Do Intellectual Property Rights Impede or Assist Developing Country Firms in Reaching Technological Competitiveness? Case Studies of Three Chinese Manufacturing Firms

Yangao Xiao
School of Management & Economics, University of Electronic S&T of China
Chengdu, P. R. China 610054
xiaoyg@uestc.edu.cn

Andrew Tylecote
Management School, Sheffield University
9 Mappin St, Sheffield, UK S1 4DT
a.tylecote@shef.ac.uk

Jiajia Liu
Management School, Sheffield University
36-38 Victoria Street, Sheffield, UK S3 7QB
jiajia.liu@sheffield.ac.uk

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Andrew Tylecote
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9 Mappin St, Sheffield, UK S1 4DT
a.tylecote@shef.ac.uk

Jiajia Liu
Management School, Sheffield University
36-38 Victoria Street, Sheffield, UK S3 7QB
jiajia.liu@sheffield.ac.uk

Abstract

This paper uses the intellectual property management strategy of three Chinese firms as a point of entry to two debates: first, how can 'latecomer firms' (LCF) in developing economies manage their development of technological capability (and within it their IP) strategically, in order to become fully competitive internationally? Second, how has the accession of mainland China to the World Trade Organisation (and within it the acceptance of the TRIPS agreement on IP protection) affected the scope for Chinese firms to become technologically competitive internationally? The answers to the second question are somewhat sector-specific: positively for low- and medium-technology, negatively for high-technology sectors.

Keywords: Latecomer firms, technological competitiveness, intellectual property, TRIPS agreement, WTO entry.

1. INTRODUCTION

This paper uses the intellectual property management strategy of three Chinese firms as a point of entry to two debates:

1. On technology strategy at firm level: how can 'latecomer firms' in developing economies manage their development of technological capability (and within it their IP) strategically, in order to become fully competitive internationally?
2. On technology policy (and within it intellectual property [IP] rights policy) at national level: how has the opening up of the Chinese economy to (almost-free) trade and foreign investment through World Trade Organisation (WTO) entry in 2001-5 affected the scope for Chinese firms to become technologically competitive internationally? How have Chinese firms been affected by the acceptance of the TRIPS (Trade-Related Aspects of Intellectual Property Rights) agreement[i] on intellectual property protection, within the terms of WTO entry?

One issue in the first debate is the terms of technology transfer and the timing of innovative effort: the received wisdom is or has been that latecomer firms should focus on getting production capability through licensing or joint venture deals with advanced 'Northern' firms, building independent technological capability by stages thereafter (Gao, 2003). An alternative view is that such 'dependent' strategies have a way of becoming permanent, and that it may make for more success in the long run if technology transfer takes place through 'imitative' strategies in which learning takes place more independently, with little help from the firm(s) being imitated, and even without their permission. (We derive the dependent/imitative distinction from Freeman, 1992, though our definitions are not quite the same as his; see next section and Liu and Tylecote, 2009.) An imitative strategy will typically 'unbundle' what in a dependent strategy would be a package or bundle of technologies all provided by the same Northern firm[ii]. Each component of the bundle would be sourced as convenient – where possible by reverse engineering, or purchase from a domestic supplier; where necessary and possible using the firm's own design and engineering capability. Gao (2005) compares the strategies and performance of Chinese firms in two high-technology 'IT hardware' areas: telecommunications capital equipment and television. He argues (in effect) that the Chinese telecommunications equipment firms gained by the fact that they were forced (by American strategic technology transfer restrictions) to use imitative strategies from the beginning, while the TV firms could and did use dependent strategies. Some telecoms equipment firms (notably Huawei and ZTE[iii]) emerged as technologically competitive, internationally, while the position of all the TV firms remained weak. Lu and Feng (2004) made their comparisons within one sector, motor vehicles, arguing that 'insider' firms favoured and financed by central government settled into comfortable dependent strategies vis-à-vis their foreign joint-venture partners – and remained dependent; while 'outsider' firms not favoured and financed by central government (like Geely and Chery), for which such (expensive) strategies were not an option, used unbundled imitative strategies with remarkable success (see also Liu and Tylecote, 2009)[iv].

If the arguments of Gao, and Lu and Feng, have merit, they have ominous implications for technology policy. During the 1990s Chinese central government policy followed received wisdom and (in effect) encouraged 'insider' firms to follow dependent strategies – while they were also expected, in parallel, to develop independent technological capability. They were easily able to strike bargains for joint ventures with Northern partners, since the latter would have no other possibility of access to the Chinese market, or to Chinese (labour) resources. Meanwhile 'outsider' firms found imitative strategies also the more easy to follow, in that foreign intellectual property was protected neither *de jure* nor *de facto* in China. Both dependent and imitative strategies were bound to become more difficult later, simply because Chinese production capability was closing on the technological frontier: a foreign firm might happily transfer obsolete technology to a Chinese partner, while inevitably having grave misgivings about transferring more or less up-to-date technology. (See Case Study Two, below.) Likewise, the newer the technology, the harder to imitate, because the better protected by patents, secrecy and general unfamiliarity. The situation changed also, however, through an act of deliberate policy - Chinese accession to the WTO after 2001 (Kong, 2002). At least *de jure,* WTO entry has given foreign firms protection for their intellectual property in China: they are free to challenge infractions in the Chinese courts and even if their success rate has been initially low (Yu, 2005), this must represent an increasing constraint on imitative strategies. Meanwhile WTO entry has made dependent strategies less attractive from the point of view of the prospective foreign partner – why share technology, and the profits from it, with a Chinese firm, when one is now entitled to set up a wholly-owned subsidiary in China instead? (And exporting direct to China is now less constrained by tariffs and other restrictions.) The freedom to enter the Chinese market directly must indeed represent another obstacle for imitative strategies too: why should Chinese customers accept what is initially an imperfect imitation of foreign product X or Y when the real thing is now on sale? If imitative strategies are really the (or a) route to follow for ascent, has this policy change made it more difficult for Chinese firms to achieve technological competitiveness in future?

The case for WTO entry was and is also compelling. China's general economic strategy at least since the early 1990s has been founded on access to world markets (Ito and Krueger, 1995). On world markets, its firms would have to face the competition of Northern firms, and their challenges to infractions of intellectual property rights, even if it stayed outside the WTO. Better to subject them to the same disciplines at home as abroad. Better, indeed, to give the more innovative Chinese firms the same protection at home as they would get abroad – protection from rivals who would imitate *their* products and cripple them by competition on price. The first priority, indeed, in the development of the Chinese intellectual property rights regime has clearly been the protection of *Chinese* IP (Yu, 2007). How far has the new IPR regime strengthened the position of the more innovative Chinese firms, and helped them to shape new technology strategies which will lead directly toward being technologically competitive on world markets?

This paper distils and reviews the findings of a research project which examined the strategies of intellectual property management, and more broadly of technological capability development, in three Chinese firms chosen as leaders in their respective sectors. These sectors were selected to range widely across levels of technology: one from low tech (viscose spinning), one from medium-high tech (heavy plant for steel mills) and one from high technology (digital television sets). After the literature review we proceed to case studies of each firm. We then put the insights derived from them in the context of secondary data on the technological (patenting) and trade performance of Chinese firms in general in their sectors, and the strategies now being followed by them. We come thereby to at least tentative answers to all the questions posed above. They vary decidedly by sector.

2. LITERATURE REVIEW

2.1 The Role of Intellectual Property in the Technological Capability Development of Late-comer Firms

Mathews (2002) defines a late-comer firm (LCF) as one which meets four conditions: (1) Industry entry: The LCF is a late entrant to an industry, not by choice but by historical necessity; (2) Resources: The LCF is initially resource-poor, e.g. lacking technology and market access; (3) Strategic intent: The LCF is focused on catch-up as its primary goal; (4) Competitive position: The LCF has some initial competitive advantages, such as low costs, which it can utilize to leverage a position in the industry of choice. Clearly this describes the typical situation of the more ambitious firms in developing countries.

Technological capabilities are most broadly understood as the ability to use technological knowledge efficiently to assimilate, use, adapt and change existing technologies; and also as the ability to create new technologies and to develop new products and processes. They are the major determinant of industrial competitiveness (OECD 1996; Schacht 1997; Kim 1997, 1999). We distinguish between *static* technological capability - the ability to use specific existing technologies for production at a point in time – and *dynamic* technological capability – the rest of the capabilities set out above (Cai and Tylecote, 2008). This distinction gives us a way of classifying and evaluating Christopher Freeman's (1992) classic categorization of technology (or innovative) strategies – dependent, imitative, defensive and offensive.[v]

An offensive strategy is designed to achieve technical and market leadership by being ahead of competitors in the introduction of new products. It thus gives the highest level of static and dynamic capability. A firm which follows a defensive strategy does not seek to lead but to respond to the advances of an offensive innovator – although its response may turn out to be better engineered, cheaper or more suited to customer needs. We can then say that it has significantly less dynamic, but perhaps not less static, capability. The 'imitative' firm is content to follow behind the leaders in established technologies, possibly a long way behind. So is the dependent firm: the difference between the two strategies, as we indicated in the Introduction, is in the relationship with leading firms. Both strategies may involve taking licenses from leading firms (as indeed may defensive or even offensive strategies) – but the imitative firm is seeking to minimize its dependence, so that it will 'unbundle' the technologies it requires, licensing one element from Firm A, another from Firm B, reverse-engineering a technology of Firm C's. A dependent strategy, on the other hand, will typically involve buying (or rather renting) a bundle of technologies from one provider – the classic case is buying a 'turnkey' plant. In a developing economy it is highly likely to involve a joint venture in which the foreign partner provides all the technology, including training, and the domestic firm provides land, contacts, market access, and perhaps finance.[vi] If the dependent firm is able and willing to spend enough money, and if its bargaining position (for example in terms of market access) is strong, it may be able to acquire rather advanced product and process technologies – so its static capability would then be quite high. Its dynamic capability – its ability to assimilate, adapt and change existing technologies, to create new technologies and to develop new products and processes – is very low, because it need not do, and does not do, any of these things for itself. (See **Error! Reference source not found.**.)

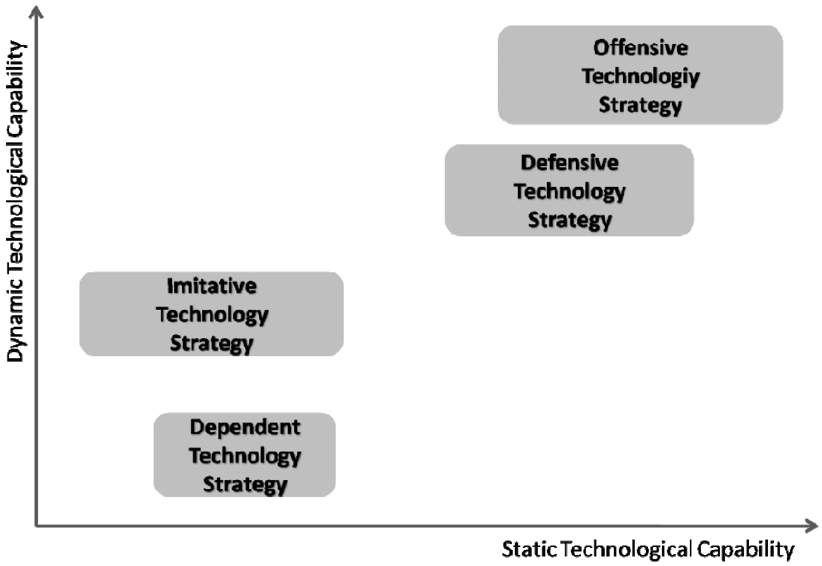

Figure 1 Technology strategies and technological capability

Source: Authors

The link between capability and intellectual property arises because technology can be comprehended as a set of knowledge. Teece (1998, 2000) argues that competitive advantage flows from the creation, ownership, protection and use of difficult-to-imitate knowledge assets (including tacit knowledge and explicit knowledge). Superior performance depends on the ability of firms to innovate, to protect (intangible) knowledge assets and to use knowledge assets. Sullivan (1998) and Poltorak and Lerner (2002) use the term 'intellectual capital' instead of knowledge assets. Intellectual capital is knowledge that can be converted into profits, which originates with a company's individual employees, each of whom has skills, abilities, knowledge, and know-how. An intellectual asset is knowledge which is codified and defined. Those intellectual assets which are legally protected are called intellectual property. The term 'intellectual property' has been used for almost 150 years to refer to the general rights that encompass patents, copyrights, designs and trademarks, as well as a host of related rights (Comish 1996; Bently & Sherman 2004).

The degree to which innovations are protected by legal and other mechanisms affects how firms profit from innovation (Teece 1986). The Levin *et al.* (1987) study of U.S. firms finds that firms do not, in general, regard patent protection as very important to protecting their competitive advantage. However, comparison of the findings of Levin et al., with those of Cohen et al. (2000) suggests that patents may be relied upon somewhat more heavily by larger firms now than in the early 1980s, notably in the information technology fields; and they are more important for products than for processes. Moreover these findings must be seen in context. The American managers in large firms who answered Cohen *et al.*'s questions would have been concerned above all with their competitive position vis-à-vis other leading firms. Such rivals would have a range of responses available to their patents – notably, legal challenge, and 'inventing round'. ('Inventing round' can be defined as Firm B inventing a product or process which is functionally more or less equivalent to that which Firm A has already patented, but not covered by Firm A's patent; and which is itself patentable by B.) For such firms a patent might therefore be a rather minor obstacle to competition. For the late-comer firm, weaker in skills and resources, both legal challenge and 'inventing round' would be more difficult undertakings.

The difficulty of inventing round may however vary by sector. In "discrete" product industries, such as chemicals and pharmaceuticals, a product innovation will be defended by a relatively small number of closely related product and (perhaps) process patents. In "complex" product industries, such as telecommunications equipment and indeed most areas of information and communication technology, we may expect each product to be composed of a relatively large number of components and elements, each of which is likely to be protected by patents – together forming a 'technological blockade'. Rarely will a single firm have all the patents relating to the product, of course. But the larger one's share in the total, the better one's position in negotiation – you let me use your patented technology, and I'll let you use mine…. Clearly all that the late-comer firm can aspire to do initially is to accumulate enough relevant patents to get to the bargaining table, but even that may be a formidable undertaking. The existing players are unlikely to want more players at the table, and are not forced to admit another player unless that firm has 'blocking' patents: inventing round will not be enough, one must have control over some valuable novelty that the existing players cannot quickly invent round.

We have also to differentiate sectors by technological level. High-technology sectors can be assumed to be advancing faster than medium-tech, medium-tech faster than low-tech. (The OECD definition of technological level goes by R&D intensity, and we can assume that there is some relation between rate of spend on R&D and rate of advance.) Compare, then, a high-tech product X with a medium-tech product Y, with the same degree of complexity. There is no reason why X should incorporate more patented inventions than Y does. However, there is good reason to expect that a larger number of the patents relating to Y have expired, the due period since patent grant having elapsed. Among those which have not yet expired, there will be a larger proportion of 'old' ones, for which there has been ample time for inventing round – so the patent-holders will be in a weaker bargaining position. Overall, the entry barrier posed by intellectual property rights will clearly be lower. In the next section we consider the special tactics which may be required to break through a technological blockade in a high-technology sector.

2.2 How Can Late-comer Firms Break through Technological Blockades in High Technology?

We presented the speed of change in high-technology sectors above as making entry more difficult for late-comer firms. The potential exception to this generalization arises from the appearance of an *emerging* technology. Day & Schoemaker (2000), Yin *et al.* (2004) and Li *et al.* (2007) propose that emerging technologies are science-based innovations that have the potential to create a new industry or transform an existing one. The major characteristics of emerging technologies are: (1) great uncertainty, including technology and market development (Courtney 2001), (2) creative destruction (Schumpeter 1939; Tripsas 1997), and (3) (more arguably) winner take all (Barney 2002). In terms of intellectual property, many of the patents protecting the market position of incumbent firms will quickly become irrelevant – being replaced by patents relating to the emerging technology. The newness of the emerging technology may mean that the incumbents have little – at least, less –

advantage over late-comer firms in getting patentable inventions in it. With luck, their strength in the established technology may make them less interested in or aware of the potential of the emerging technology. There may be a number of competing emerging technologies, any of which might come out on top. The challenge to the late-comer firms is to accumulate patents in as many of them as possible – and of course to pick the winner.

Late-comer firms in a large economy have two further ways of making breakthrough easier. First, there will probably be a considerable number of them, and they can band together to do joint research and (even without that) to form a *patent pool*. A patent pool is an arrangement between two or more patent holders in which the relevant patents are licensed jointly as a package. It is often based around a specific technology or standard (Aoki 2005; Aoki and Shiff 2008). In the field of ICT, the patent pool is the major mode that industrial leaders use to profit from licenses and to share technology information among internal members (Shapiro 2000; Lerner and Tirole 2004); but equally, LCFs can band together in a patent pool to strengthen their bargaining hand vis-a-vis the leaders. Second, whenever there is a step-change in technology, such that a new standard is required, they may join together (perhaps under government leadership) to define a different standard from that (or those) of the main incumbents. That choice carries an obvious risk, that the standard fails; but if it does succeed, there is a better chance to manoeuvre past the patent blockade which will form around the incumbents' standard(s).

2,3 The general context of IP strategy in developing countries.

According to the Paris Convention for the Protection of Industrial Property (1883) and TRIPs of WTO (1995), patents applied for in the various member countries shall be independent of patents obtained for the same invention in other countries, whether member countries or not. Simultaneously, the conditions for the filing and registration of trademarks shall be determined in each member country by its domestic legislation. That means it can be different in protection range, period of validity, registration, examination, permission condition of IP in different countries.

In spite of the internationalization of the IP regime, the remaining national specificities give LCFs opportunities to exploit IP to motivate and protect innovation. Like all other firms, they can begin by discovering competitors' technology development and their technological innovation path through published patent information – particularly from the U.S. Patents and Trademark Office (USPTO) and the European Patent Office (EPO). They may then be able to exploit the expiry of patents of leading firms; or they may find that a leader has not troubled to apply for a patent in this or other developing economies. That will then give the LCF freedom to produce at home, as long as it does not attempt to sell where there is patent protection of the product. If and when they succeed in 'inventing round' leaders' patents, they are likely to find their own country's patent examiners more inclined to concede novelty, than the examiners of the major developed countries – where the leader is likely to challenge the new patent.

2.4 The rules of patenting in China

Table 1: Categories, term and requirements of patents in China

Invention	20 years	'Novelty, inventiveness, and practical ability or usefulness'; an invention must have *prominent* substantive features and represent *notable* progress compared with the technology existing before the date of filing
Utility model	10 years	'Novelty, inventiveness, and practical ability or usefulness'; the utility model must have *substantive* features and represent *progress* compared with the technology existing before the date of filing
Design	10 years	'Novelty, usefulness'; most incremental of improvements in aesthetic rather than technical features

Sources: 1. Fai (2005). 2. http://www.sipo.gov.cn/sipo2008/zsjz/

Patent laws of some kind date back in China to the late 19th century, but only in 1984 was the first modern patent law adopted, the same year as China signed the Paris Convention on the Protection of Industrial Property. In 1992 the scope of patent protection was broadened and China's patent law was brought broadly in line with international standards, as of 1 January 1993. In 2000 another revision of the patent law was made in line with China's entry to the WTO, effective in July 2001. However the formal position is one thing, the practical position is another: it was only rather gradually, after 1993, that patent laws began to be taken seriously by Chinese firms (Fai 2005). The three categories of patents available in China are shown in Table 1. The main (though small) difference from other national systems lies in the term 'practical applicability': this is broader in meaning (as construed by the Chinese authorities) than the term 'industrial applicability' adopted in other countries. Its breadth enables more inventions and utility models to qualify for a patent (Fai 2005). In general, China's IP authority SIPO (State Intellectual Property Office of China) has rules and procedures resembling those of the European Patent Office most closely; not surprisingly, since they are modelled on those of the EPO (Neobard 2009). There is however one very significant difference in practice. SIPO is unusual in the amount of detail it requires in the patent application on how the invention works. Not enough detail: patent refused. Of course, the more detail is given, the more help is given to any prospective 'inventor round' (Neobard, 2009).

3 THE CASE STUDIES

In this section we discuss three cases of technology strategy and intellectual property management in domestic mainland Chinese firms. Case One is in textiles - Yibin Grace Group Co. Ltd - 'Grace'. Case Two is in heavy machinery - China National Erzhong Group Co. - 'CNEGC'. Case Three is in digital TV - Changhong Electronics Group Corporation - 'Changhong'. They are as we shall show very different in their industrial context and in their performance, but they have in common that they are all based and located in Sichuan province, Western China: that is, inland and well away from the most dynamic coastal regions. (This is of some significance in terms of intellectual property rights, since in the inland areas the courts are relatively parochial, more likely than those in the ‘cosmopolitan’ coastal areas to rule in favour of local (big) firms (Neobard, 2009).) In explaining differences among them we can thus discount locational factors, though these will have to be taken into account where any similarities appear.

3.1 Research Methods

We used case studies to understand the different opportunities for technology development in the three firms and to examine their strategies of IP management to profit from technological innovation. In organizational research, the case study method is one of the frequently adopted research methods, and the appropriateness of the method is well documented (Eisenhardt 1989; Yin 2003). Different sources of evidence were utilized, including questionnaire, interviews, direct observation, archives and statistics:

1. Semi-structured postal questionnaires were filled out by the IP director of each of he case study firms between July 2007 and December 2008, to facilitate an initial understanding of the firms' general technological strategy and IP management.

2. A total of 15 semi-structured interviews were conducted by one of the authors from September 2007 to January 2008 in the three case study firms. The interviews were held individually and each lasted around one and half hours. We followed a top-down interview technique: starting from General Managers, to Deputy-general Managers, then to Directors of middle-level management (at technological centres), and to directors of IP management office and then marketing departments (see Appendix). Additional casual talks were also conducted with engineers and workers to contextualise the formal interviews. Such “top-down” interview technique helped to generate holistic maps of the cases in a limited time period. More importantly, it helps to triangulate key issues of interest and enhances the rigor and quality of qualitative data collection (Liu & Tylecote, 2009). Interviews were carried out in Chinese and recorded by hand-written notes during the interview. Tape recording has been reported to be very difficult in the Chinese culture (Cooke, 2002). Initially, interviewees were asked if they would accept tape recording; however all informants were reluctant to share their views on record. In the interviews adjusted sets of questions were put to each informant according to their operational roles, in particular, special discussions were held during the interviews with directors of technology centres and IP office, to collect detailed data about the technological development and IP strategy in the firms.

3. Statistical data. This paper cites published statistical data on official websites (SIPO of China, USPTO and EPO, etc.) to get some information on the technology development and patent application in different industrial technologies. In addition, unless otherwise stated, firm level data in this paper were collected from, or calculated based on the firms' internal statistics and archives.

4. Observations. One of the authors visited Technology Centres of the three firms, and a manufacturing plant in each (viscose fibre plant in Grace, heavy machinery plant and foundry plant in CNEGC, PDP subsidiary in Changhong).

5. Other published sources. Case Three in particular draws substantially on the rich material in Xie and Wu (2003).

3.2 "2S" in Grace—Improving Mature Technology

Grace is located in Yibin city of Sichuan province. It is a state-owned-enterprise and has grown out of a small chemical fibre factory founded in 1984. It has now become a group with five subsidiary companies, and 12,000 employees. It is now the biggest manufacturer of viscose fibre in the world. The domestic market share of Grace's viscose fibre reached 33%, and its international market share is 17% in 2006. Grace has 30 economic indicators ranking first in China's chemical fibre industry, including labour productivity, return on equity, profit margin, and growth rate of investment return. Their products are exported to 29 countries in Europe, North America, Asia, and the Middle East. But till 1997 Grace was still a small factory on the edge of bankruptcy with 3,000 employees and a production of 21,000 tons. It is the technological innovation of "2S" that saved it.

"2S" is an epoch-making process innovation which our informants described as an A-bomb in the textile industry. It breaks the traditional, 'semi-continuous' spinning technology of the past century in the viscose and other chemical fibre industry. (Advanced countries have for decades used a 'continuous' spinning technology, which is capital-intensive and accordingly is not the most profitable for use in developing economies with low-cost labour.) The typical methods to raise output of semi-continuous spinning machines are to lengthen the spinner or to speed up spinning. But "2S" does it differently: it produces two yarns at the same time. With "2S" the textile company can dramatically increase its production at very low cost. The fibre industry in developing countries is labour-intensive and low value-added. Cost of production is always the most important competitive factor. "2S" technology successfully helps Grace to be the cost leader in this industry. Grace patented this innovation with 1 invention and 15 utility patents, in additional to a series of know-how patents. The key inventions were completed in 1999, patents applied for (invention and key utility patent) in December 2000, and patents were granted in 2001 (utility) and 2002 (invention). They were introduced into production by Grace in 2002 and already generated RMB 110m. of new sales in 2003. It also effectively prevented infringement of its IP. Up to 2006, Grace had earned more than 15 million RMB of compensation and license payments from 10 domestic firms in the field of "2S".

"2S" is not a complex technology. It is so simple that almost any expert in textile machinery can work out the technological secret if they take a close look at this mechanical invention. How to protect its invention, patent or not? Grace was in a dilemma at the time when "2S" was invented. On the one hand, patenting would mean invention disclosure but not necessarily perfect protection. It applied for the main patent in December 2000 when the Patent Law of China had just been revised and it was still far from clear how effective the IP protection regime was going to be. On the other hand, not to patent would mean keeping "2S" a proprietary technology, but only temporarily. Imitating would be only a question of time for competitors, with the circulation of personnel. Finally the top management decided to patent "2S". As the Chairman and President (who was also one of the four inventors of "2S") commented: "This is a risky decision. It is based on the belief in law". In fact, the benefit from increased production and patent license due to "2S" has already made up its investments in development and legal fees, and provided Grace a large amount of profit.

In spite of the relative simplicity of the key technological advance, the IP portfolio associated with 2S – including 15 utility patents – is substantial. In the process of technological evolution, once a core technology has settled on a particular kind of design, further advances are concentrated in peripheral technologies. This has been the case with 2S. If the peripheral technologies of 2S had been patented by competitors, Grace's dominant situation would have been compromised.

The Chairman's remark about 'belief in law' is a significant one. The reform process in China was barely 20 years old when the decision to patent was taken. The market reforms initially did not rest on any firm basis of judicial protection of property rights in general (Huang 2008), and the protection of intellectual property rights was a particularly novel idea without any firm basis in Chinese history or tradition. According to the legal rules as just promulgated by the central government, Grace would be on strong ground in obtaining and using patent protection. But much in China is devolved to local administrations: 'the mountains are high and the Emperor is far away'. The risk arose from trusting to the law. Clearly Grace's management had initially rather little trust in the law; but secrecy would not work, so they had little choice.

3.3 Hot Tandem Mill in CNEGC—"Re-inventing" Mature Technology

CNEGC was established in 1993. Its predecessor, No.2 Heavy Machine Factory, was founded in 1958 in a heavy-industry hub in Sichuan. CNEGC is now a state-owned 'backbone' enterprise making key technical equipment for the Chinese national economy and national defense construction. It is one of China's 21 domestic 'heavy machinery bases' – key manufacturers. By the end of 2006, it had over 12,900 employees and more than 1,200 R&D personnel. It has a particular specialization in heavy plant for steel mills, the subject of this case – in most of the main products it has at least 50% of the Chinese market, as well as substantial export sales to developed as well as to developing countries.

It should be noted at the outset that this industry is much more high-technology than viscose fibre spinning. The latter is defined as low-technology and accordingly is very much the preserve of developing countries. Steel plant, like the rest of CNEGC's products, falls into the category of 'machinery not elsewhere specified': this is a medium-high technology sector, by the OECD definition, like, for example, motor vehicles. Quite unlike motor vehicles, however, it is produced in small volume – single units or small batches. This has important implications. The process of manufacture is genuinely difficult, with much more depending on the skill of the production workers than in a mass-production industry, much less knowledge embodied in the equipment they use. Likewise the design function (or part of it) is a repetitive one, for each unit or batch, closely connected with manufacturing (and with sales).

The hot tandem mill is perhaps the key set of equipment in large steel plants, and accordingly the leading product of CNEGC. Here as across its product range, CNEGC found itself far behind the technological frontier when the reform process began in 1978. It was however among the first group of state-owned enterprises funded and permitted to seek foreign help in 1979: it was an 'insider' firm. It depended heavily on licensed foreign technology, from three different foreign firms, in mastering advanced techniques of casting and forging during the 1980s, though at the same time it set up two important R&D

departments, the Heavy Machinery R&D Department and Large-size Casting and Forging Research Department. By 1990 it had developed what could be described as detailed design capability – the ability to tailor a general design for the specific requirements of an individual customer – as well as reaching international standards over a wide range of manufacturing processes – and these capabilities steadily improved during the 1990s. Meanwhile it drew on no fewer than eight foreign firms for product technology for steel plant alone. Nonetheless, the 1990s were a decade of deepening crisis for CNEGC. Small and relatively simple equipment, where it depended little on foreign technology, was by the same token a field open to newly-founded private firms, who duly took most of the market (and ravaged the profit margins on what CNEGC continued to make). Large items like hot tandem mills were safe from the private firms, but there CNEGC continued to depend on foreign firms. There was a heavy price to pay for such dependence: as Mr Zeng, vice general manager, said (interview, summer 2007), during this period CNEGC did 80% of the job but only received 20% of the profit.

Hot tandem mills were a classic example of the 80:20 problem. To solve the problem there, CNEGC needed to become a one-stop contractor (i.e. provide a full service from product design, manufacturing, adjustment to installation). The key obstacle to this aspiration was the hot coil box. This is the key technology in the hot tandem mill, and patented by foreign firms in 69 countries – but not including China, as CNEGC found when it searched the patent records of SIPO. The hot coil box was a 'black technological box' to CNEGC at that time – it had not been licensed to produce it, and knew little or nothing about the technology. It was vitally necessary for CNEGC to break the technical blockade. In order to do so, CNEGC set up a hot coil box project team in 1995. It succeeded in opening the black box and by 1999 had by itself developed its own design of hot coil box, which was different from foreign firms' in structure to some extent, and matched the requirements of Chinese domestic firms better than foreign designs. It proceeded directly to apply for patent protection in China, which it duly achieved.

Unfortunately it turned out to have been inventing round a moving target. By this point, foreign firms had improved the technology, bringing out a new type of 'coreless conveying-type' hot coil box. CNEGC set up a coreless conveying-type hot coil box project team and in 2001 again succeeded in inventing round; again it patented it in China. By this time it was at the technological frontier not only in production but in design and development capacity: it continued work on hot coil boxes and by 2007 developed another new coreless conveying-typing hot coil box in 2007, and again patented it in China. By this time it is no longer appropriate to talk of 'inventing round': it was CNEGC which was in some degree pushing the technological frontier out, and so in a period of some ten years it had gone from some combination of dependent and imitative technological strategy to a full-fledged defensive technological strategy.

CNEGC's success with the coreless conveying-type hot coil box solved not only its own problem, but a serious problem for the Chinese steel industry. The hot coil boxes available on the international market had not suited its particular conditions[vii]: CNEGC's, did. Moreover CNEGC was able to make them for a price 30-40% cheaper than imported coil boxes. Due to such technological success and its ownership of the IP, CNEGC gradually took over foreign firms' role as one-stop contractor in this field. From 2000 to the end of 2008, its hot rolling strip steel projects with patented hot coil box technology created an output value of 6 billion RMB (some $900 million at 2008 exchange rates).

3.4 Digital TV in Changhong—an Example of LCF in high technology

Changhong was established in Mianyang city of Sichuan, in 1958, originally called State-run Changhong Machinery Factory. Until the 1980s its main product was radar for military airplanes. In the 1980s and 90s it transformed itself into a diversified electronic and electrical consumer goods producer – with TV as its largest product area. Unlike CNEGC, Changhong was not one of the 'favoured' 'insider' firms during the 1980s. (The three favoured firms in the TV industry made little effort at technological learning and became completely uncompetitive during the 1990s (Xie and Wu 2003)). Like CNEGC, Changhong did not set up joint ventures with foreign firms, and broadly chose an ambitious imitative rather than dependent strategy. Thus, while it imported assembly lines from Matsushita of Japan, it put heavy emphasis on assimilating and understanding the technology employed: the Changhong engineers who worked with Matsushita's engineers on the installation and adjustment of the second assembly line in 1985 were in consequence able to develop their own process technology. 'From 1987 to 2000 it designed and manufactured by itself 13 state of the art assembly lines.' (Xie and Wu, p.1471). During the 1990s it used reverse engineering in combination with internal R&D to learn how to design CTV electronics circuits. (By CTV we mean colour TV, of the old type – using analog technology, and cathode ray tubes (CRT) for the screen display.) By 1997 Changhong's share was 25 percent in China's CTV market – more than the next two firms combined, and far ahead of all foreign brands. In 1998 Changhong made the strategic decision to enter international markets. As Xie and Wu put it, Changhong learnt the art of assembly in 1979-84, process engineering skills in 1985-89, they implemented technological adaptation in 1990-95 and started acquiring product innovation skills after 1996. It was, in short, a model of successful technological learning, and praised and analysed as such by Xie and Wu.

What Changhong was not doing in the late 90s, unfortunately, was moving over in good time to a defensive technology strategy. By the late 90s it was inching in that direction, according to Xie and Wu: it was strengthening its relationship with domestic research institutes and universities in order to get access to the latest technologies. But it was trying to do so for pennies, as Figure 4 shows. Through the late 90s its average R&D intensity, as a proportion of sales revenue, was less than 2%: a niggardly spend for a high-technology industry. And this was at a time when it was willing and able to raise risk capital on the stock market: in 1995 it raised about 426 million RMB on capital markets, and in 1997 it raised 2299 million RMB (Wu and Wang, 2009). The latter figure was more than its entire R&D spend in the five years, 1996-2000. Most of the money was spent on improving its manufacturing capability.

While the Chinese CTV firms improved their manufacturing capabilities and began to increase their market shares in the international market during the 1990's, an industrial technological revolution - DTV - was happening stealthily. DTV (digital TV) is a TV system which adopts digital technologies. As shown in Fig. 2, the patent applications for DTV began at the end of the 1970s, increased massively during the 1990s, and began (in the USPTO and EPO) to decline after 2000. DTV standards, e.g. ISDB-T of Japan, DVB-T of Europe and ATSC of USA, have come into being, which are covered by a large number of patents. The top 10 patent applicants in EPO, USPTO and SIPO of China are shown in Table 2. The 'incepting port' of DTV (the point at which the transmission is received by the television set) has been a focus of R&D in the top firms of Europe, USA and Japan since

1977. During the same period, there has been a separate but also major revolution in display technology: CRT has been displaced, at least in advanced markets, by LCD (liquid crystal) and PDP (plasma). The patented technologies of LCD are owned by Sharp, Hitachi, Canon, Samsung, Philips, LG Philips, Toshiba, Seiko Epson, NEC and SEL. According to the statistics of USPTO in 2004, the patents of the top 20 applicants amounted to more than 6,500. The technologies of PDP are owned mainly by Matsushita, FHP, NEC, LG, Samsung, and Hitachi.

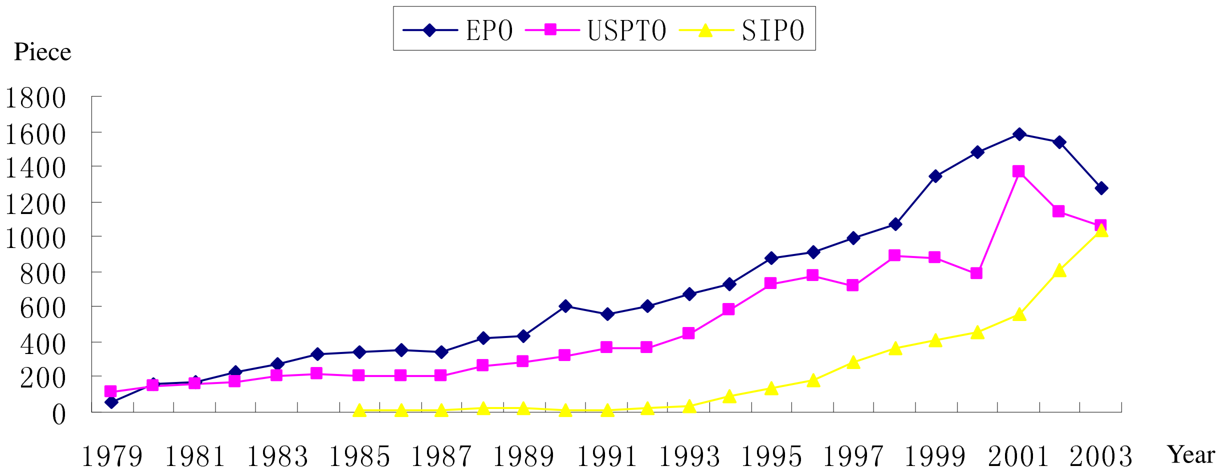

Figure 2 Invention patent application of DTV in EPO, USPTO and SIPO, 1979-2005

Sources: EPO, USPTO, SIPO

Table 2 Top 10 applicants for DTV technology patent in EPO, USPTO and SIPO of China, till 2006

EPO		USPTO		SIPO of China	
Firm	Piece	Firm	Piece	Firm	Piece
Philips	1285	Sony[jp]	1176	Samsung	556
Thomson[fr]	1162	Samsung[kr]	947	Philips	419
Sony	1141	Philips	883	Thomson	404
Siemens	605	IBM[us]	740	Sony	338
Panasonic	389	Thomson	647	LG	304
IBM UK	362	Panasonic	645	Tsinghua System[cn]	260
GEN Electric	291	Fujitsu	551	Huawei Tech[cn]	126
Samsung	285	Texas Instruments INC	532	Mitsubishi	81
CIT ALCATEL	236	LG	455	NEC	78

Note: ‘DTV Patent Development’, Changhong Internal Report, November 2007.

As scheduled, terrestrial DTV began transmission in the US in 1999, and analog TV was due to close in 2009. The dates of start of transmission of DTV and closing analog TV in UK are 1998 and 2012 respectively; in Germany 2002 and 2010, in Japan 1998 and 2005; in China 2007 and 2015. By the time the Chinese CTV firms realized that the DTV time was coming, the main foreign firms had distributed their patents in the field of DTV all over the world. They are in a position to sue the Chinese TV firms for royalties; and they do. E.g., the royalty for a licence to use the ATSC (American) standard is 30 US dollars per set. It has been calculated that, using that standard, the royalty will cost Chinese TV firms 1 billion US dollar per annum (Changhong interview, IP Office Director). Weak in patenting, China's domestic DTV producers are quickly losing the local market: take LCD TV as an example. Between 2005 and 2006, domestic and foreign brands shared around 60% and 40% of the Chinese market; in the first half of 2007, the domestic brands fell to 56.4% and was less than 50% in 2008 (Wu and Wang, 2009). Thus it can be seen, Chinese CTV firms are late-comer firms in the field of TV technology once again.

This problematic situation is a rather general one for Chinese firms in information and communication technology – now by far, China's largest export industry – and accordingly the response to it has not been Changhong's alone. The central government has led in constituting a number of independent Chinese digital technology standards based on three broad systems: IGRS (Intelligent Grouping and Resource Sharing)[viii], AVS (Audio and Video Source Coding-Decoding Standard)[ix] and UCPS (Unified Content Protection System)[x]. Changhong has zealously participated in constituting these. One of the most important for Changhong is DTMB (Digital Terrestrial Multimedia Broadcasting)[xi] – the Chinese standard which competes with ISDB-T of Japan, DVB-T of Europe and ATSC of USA. In the core technologies of DTV, it has developed a 'sink chip' (a key component) for mobile DTV based on DTMB. Changhong has applied for three patents in the AVS-based DSP (digital signal processing) platform and a patent on a UCPS chip used for the protection of data transmission.

Changhong has also joined with nine other Chinese CTV manufacturers, including Konka, TCL and Skyworth, to establish "Shenzhen China-CTV-Alliance S&T Co. Ltd" in April 2007, in which shares—10 million RMB— are held by the ten CTV firms equally. This joint venture focuses on the technological alliance patent pool the ten firms have formed, and negotiating with foreign industrial leaders.

Changhong also felt obliged to review its strategic direction – its choice of products and technologies on which to focus. It is notable that intellectual property played a key role in this strategic review. The display field of DTV is an example. In 2005, in order to try to find weak points in the technological blockade in the display field, Changhong established a database of multinational patent information and a system to analyse patent information. Moreover, it employed a well-known US IP management firm - Wilson Sonsini Goodrich & Rosati - to collect and analyze the patent distribution all over the world in LCD and PDP. Its analysis of the situation for LCD led to the grim conclusion that it had little or no opportunity to obtain competitive advantage in LCD. It concluded that there were fewer patents and more uncertainty in PDP than LCD. So it decided to invest in PDP instead of LCD. In general it decided to try to extend its value chain, changing from a mere terminal producer (that is, of television sets) to include activities further up the value chain. But it was too late: it was caught in a trap, or rather a blockade. As Figure 4 shows, in 2004 its R&D intensity at last went up to respectable levels, and stayed there – above 6%. But in the financial years 2004, 5 and 6 it lost, on average, more than a billion RMB a year (Figure 5). As competition from advanced foreign firms had increased in the upper levels of the Chinese market, Changhong's market share had begun to fall: from 25% in 1997, it was down to 19 percent by 2000; it was 15 percent by 2007.

Let us review Xie and Wu's account of Changhong's rise to see if we can get a better understanding of its decline. As we pointed out, it was not one of the favoured insider firms, but nor was it the only outsider which came in to challenge them. With one outsider after another piling in to add to the competition, Changhong took a long time to emerge from the melee. By 1992 it was facing six domestic rivals – all but one state-owned – and three joint ventures of state-owned firms with multinationals; by 1997 it faced another powerful state-owned rival (Haier) and four more joint ventures (Xie and Wu, 2003, Table 2). Even at its strongest, in the late 1990s, Changhong faced fierce price competition within the Chinese market. State-owned competitors could not simply be driven out of the market by losses – Changhong had to acquire its weaker rivals, and with it the cost burden of their operations, in order to take their market shares (Xie and Wu p.1472). There was little product differentiation in the market, and thus there was strong price competition[xii]; even in the absence of foreign IPR, this was not the basis for profit which could have funded an ambitious defensive strategy. It was, in short, a long haul on a shoestring.

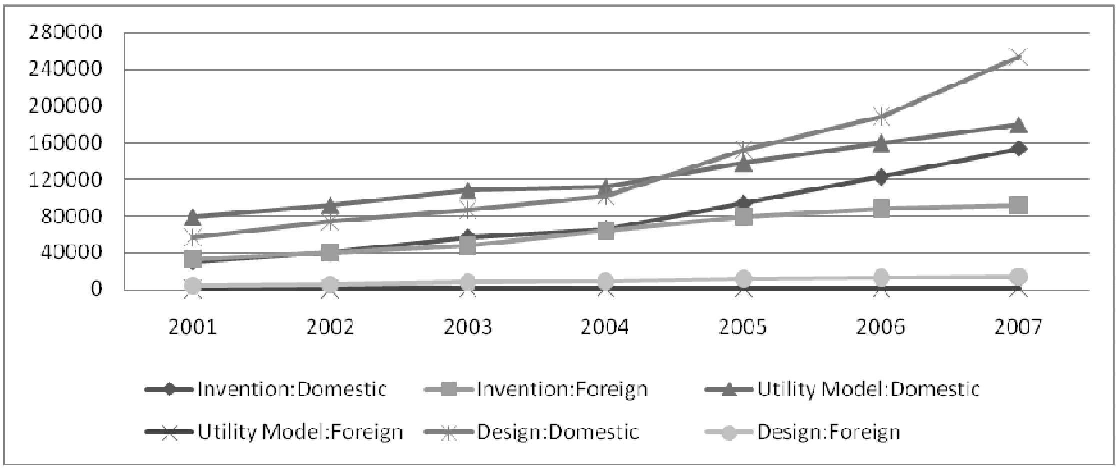

Figure 3 The domestic and foreign application of patent in SIPO: 2001-2007

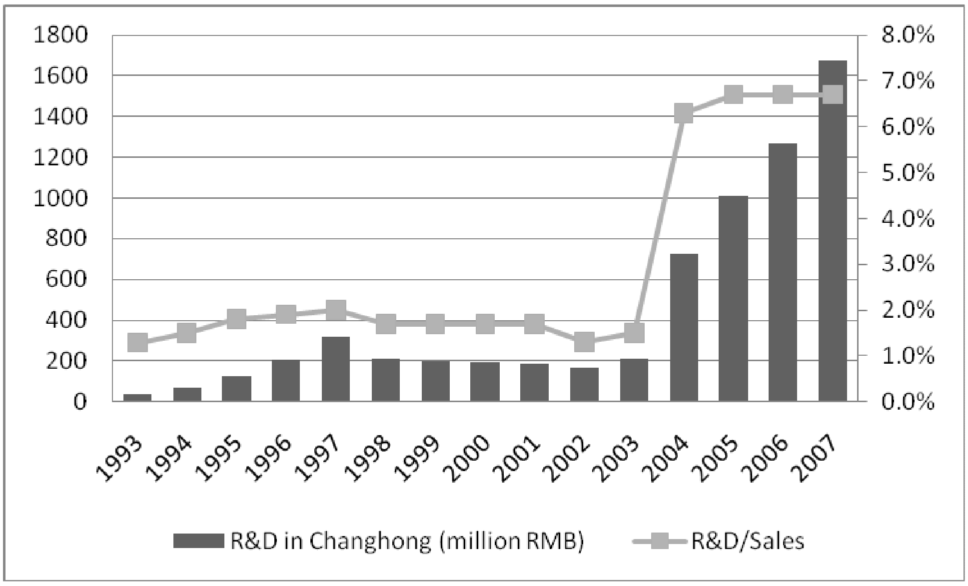

Figure 4 Changhong - R&D expenditure in absolute and intensity terms: 1993-2006 (million RMB)

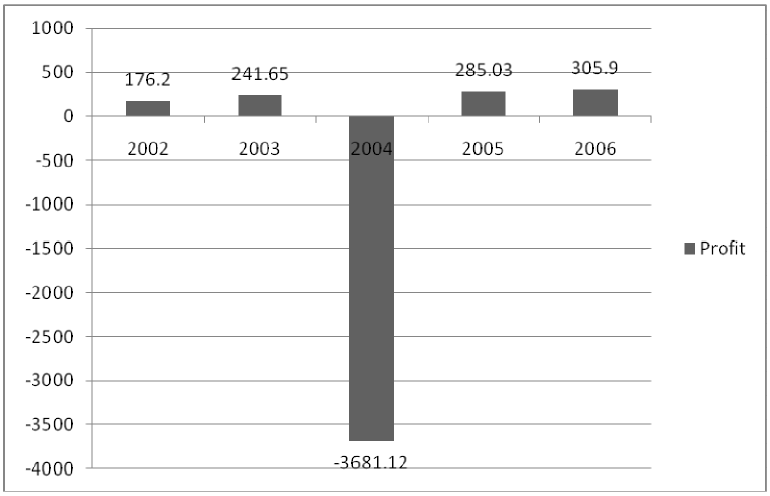

Figure 5 Changhong - profit between 2002 and 2006 (million yuan)

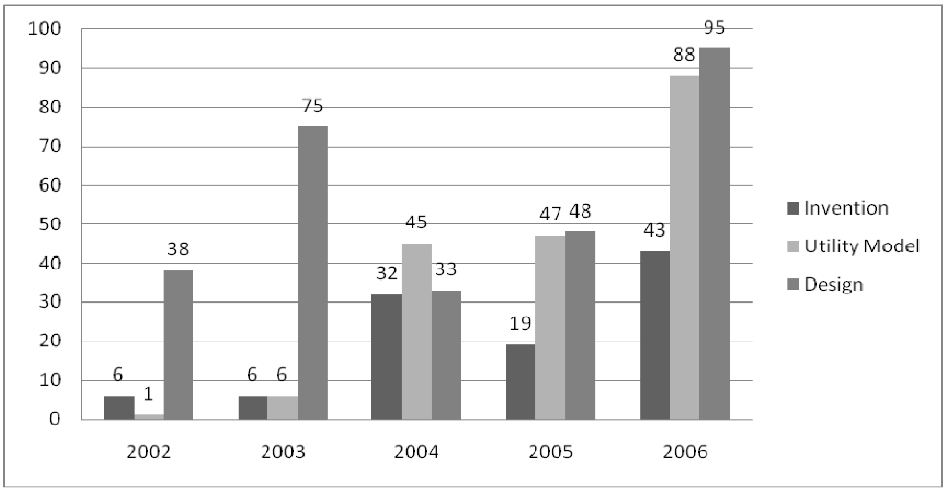

Figure 6 Patent application of Changhong in SIPO

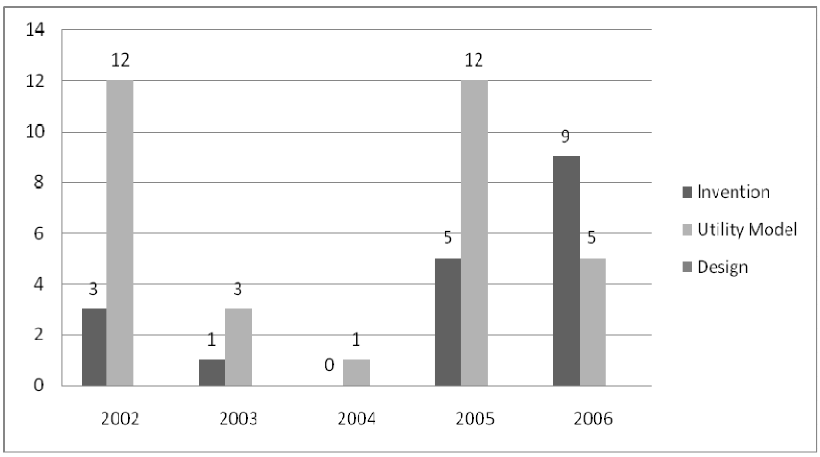

Figure 7 Patent application of CNEGC in SIPO of China

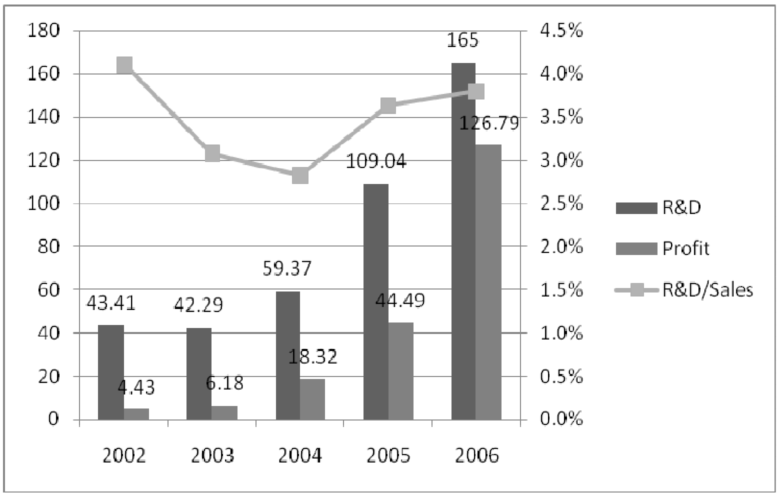

Figure 8 Performance of CNEGC: 2002-2006

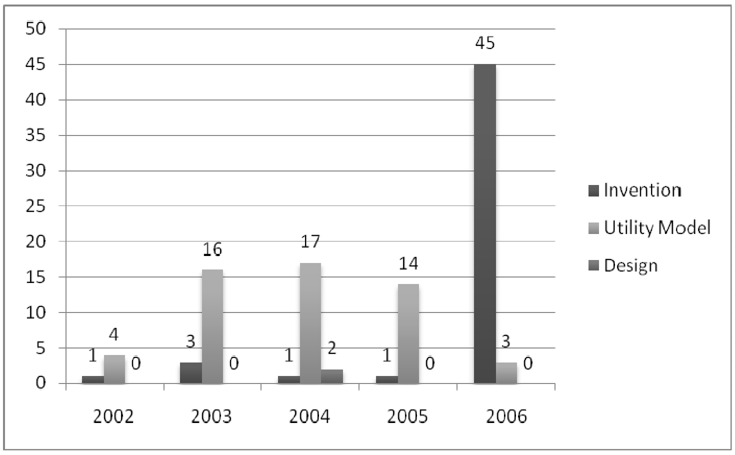

Figure 9 Patent application of Grace in SIPO

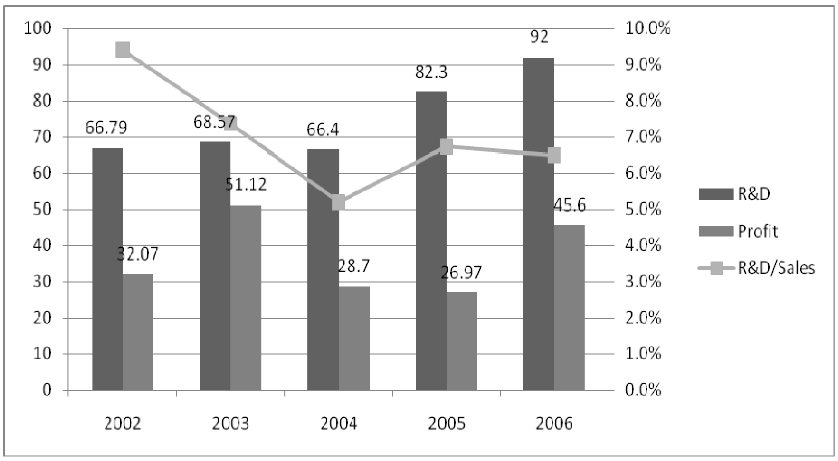

Figure 10 Performance of Grace: 2002-2006

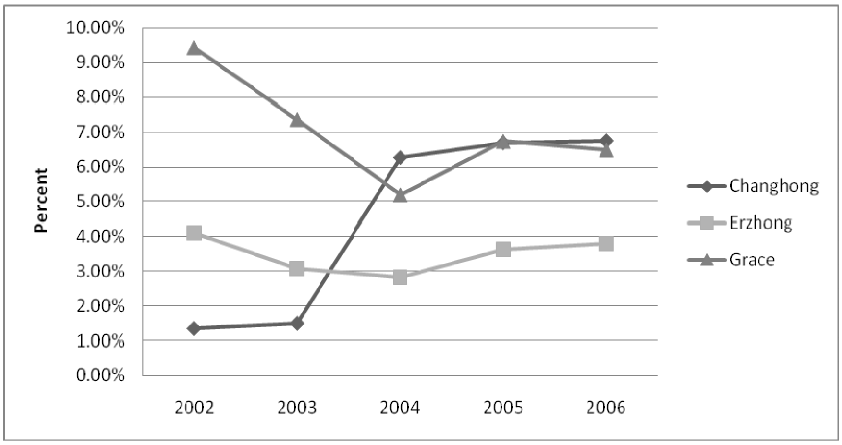

Figure 11 R&D intensity (R&D/Sales) in Changhong, Erzhong and Grace: 2002-2006

4. DISCUSSION

4.1 Outcomes compared: revealed technological advantage in the three sectors.

We follow previous research (Soete, 1987; Malerba *et al*, 1997; Mahmood & Singh, 2003) in using a "revealed technological advantage" (RTA) index that measures the relative distribution of China's patenting activity in each of the three fields. By definition the index is calculated as the world share of the country's patent stock in a given time period held in a technological class, divided by the country's share of the world's total patent stock in the same period in all technological classes (Malerba *et al,* 1997). Since disaggregated data by sector or technology class is not available at SIPO, we used data from USPTO, which records China's patenting activity between 2004 and 2008. By definition, this index equals 1 if the China holds the same share of worldwide patents in a given technology as in the aggregate, and is below (above) 1 if there is a relative weakness (strength).

We have chosen the patent classes that we judge best matched to the areas of activity of the three firms. We give data including and excluding Hong Kong (a 'base of convenience' for many firms really based on the mainland). With or without Hong Kong the upshot is the same: China's RTA is much higher for the low-tech sector in which Grace operates than the high-tech sectors in which Changhong operates, with CNEGC intermediate.

Table 3 China's patenting performance in the three technology areas at USPTO*

Technology type	Class number	China's absolute no. of patents in the class (excld. HK)	China's share of all non-US countries' total in the class (excld. HK)	RTA (excld. HK)
Textiles: Spinning, Twisting, and Twining	057	3 (1)	1.41% (0.47%)	2.14 (2.30)

Metal working	029	40 (21)	1.23 % (0.65%)	0.99 (0.75)
Television and Television Signal Processing for Dynamic Recording or Reproducing	348, 386	18 (16)	0.29 % (0.26%)	0.32 (0.41)

* Calculations are based on Utility Patent (patent for inventions) granted, 5-year total of 2004 -2008.

Source: Authors' calculations based on USPTO statistics, URL: http://www.uspto.gov/web/offices/ac/ido/oeip/taf/reports.htm

4.2 The successful use of IPR in Chinese LCFs' catch-up strategy.

Our cases were chosen to show three firms which had all, so far as we could judge, recently developed a well-worked out intellectual property strategy which nested comfortably within a well-worked out technology strategy. The differences in outcome can then be put down to differences in starting point and context. Grace, our firm in the low-technology field of viscose spinning, was not facing competition from developed countries, which had effectively abandoned the industry. Grace demonstrated that there is no technology so mature that it cannot be significantly improved. They were able to take advantage of the strengthening of IPR in mainland China to make a large profit from their innovation. The backing by law of their IP strategy, was very good for them, and might well be of some benefit for China if it stimulated further innovation and perhaps protected Chinese firms from competition from other developing countries. On the other hand IPR can be given no credit for the initial key innovation, since that was made in apparent ignorance of it, and certainly without any intention to take out a patent.

But Grace's innovation is small beer. There will not have been celebrations by economic policy-makers in Beijing when (if) they heard of the advance in the spinning of viscose. CNEGC's advance in hot tandem mills is of much greater significance. Medium-high-technology sectors like heavy steel plant are and will remain of economic value for developing and even for developed economies. We should begin by considering CNEGC's general technology strategy. Although it was a classic government-favoured 'insider' firm with privileged access to capital and resources, its technology strategy was some way from the highly dependent strategy followed (for example) by the 'insider' firms in the car industry (who set up joint ventures with foreign firms, completely under the latter's control – Liu and Tylecote 2009). It got its various technologies from a large number of different foreign firms, by license rather than joint venture. Moreover its (sub-) sector, with its demand for high skill in production and some capability in design, dictated that one could scarcely gain much static capability without getting some dynamic capability. It may well have been with this need in view that CNEGC set up its two R&D departments during the 1980s. There was indeed more imitation than dependence in CNEGC's strategy, as of the mid-nineties.

CNEGC was thus in a relatively strong position – with what could be described as substantial dynamic capability – when it found itself blocked in hot tandem mills by the hot coil box patents. It had both motive and opportunity to move, via inventing round, towards a full defensive technological strategy. The special needs of its (very large) Chinese customers were of considerable advantage to it in this situation: it was not simply inventing round, it was inventing in order to achieve a slightly different set of functions from the existing technology. The IP protection enjoyed by the foreign leaders for the successive hot coil box technologies did not prove an insurmountable barrier, and its own IPR for its versions of the hot coil box should be a substantial source of profit for the future.

All was well that ended well for CNEGC, but the favourable sub-sectoral conditions we have set out are not very widespread in the machinery sector, where volume production is as common as unit and small-batch. Where production is in volume, much knowledge is effectively embodied in the production equipment, encouraging a relatively dependent technology strategy. The situation of Chinese firms in machinery in general is poor, those producing high value-added products having mostly been taken over by foreign firms (Wu Xiaobo, 2007).

In at least one other medium-high-technology industry there are important similarities with CNEGC's situation. Motor vehicles is a good example of a sector where the special characteristics of a key part of the Chinese market provided a route away from technological dependence. While the three big 'insider' firms found their dependent strategies suited the demand of the middle and upper parts of the market for cars of 'international' quality, 'outsider' firms, notably Chery and Geely, using imitative strategies, were able to undercut them substantially on price at the bottom end of the market, where price took precedence over quality. They initially offered a combination of low price and low quality which suited their customers and had not been designed for by the world's leading firms. They were then able to move towards defensive strategies as they built volume and could fund R&D; and thereby to move up market (Lu and Feng, 2004; Liu and Tylecote, 2009). To take the example of Chery, while they were accused of serious infractions of foreign IP during their imitative phase, they worked hard and successfully later to build their own IP portfolio. This raises the question: could a Chinese firm repeat under the present relatively strict IPR regime, the sort of imitative strategy which worked for Chery around 2000? Happily for China, in motor vehicles this will not be necessary: the blockade has been broken.

4.3 The difficulties of IP management and technology strategy for Chinese firms in high technology

Unhappily for China, there are very few *high*-technology sectors where it can be said that the technological blockade has been broken. The crude trade data is thoroughly misleading on China's position here. Thus the share of high-technology exports (mostly ICT) in total exports rose from 7.9% in 1995 to 29.9% in 2004 (www.stats.gov.cn/tjsj/qtsi/zgktjnj). Given that total exports were themselves rising rapidly, this would appear a remarkable performance. However between 1998 and 2005 the share of Chinese-owned firms (aside from joint ventures) in exports of high-tech products fell by more than half (Figures 2–10) (www.sts.org.cn/sjkl/kjtjdt/data2006); in 2003 61.9% and 21.4% of high-tech exports were produced by fully foreign-owned and partly foreign-owned firms respectively (Gu and Lundvall, 2006, citing China S&T Indicators, 2004). The export data, moreover, is by turnover. Given the high dependence of Chinese manufacturers on imports of components (and equipment), the value-added picture must be far worse. Given the weak IPR position of

Chinese manufacturers, we would expect their position in terms of profit to be worse still. It is. Gu and Lundvall (2006) mention Changhong's sub-sector of electronics, TV manufacturing, in which mainland China has a 'well-developed competitive advantage', but in which value added is low because key components are imported from elsewhere in East Asia, and profit margins were as of 2005 around or below 3%. An indicator of the domestic Chinese weakness is the R&D intensity, since R&D tends to be performed near a firm's home base: the R&D intensity (over value added) of electronic and telecommunications equipment in mainland China in 2004 was 5.6% (cf. USA, 25.4) and for computers and office equipment, 3.2 (USA, 32.8) (www.sts.org.cn/sjkl/kjtjdt/data2006). (These two sectors together made up 72.4% of the value added of high-technology industry in China in 2004 – the other sectors, in descending order, being pharmaceuticals, medical equipment and scientific instruments, and aircraft and spacecraft.)

Two insights into China's difficulties in ICT can be drawn from our account of Changhong's situation and strategy. First, the Chinese firms had missed any real chance of using an emerging technology as an opportunity for catching up or even leapfrogging the leaders. As we saw, the 'emerging' DTV technology had emerged by the end of the 1990s. The opportunity had been taken by late-comer firms from Korea – notably Samsung and LG (Kim, 1997b; Poon *et al*, 2006) – not the even later-comers from China. Second, the leading foreign firms had by this point established a long technological lead over the Chinese firms, entrenched by their patent portfolios. The only chance the Chinese producers had of (in effect) 'inventing round' the technological blockades already established in DTV was the development of independent Chinese standards. This path was chosen. However, it is typical of the Chinese situation that in the main DTV technology, virtually all the valuable markets of the world have been occupied by the three main standards, leaving such markets as Venezuela, Iraq and Nicaragua as export markets for Chinese producers. For the foreseeable future, such a standard merely provides a modest non-tariff protective barrier round the Chinese market. This is somewhat ironic, given that the main point of WTO entry was avowedly to expose Chinese industry to international market forces (Perkins and Shaw, 2000). It is far from clear that Chinese firms have gained by the exchange of one form of protection for another. The old and new forms have in common that they protect the home market; they differ in that with the new form, what domestic producers have to develop and produce for that market may not be saleable abroad.

5 CONCLUSION

We sought to use the intellectual property management strategy of three Chinese firms as a point of entry to two debates, one at firm, the other at national level:

1. How can 'latecomer firms' in developing economies manage their development of technological capability (and within it their IP) strategically, in order to become fully competitive internationally?
2. How has the opening up of the Chinese economy to (almost-free) trade and foreign investment through World Trade Organisation (WTO) entry in 2001-5 affected the scope for Chinese firms to become technologically competitive internationally? How have Chinese firms been affected by the acceptance of the TRIPS

(Trade-Related Aspects of Intellectual Property Rights) agreement on intellectual property protection, within the terms of WTO entry?

The Grace and CNEGC cases provided useful examples of successful IP and more general technology strategy in, respectively, low technology and medium-high technology sectors. Grace was operating in a low-tech sector where such 'Northern' firms as there were, were not interested in the more labour-intensive trajectory of development. Northern IP was therefore no obstacle at all, and the impact of Chinese adherence to international norms of IP protection was entirely positive – allowing it to protect its key invention (from domestic rivals above all) and move into a virtuous circle of high profits, high R&D intensity and continuing high patenting. For CNEGC Northern IP *was* an obstacle, and had to be 'invented round'. In this strategy, SIPO's insistence on informative patent applications must have been helpful. So was the relatively slow pace of technological change – the target was not moving fast. Once the 'inventing round' had been successfully accomplished, CNEGC was not only able to act as a 'one-stop shop' in competition with Northern rivals: it was able to count on its IP to protect it from Chinese rivals which might otherwise have hoped to reverse-engineer its innovations. Again, there seemed to be a virtuous circle of high profit, high R&D, continuing patenting. In this sector as in textile spinning it was hard to see any serious problem arising from WTO entry or the acceptance of TRIPS.

The third case study is more ominous. It is a story of failure for a high-technology firm and industry whose prospects looked bright at the turn of the century. Changhong and the other domestic Chinese firms were unable, after 2000, to break through the technological blockades which had been constructed in the newer TV technologies which were 'emerging' during the 1990s. IPR prevented them from simply imitating Northern advances in these technologies; and WTO entry allowed foreign firms to take market share away from them, with superior product technology, by importing into China or producing within it.

It is hard to imagine that Changhong and the other more innovative Chinese firms would have been better off without effective IPR laws in China. True, they would have been free to reverse-engineer foreign technologies for production for the Chinese market – and foreign firms might have been the more wary of producing in China and thus making the reverse engineering easier. On the other hand, Chinese imitators would have been free to do to them what they did to foreign firms, and thus squeeze their volumes and profit margins from below. Only a completely nationalist IP regime would have served – one which protected Chinese and not foreign IP, within China. (This might seem, and be, unworkable now, but according to Chang (2002) something of the sort operated in the United States during the early 19th century.)

A more attractive counterfactual is later WTO entry, with delayed reduction of tariffs and of barriers to the establishment of wholly-owned subsidiaries by foreign firms. At least inside a protected market, a firm like Changhong might have used profitable large-scale production as a basis for funding high R&D spending and a (belated) defensive technology strategy – even if it did, for a time, have to pay high royalties to the foreign firms whose IP it was using.

But if a protected market was the answer, why had more than twenty years of protection, between the beginning of reform and WTO entry, not been enough? Because they had been, in large measure, wasted: above all, the 1990s had been. That protected market needed to be dominated by the fittest, best managed firms. As Huang (2008) shows, during the 1980s there had been a burgeoning of entrepreneurial firms, which were privately owned (in effect if not, for the most part, in name). From 1989 onwards, however, private entrepreneurs were at a severe disadvantage. Even when the reform process resumed, in 1992-3, it focused on helping state-owned firms to adapt to the market – with huge infusions of effectively free capital, particularly for the ‘insider’ firms of the ‘national team’. These firms were intended to become ‘national champions’ much like the most successful Korean chaebol – Samsung, LG, Hyundai. In each sector the central government generally picked three ‘insider’ firms to favour with subsidies and access to resources, presumably on the grounds the resources required for catching up needed to be concentrated.

This was similar logic to that behind the Korean government’s relationship with the chaebols. But the Korean government combined strong support with stringent conditionality and dumped failing chaebols quickly and mercilessly (Kim, 1993; Tylecote and Visintin, 2008, ch.6). The Chinese central government’s industrial policy was both internally incoherent and undermined by the insubordination of lower tiers of government (Nolan, 2005); its governance of the favoured firms, moreover, was at the same time disengaged and bureaucratic (Tylecote and Cai, 2004; Cai and Tylecote, 2008). The policy failed: instead of winners being picked quickly by the government (guided perhaps by the market), they were picked very slowly by a distorted Darwinian process of selection: the fittest prevailed over the fattest (at least in some sectors) after the fattest had been kept un-dead by government help for years. The liberalisation of trade and foreign investment thus merely exposed weaknesses which were due at root to failures of governance.

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Endnotes

[i] http://www.wto.org/english/tratop_e/trips_e/t_agm0_e.htm

[ii] The 'bundling' effect will be more pronounced in assembled products such as vehicles and telecoms equipment than in (for example) most software or pharmaceuticals (Gu Shulin, personal communication) See our distinction between complex and discrete products below.

[iii] Zhong Xing Telecommunication Equipment Co., Ltd

[iv] Like Gao, Lu and Feng did not use our terms, but the argument is essentially as described here.

[v] There are also traditional and opportunistic technology strategies, but they do not concern us here.

[vi] In our definition of dependent and imitative technology strategies we are departing somewhat from Freeman, who made 'dependent' a more limited category, in which the dependence was not merely technological, but total.

[vii] Long production line, large temperature difference between the head and tail of 'embryonic strip', and unstable quality

[viii] **IGRS Standard [http://www.igrs.org/en/]**

IGRS aims at delivering the IGRS Standard (Intelligent Grouping and Resource Sharing Standard) to enable intelligent grouping, resource sharing and service collaboration among information devices, consumer electronics and communication devices in a limited network domain (wired or wireless), to improve the interoperability and usability among these digital devices, and to create new collaborative application models for digital devices and maximize the resource usage of each device.

The original intent of IGRS is not just simply a plug and play concept, but rather is a way for digital devices to interoperate and to create new application models for our users through the notion of collaboration.

Its three key technical design goals are the following:
-Intelligent grouping: which means each IGRS device will automatically discover each other upon entering a network and will form either a peer-to-peer or master/slave device group depending on the devices' capabilities (no manual configuration is needed)
-Resource sharing: upon making automatic interconnection, each device will open its resources to be shared and used by other devices, varying by device types; for instance, an IGRS PC will share its media contents such as AV, images to a digital media player such as TV or STB, or share phone books or Multimedia Service (MMS) messages to an IGRS mobile phone
-Service collaboration: after sharing all available contents on the network, multiple digital devices can automatically collaborate together to perform brand new applications whereas a standalone device cannot.

Approval of IGRS Standard

On June 29 2005, the Intelligent Grouping and Resource Sharing (IGRS) Standard was formally approved, by Ministry of Information Industry of China, as China National 3C – Convergence Industry Standard. IGRS Standard is mainly developed by Chinese enterprises and focuses itself on industry development. With self-developed & owned IP technology system, IGRS holds the leading position in the 3C convergence era and becomes a flagship of "Chinese Standard".

IGRS Alliance

IGRS adopts in its operations a fair, open and interoperable policy that any companies, foreign or domestic, are welcomed to join, participate and contribute to the standards work. Its processes are transparent and fair to all. IGRS Working Group (IGRS Alliance) formed a strong alliance by bringing together many major Chinese and International enterprises and research institutes, to successfully build a complete IGRS industry chain with enterprises in IT, computer and CE industries and to unify the industry and research forces to form strong alliance. IGRS has 59 members today (April 2006). These members include TV, PC, ISP, ICP, hardware/IC, software, middleware, research institutions, communication equipment manufacturers etc. Members include some of the largest companies in China, such as China Telecom (internet service and content provider), Huawei (telecom equipment maker), Changhong (TV manufacturer), Hisense (digital device manufacturer), TCL, ZTE etc.

[ix] **Brief Introduction to the AVS Development [http://www.avs.org.cn/en/]**

The full Intellectual Property of second generation Source Coding-Decoding Standard – AVS is owned by China. Source coding technology mainly focuses on mass video and audio (original data and sources) compression technology, also known as digital video and audio coding technology. Obviously, as the premise of digital information transmission, storage and broadcast it is also the general foundation character standard of the digital video& audio industry.

There are two video and audio decoding standard series implementing international: ISO/IEC JTC1 formulation MPEG series standard; ITU which in view of multimedia correspondence formulation H.26x series video coding standard and G.7 series audio coding standard. MPEG-2 which formulated by MPEG and ITU cooperation in 1994 was the representative of the first generation video and audio decoding standard and is also the most broadly used internationally.

Evolves after more than ten years, both video and audio coding technology and industrial application background had changed significantly. At present there are four optional video and audio industry coding standard: MPEG-2, MPEG-4, MPEG-4 AVC (for short AVC, also known as JVT, H.264) and AVS. The first three standards are complete by the MPEG experts group, the fourth is China independent formulation. Divides from the development phase, MPEG-2 is the first generation of information source standard, other three are the second generation of standard. Compares from main technical specification - coding efficiency: MPEG-4 is 1.4

times of MPEG-2, AVS and AVC are similar and more than twice of MPEG-2.

[x] Unified Content Protection System (UCPS) [http://www.highbeam.com/doc/1G1-148061777.html]

[xi] *[http://en.wikipedia.org/wiki/DMB-T/H] DMB-T/H or DTMB (GB 20600-2006)* is the digital terrestrial television standard applied in the People's Republic of China (PRC), including Hong Kong and Macau. This mandatory standard will cover both fixed and mobile terminals and will eventually serve more than half of the television viewers in the PRC, especially those in suburban and rural areas.

The standard is being officially called Digital Terrestrial Multimedia Broadcast (abbreviated as DTMB. The standard was formerly named as Digital Multimedia Broadcast-Terrestrial/Handheld and in short DMB-T/H). DTMB is an outgrowth of work at Jiaotong University (developed ADTB-T, similar to ATSC, which coexists with DVB-T) in Shanghai and Tsinghua University (developed DMB-T) in Beijing, each of which had hoped to provide the sole technology – but neither of which had the technical or political muscle to achieve that goal, the final decision was to opt for a dual standard and fuse with the TiMi 3 standard, as a direct result of backward compatibility as the exploitation of ADTB-T, DMB-T and DVB-T for HDTV transmission via set-top boxes occurred prior to the final draft of the standard, thus making DTMB a fusion of the two aforementioned standards, the ADTB-T and DMB-T.

[xii] This price competition was in fact initiated by Changhong in 1989; it escalated to price war in 1996, due partly to the increase in numbers of manufacturers, partly to the progressive reduction in tariffs, starting in 1992 when they stood at 40% (Xie and Wu, 2003)

Appendix 1: Interviewees in Grace, CNEGC and Changhong

Firm	Department	Name	Job Title
Grace	Top management	Feng Tao Wang Yi	General manager Vice general manager
	Technological Centre	Liu Ying	Director
	IP Office	Xu Bing	Director
	Marketing Department	Tang Yufang	Deputy director
CNEGC	Top management	Shi Ke Zeng Xiangdong	General manager Vice general manager
	Technological Centre	Liu Xiaoguang	Director
	IP Office	Gu Faying	Director
	Marketing Department	Liu Dong	Director
Changhong	Top management	Zhao Yong Zheng Guangqing	Chairman of the Board Vice General manager
	Technological Centre	Ren Fei	Program General supervisor
	IP Office	Dai Dejian	Director
	PDP (Plasma) division	Fu Weirong	IP manager of Technological Department