serious research and development independently from then on. Meanwhile, the gap between CRT and other types of display technology is too big to be understood by South Electro. We tried to seek technology imports from Japan; however, as a monopolist in the industry NEC holds its technical details so tightly that it is impossible for South Electro to have a glance. By that time we were already in deep debt and couldn't afford to buy necessary machines. We are in a poor province and the investment needed far too much money, the bank simply couldn't help.'

Sagging profits and the urgent need to meet all sorts of payments mean that South Electro hardly has any R&D expenditure. Mr Xie, line manager of circuit board factory mentioned that he once proposed that with only 7,000 *yuan* (£ 400) his factory could improve the lighting system which will cut the operation cost. 'The investment will pay off in just 2 to 3 months, but my suggestion was not taken. They (senior managers) told me that they sent my report to the headquarters for discussion, but it involved too many departments and I heard nothing ever since.'

During the site visit, the factory managers were very eager to show the glamorous chip-placement machines they imported from Mitsubishi in Japan, and claimed it as evidence that the firm is technologically advanced. However, since these machines are 'highly automatic and don't require specific training to operate, and Mitsubishi provides 24/7 door-to-door technical support' (quoting Mr Jiang, assistant general manager), it does not reflect any indigenous capability in production and equipment maintenance.

c. Smoke Detect

Smoke Detect is an interesting case because of its unique self-reliance strategy. When most other local firms sought various technology acquisition options such as joint venturing or licensing, Smoke Detect insisted on carrying out design and R&D all by itself: 'the more we do the more we can do, and we don't need to worry about loss of control to the technology suppliers', says the CEO:

'We believe the only way to become competitive is to have our own technology. The process of technology development is the process of building core competence and capability. We started from scratch, and at that time none of our competitors –SOEs or joint-ventures – believed that we would one day become a threat, but now we are the only local firm that can supply alarm systems for high-rise buildings over 20 floors'. Smoke Detect's four executives were all postgraduates in automatic control. By using what they learnt from universities they started their own business by assembling knock-off versions of simple control machines and devices. These machines were technologically inferior to their originals and had problems in functionality and stability; however, the four of them managed to work together and made constant improvements. The first generations of products were mainly sold to rural areas at competitive prices. When primary capital accumulation was accomplished, they started to invest heavily in R&D and staff training. Pure imitation was gradually replaced by incremental modifications. Later the experienced R&D

[5] The wage rate in inland firms was still very rigid in the 90s; according to the CEO, a university graduate in South Electro was paid 150 *yuan* (£12) per month, roughly the same as a skilled worker, whereas in Shenzhen, salary for an experienced engineer can be as high as 1500 per month.

team was able to identify flaws in the design and processing of mainstream products, and developed their own ones with superior product feature and quality. The unique and highly independent approach to technology development has paid off – its innovative products have kept Smoke Detect in the lead and have brought the firm fast growing market share.

With Smoke Detect growing bigger and more successful, foreign investors such as Panasonic, GE, and Yamaha started to show interest in collaboration. They proposed various cooperative plans, such as joint product project, joint management or even acquisitions. But since all multinationals demand more than 50% of the company's shares, none of the proposals was accepted by Smoke Detect. 'We are an organisation with principles…past experience proved that we can benefit from having control, and consequently we may suffer from loss of control. The multinationals have clear-cut purposes and so do we. But their objects may conflict with ours, and once they have got control over us it is very likely that they will override our benefit for theirs…' This explains why Smoke Detect finally decided to use stock the market for future financing.

d. Fire Sensor

The case of Fire Sensor gives a good example of the impact of different technological strategies - bundling /unbundling - on firms' long-term development. In the early 1980s the revenue received from two businesses' nuclear projects and medical devices was falling. Some engineers suggested a new possibility - the fire alarm system which requires some technological competence in nuclear radiation and integrated circuit. The management team by then decided to use licensing to import fire detectors (700 series, one part of the fire alarm system) from Cerberus - a Swiss company later on merged with Siemens. Despite the fact that Fire Sensor had accumulated certain know-how in nuclear radiation technology, complete self-reliance in new product development was impossible due to lack of systematic knowledge of other areas (optics in particular). The second driver for licensing was that the 700 series in the early 1980s was a mature product. The supplier was willing to sell Fire Sensor all the technical specifications it needed at a reasonable price. The technology supplier Cerberus imparted most key technologies to Fire Sensor such as how to design integrate circuits and how to improve the hermetic seal of detectors. A considerable amount of indigenous effort was also made by the recipient to absorb and digest acquired technology. Other factors also contributed to the success of new technology assimilation. Before the economic reform, intellectuals in SOEs were highly devalued during the great culture revolution. Technicians were used to be selected and promoted from the shop floor workers who then took complete responsibility for research and design activities, but skills were restrained by their limited education. Around the time when Swiss technology was introduced, such tradition was changed by a newly promoted executive from within the organisation. Being a former technician himself, the company leader believed that technological competence was the cornerstone for Fire Sensor's growth. He then down-played seniority by promoting young researchers and engineers (university graduates) to important managerial positions. As a result young researchers were highly motivated, not financially but spiritually. Several research project teams were set up, one on integrated circuit design, one on sensor sensibility and one on hermetic seal of sensor. In less than a year, the project teams successfully designed their new improved version – 732 smoke detectors which achieved higher accuracy in detecting causes of

fire. These young researchers did not just stop there. From the mid-1980s they started to work on regional and central control panels – the 088 system. Due to its advantageous technical features and competitive price, 088 held more than 50% of the Chinese market throughout the 90s.

From the end of 1980s Fire Sensor begun to aim for a position in the international market by producing a new standard duo-line control system. The management again opted for technology supplies through joint programmes; however, unlike the courtesy they received from their former Swiss partners, none of the gatekeepers of duo-line control system technology was willing to release key specifications. It is because that the system was still new in the international market. Considering the accumulated know-how from the N+1 system, the top management finally decided to go for the second option of independent development. However, it was a poorly executed project and the self-designed 4700 system soon proved unappealing to the market.

Several factors accounted for the failure. First, as mentioned in 4.1, Company profiles and performances, the firm did not manage to keep its key research staff when private companies and joint-ventures were offering attractive pay. According to an interviewed engineer the compensation scheme in Fire Sensor was hardly changed. Second, the project did not get consistent support and supervision from top managers. The project leader did not have autonomy to promote the talented or to dismiss the incompetent. Hence hard-working contributors started to feel that their effort was not properly rewarded and their initiatives suppressed. Third, lacking communication and co-operation within the R&D department and between R&D and other departments, technical disagreements remained unsolved and negative market feedback ignored. Within the project team, information was regarded as personal possession – researchers locked blue prints in their drawers to hide ideas from each other. Soon after installation of the first batch of the new system, quality problems were identified and reported by the customers, however, the slow response to customers' feedback resulted in loss of Fire Sensor's brand reputation and customer loyalty. By the mid 1990s, the 4700 system has almost disappeared from the market.

Under the great pressure of market loss, Fire Sensor was eager to find a way to regain market share. The solution sought in 1993 was a joint venture with an American equipment manufacturer. The appeal of a joint venture to the managers was obvious: it was encouraged and favoured by the government authorities at all levels and was therefore politically risk-free; the problems of employment could be partly solved; plus, a reasonable percentage of revenue can be shared. But later Fire Sensor learned that the ultimate price was bitter and high. Having once been the market pioneer and champion Fire Sensor found itself competing with its own joint venture that operated with its own marketing resources and technology intelligence.

V. Initial Findings and Remarks

Longertek and Smoke Detect were both bridgeheads of technology and market in their areas; both showing dynamic capabilities of executing independent development and innovations. According to the case studies, both companies have had extensive reverse engineering, coupled with various combinations of sourcing from abroad, sourcing domestically, and different degrees of self-reliance in their early days of

catch-up. All these behaviour were indeed associated with the strategy of *unbundling*, although the interviewees never used the exact term. Meanwhile, Longertek and Smoke Detect had very similar governance that featured high shareholder engagement; and industrial expertise - the shareholders in both cases being one or more senior managers. There was also trust in, empowerment of, commitment by, lower-level managers and shop-floor workers: employee inclusion. The interviewees agreed that these factors contributed to the process of organisational learning and capability building.

By contrast, South Electro and Fire Sensor conformed to the traditional Chinese pattern of state-owned firm governance referred to above. They started off well-equipped and favourably-financed. Top managers rotated on a regular basis and all cared more about their career prospects as officials than what was best for the company (according to our informants among lower level managers or former employees). Relatively rich, the decision makers wanted quick pay-off and money spent in their horizon of responsibility. And this was achieved by the import of bundled technology in one firm, and joint-venturing in the other (two forms of bundling). Over the years both firms proved failures in their technological and market performance.

Our research in the near future will focus on two areas. First, indicators of various aspects of technological capabilities that are generally-applicable in the industry will be defined and developed; this will help us map a firm's position on the spectrum with confidence. Moreover, industry-wide survey through questionnaires will be used to gather data for hypothesis testing and hopefully, a widened perspective of the phenomenon.

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Appendix I: Summary of Interview Questions

Block A: Bundling and Unbundling:
1) How far are local suppliers used?
Do you simply buy parts from them or work with them? If the latter case, then do you work towards an existing prototype or you supply them with an idea and you both work out the specifications together? If you work towards a prototype, do they manufacture against the stated specification?

2) Ask specific questions about unbundling, i.e. the way how technology is acquired and development within the organisation in the context of the industry and the product.

Block B: Problems in Technology Transfer/ Equipment/Parts of Bundle
1) What are the costs of the imported product/process technology and/or equipments and parts, especially in comparison with the alternatives?
2) are they suitable for the specific organisation, i.e. can they be easily adapted?
3) How to make technological conversion work? Who play the role to make it work? (Detailed questions are to be asked from both Human Resource and Finance angles). Who do you look to for help? (Universities? Research Institutes?)
4) In the process of technological acquisition and conversion, what roles do shop floor workers and maintenance workers play?
5) In the process of the technological acquisition and conversion, what problems have come up? How were they solved? Who were involved?

(Longitudinal questions were asked. For example, the evolution of a certain product

from Model 1 - Model N)

Block C: Relationships between CEO and officials, i.e. external governance factors

1) Who are controllers of the organisation?
2) What do they want?
3) How much do they understand? i.e. How do they measure the success? What are the criteria? If they are happy with the performance then why? If not, why?
4) How much do they care? i.e. How often do they come down? Who comes? What questions do they ask? What aspects are they most interested in?

Block D: Relationship between CEO and top to medium managers (depending on the size of the firm) i.e. internal governance factors
1) How is performance measured?
2) What are the main methods of communication between them? Does the CEO only read the reports or does he talk to the person?
3) Is their relationship hierarchical or horizontal? How much is the CEO respected?

Block E: Inclusion, i.e. relationships with employees and other firms
1) How co-operative is it between you and your suppliers?
What is the physical distance between you two?
How far do you stick to the contractual relationship? How far do you work with them to make improvements?
2) How do you make sure that your employees are well motivated and included in the process of improvement?

Appendix II: A brief introduction to Air-conditioning and refrigeration control technology

1. PMRV - Permanent Magnet Variable Refrigeration. This is the third generation of Variable Frequency Drive (VFD) technology used in the drive and control of air-conditioners. Air conditioners are designed to use a compressor to cause pressure changes between two compartments, and actively pump the refrigerant around. In the past an air conditioner used a fixed-frequency motor, which in short means that it could not adjust its workload according to the temperature and humidity of the environment and therefore wasted energy and reduced comfort. Since 1983 when Toshiba introduced the world's first Variable- Frequency air conditioner the industry has experienced constant technological upgrading and product evolutions. From the concepts of how a compressor is controlled, it has gone through three stages: **1) 1983-1998, VVVF** (Variable Voltage Variable Frequency). During this period frequency variation is realised through variation of electricity voltage: the 220 Volt alternating electric current (AC) goes through an inverter in which it is converted to 310 Volt direct current (DC) and then is sent to an power module which receives control signals from a micro processor to convert the current back to AC but with variable voltage so that it can change the speed of rotor on the compressor motor accordingly. In practise such control is done by an Intelligent Power Module (IPM) with surrounding circuits and chips. 2) **1998 – 2005**, the adoption of **Brushless DC Motor** dramatically improved the machine's precision of speed-adjustment and

energy efficiency[6], and it also solved the old problems of electromagnetic interference and noise. As for IPM, not much is changed except that a detector was added to capture the magnetic rotor's position. Now IPM controlled Brushless DC motor is prevalent amongst most A/C producers in the world. 3) **2005-**, **Permanent Magnet Variable Refrigeration**. With some fine-tunings to the motor, it is the revolution of control philosophy that provides real-time control to the compressor while reducing energy consumption by a further 55%. However, highly complex mathematical models are needed to develop the necessary software; on the other hand, it poses challenges to hardware production.

Japan has always been advanced in the industry. In developed countries more than 60% of A/Cs are variable-frequency (VF) and the figure in Japan is 99%. On the other hand China only started making VF A/Cs 13 years ago and today only less than 10% products in the market use VF technology, let alone PMRV. With the state's determination to build a greener economy there sees up-coming policies to encourage surging supply and demand for VF A/C in the next few years.

2. Multiple split system technology. With a typical split-system air conditioner, the condenser and compressor are located in an outdoor unit; the evaporator is mounted in the air handling unit (which is often a forced air furnace). As the name suggests, a multiple split system means that there are more than one air handling units attached to the outdoor unit. The machine needs to ensure that the desired temperature is achieved quickly and maintained constant through each of the units, ensuring a high level of energy efficiency and comfort. Development of such product is a very difficult task as it requires not only expertise in A/C technology, but also profound knowledge of electric and electronic engineering and the capabilities to handle software development.

3. UIPM technology. In the past an IPM has to work with a cluster of other parts, such as high-power devices, IGBT chips, SCM (Single Chip Micyoco) and processing units to achieve the controlling function. Normally these parts are acquired from different producers and there is the classical problem of compatibility. More importantly, since the production of both IPM and processing hardware are isolated from the development of software, without structural adjustment one model of control unit can only be used on one model of electronic product. Let alone the clumsy size of the entire kit. UIPM is indeed a technology that modullises these different functions by integrating the IPM, the control circuits and the software into a single chip and encapsulating all aforementioned parts in a sealed 'gray box'. After simply modifying parameters in the programme a UIPM can be used to control almost any electronic products. However, building a UIPM involves skilful applications of software control technology, frequency variation technology, electronic device control technology, power distribution, optimisation and thermodynamic technologies. Up till now China still relies entirely on import in this area.

Appendix III: A brief review of the Chinese automatic fire alarm/fighting systems industry.

[6] It saves 20%-30% energy compared to VVVF technology.

The development of the Chinese fire alarm and fighting industry started from the late 1970s. A complete fire alarm system includes fire detectors (smoke detector; heat detector and electrically calibrated radiometer), regional control panel and central control panel. By 2005 there were about 366 registered firms among which 53.8% were equipment manufacturers, 19% retailers, 14.1% sales agencies of foreign products and 13% engineering & project related firms. Several salient characteristics are:

1. Small in terms of business size. Most of the firms were small to medium (<10 employees: 12%; between 10-50 employees: 37%; 50-100 employees: 31%; 100-500 employees 16%). Only about 4% have more than 500 employees.
2. Small in terms of business revenue. More than 45% of the firms generate less than CNY 5 million annually in comparison to less than 2% whose revenue is over CNY 50 million.
3. Ownership: the overall picture of the ownership is that the state's share in this industry was continuously dropping from over 95% in the early 1990s to less than 10% in 2002 and 7.3% in 2005. Private share holdings came from nowhere in the early 1980s to 42% in 2002 and 52.1% in 2005 (among other ownership types, collective 7.3%, foreign 6.3%, joint venture 3.1% and jointed stock company 23.9%).
4. Factors influencing the development of this industry. According to a recent survey the factor 'market competition' came to the top (73.7%), followed by 'industrial regulation' (43.1%). 'Market demand' was recognised as less important (26.3%) since installation of the fire protection system in buildings over 24 meters is compulsory according to the law. The importance of 'technology' (21.2%) has not been fully understood by most surveyed firms. As with customers the most decisive factor of product purchase is the 'price' (79.5%), followed by the 'product compatibility' (72%) and the 'quality of service' (50%). 'Technology content' (29.5%) is largely ignored by customers.
5. Industrial environment. This industry provides varied sectors in which firms operate. Basic accessories of detectors and control panels such as diodes, relays require little capital and technological investment. However being a system manufacture it requires a comprehensive understanding of nuclear radiation, micro-electronics and optics. Because of the fierce competition, more and more firms are running at a margin profit which reduces capital available to technology development. Foreign companies are disadvantageous at product prices. But quite a few of them have established joint ventures with local firms. Some of them look for opportunities in other developing countries like India. It is very unlikely that foreign firms will leave such a huge market untouched without an attempt.

In conclusion, after more than 30 years development, the Chinese fire alarm and fighting industry has made some impressive progress. Local firms so far have controlled more than 70% of the market share. Some of them have leveraged to system manufactures with their own proprietary products. However most of the incumbents are small. Their business scales largely hinder their future technological leverage. In addition fierce competition is mainly based on price war. Without a good understanding of technological competence from both manufacturers and customers this industry faces a big challenge when foreign makers finally swarm into the Chinese market.