

Standardized Confusion? The Political Logic of China's Technology Standards Policy

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Abstract:

Studying technology standards in emerging economies provides a unique opportunity to both examine the comparative political economy of science, technology, and innovation, as well as to analyze how economic institutions from mature capitalist countries fare when planted in different institutional settings. Of the emerging economies the largest and arguably most important for the international economy is China. Looking from the national systemic level we find a puzzle in explaining the Chinese policy: *Why do domestic standards continue to proliferate and be led and supported by government even when there is evidence that standards policies are counterproductive in terms of fostering innovation, their political and economic raison d'etre?* We argue that this is the outcome of a two steps self-reinforcing sequence dynamic. In the first stage the state initiates standards development in the hope of fostering technological independence by offering status and economic incentives. As standard development starts, however, an unintended consequence is that more and more organizations, fearing a loss of competitive advantage, begin competing standard development efforts, creating an innovation arms race and explosive growth in the number of standards. This proliferation is counterproductive, leading to more uncertainty and less innovation. Nonetheless, since this dynamic has been creating vested interests, they ensure the continuation of the current policy.

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Introduction:

Technology standards are becoming an important area of research in comparative political economy. Once thought to be of interest primarily to engineers and scientists, the growing economic implications of technology standards have raised the political stakes in their development and implementation (Mattli & Buthe, 2003). Technology standards have become increasingly critical to the operation of globally modular industries and the loci of fierce political competition (Kennedy, Suttmeier, & Su, 2008; Krasner, 1991; Lee & Oh, 2008; Mattli & Buthe, 2003; Suttmeier & Yao, 2004; Suttmeier, Yao, & Tan, 2006). In a world where production is fragmented across multiple regions both within and among companies, the ability of firms to produce compatible components and services is critical. However, many standards incorporate proprietary technology, which accrues to their owners significant profits should their particular standard become widely used. Consequently, there are major imbalances in the financial gains of producers at different positions in global production networks. Governments in emerging economies are increasingly aware of the relative distribution of benefits from adopting international standards and have begun to develop their own technology standards (Lee & Oh, 2008).

Studying standards in emerging economies provides an opportunity to have a critical venue with which to study both the comparative political economy of science, technology, and innovation, as well as to analyze how economic institutions developed in mature capitalist countries fare when introduced into very different institutional settings. Of the emerging economies the largest and arguably most important for the international economy is China – a country which is also the current paragon of indigenous technology standard development efforts, and that is seen by many as advancing a meticulous mercantilist policy approach

(Suttmeier & Yao, 2004; Suttmeier, et al., 2006). As China remains the world's fastest growing economy and an emerging technological power, the implications for how and why China develops standards have great implications for the rest of the world.

Interestingly, in contrast to popular belief, even a brief inquiry into China's technology standards policy record reveals no single strategy, least of all mercantilism, defining its standards policy. Where Japan's policies were highly coordinated (Curtis, 1997; Funk, 2002; Kushida, 2008; Kushida & Zysman, 2008; Lecraw, 1987), China's standards' strategy and policy-making is significantly disjointed. China's government funds pursuit of unique exclusionary standards, most noticeably in information technology (IT), but it is also an active participant in international standards forums (Suttmeier & Yao, 2004; Suttmeier, et al., 2006). The same Chinese companies that pay hefty royalties for foreign standards often fight fiercely *against* efforts to implement ostensibly liberating mandatory domestic standards. At the same time, companies with massive export markets and vested interests in globally accepted standards, such as Huawei or Zhongxin Telecom (ZTE), also participate in development of unique Chinese standards. The same government agencies support certain standards, but torpedo others. These patterns hardly suggest a coordinated mercantilist strategy.

Furthermore, the puzzle intensifies when we realize that in terms of its own goals – the enhancement of indigenous innovation – the outcome to-date of China's standard policy has been generally negative. China's technology standard policy has arguably held back its innovation-based growth in key sectors, the most prominent of which being mobile telephony. The long-delayed deployment of the domestic TD-SCDMA mobile telephony standard is the main reason why China significantly lags in 3G mobile adoption and has yet to commence 4G

network rollout.¹ Standards are ostensibly created to reduce uncertainty, but China's standards development efforts have increased confusion. The sheer number of new standards issued and developed annually ensures uncertainty (see table 1). Even more worrying from the point of view of long-term business strategy is the fact that in China *standards or regulations can become mandatory at any time, without warning or industry approval.*² The end result of any such a deluge of competing and unpredictably mandated standards is increased uncertainty, which negatively impacts growth.

With such results, there is a key puzzle to be answered: *Why do domestic standards continue to proliferate and be led and supported by government when there is evidence that standards policies are counterproductive in terms of fostering innovation?*

<<Table 1: China's Standard Development Projects - 2007-2009>>

The rich literature on China's technology standards policy has not, to date, uncovered any coherent logic to solve this puzzle. Research focuses on explaining specific standardization efforts. The literature provides a clear picture of the likelihood of success of particular standards and their evolution. However, it fails to look at the domain of technology standards from a broader systemic perspective which questions why different actors formulate standards in the first place. The literature supplies us with solid understanding of why a particular standard, such

¹ TD-SCDMA: Time Division – Synchronous Code Division Multiple Access.

² The most famous case of a sudden mandated regulation was 2003's WAPI wireless Internet standard. Strong resistance to the standard from foreign and domestic IT hardware manufacturers as well as a rejection at IEEE led to the standard's downfall (Clendenin, 2006b; Gao, 2007; Kennedy, et al., 2008; Liu, 2005; Smith, 2004; Suttmeier & Yao, 2004; Suttmeier, et al., 2006). In 2009, another regulation required all computer manufacturers to include Internet filtering software called Green Dam. It failed due to fears of system instability and concerns with the practicality of rapidly implementing the regulation. Companies were only given a few months to comply (Tang, 2009; Wolchok, Yao, & Halderman, 2009; WSJ, 2009).

as TD-CDMA, was adopted. Nevertheless, it does not help us to understand the broader systematic impacts of the technology standard policy, nor its internal evolutionary dynamics.

Our argument is that standards development efforts in China can only be understood if we take a systemic view which questions why standards development was stimulated in the first place, and why governmental efforts to develop them are continuing and accelerating even after it has become clear that the current policy does not achieve its stated goals. We propose that standards in China proliferate due to a two-step self-reinforcing-sequence (SRS) (Breznitz, 2009; Mahoney, 2000; Pierson, 2000a, 2000b, 2004). The Chinese government's decision to foster indigenous technology standard creation, offering economic and social status incentives, activated the first step. As the central state still enjoys great legitimacy, influence and coercive power, incentives from the central government are very effective in encouraging new behavior by economic actors (Gilley, 2008). Incentives include the recognition of technology standard development as national innovation indicator, provision of direct funding, and last, but not least, the possibility of legally mandating a standard for exclusive use in China, with the promise of securing monopoly rents to its developers. These state actions induced many organizations to enter multiple standard development efforts.

In the second step of this SRS dynamic, organizations that opted to refrain from domestic standard development realized that standards might grant their rivals significant competitive advantage. In response they then start their own technology standard development efforts or join standards alliances begun by others. This dynamic of action and counteraction has now become a classic innovation arm race where actors produce more and more standards in order to not be left behind (Barnett, 2008; Baumol, 2004; Derfus, Maggitti, Grimm, & Smith, 2008; Schelling,

1960). Some actors even join opposing alliances in order to ensure a sustained advantage whichever way the winds blow.

The un-intended consequence of this dynamic is a systematic increase in uncertainty and its associated negative impacts on innovation. Firms cannot predict which standard, if any, will be adopted and thus they have difficulty in long-range planning. However, standard development does accomplish other useful goals such as royalty payment reduction. These positive outcomes coupled with the fact that after embarking on standards development, groups in academia, bureaucracy, and industry have tied their fortunes to the current standard policy, ensure its continuation. Consequently, we foresee that this situation will persist for at least the medium term.

In developing such an explanation we demonstrate the importance of politics and political decisions above market forces, presenting how such political actions influence the trajectory of technology and market development. As such, we highlight the importance of the comparative political economy perspective to understanding economic evolution and growth.

The paper is organized as follows; it first briefly introduces the economic rationale behind technology standards and explains their growing importance. We then outline current explanations for China's standardization efforts, and advance our explanation for standardization in China using a two-step SRS model. We then proceed to show how this logic works in practice through an examination of two cases: TD-SCDMA and optical storage media. These cases were chosen as representative of two different logics, telecommunications is seen in China as a critical national and security domain; indeed it is the one market segment which is still tightly regulated and state-owned (Low, 2005; Wu, 2009). Optical storage media, is an ideal example of a domain in which the market received a free hand and has become one of the most prominent consumer

electronic niches in which the Chinese very quickly trumped all other manufacturing competition to become the undisputed world leader. We conclude by examining the broader implications of Chinese standards policy and the logic which drives it for both advanced and emerging economies.

Technology Standards, Trade, and Innovation

Technology standards are agreed-upon platforms on which other applications, improvements, and innovations can be made. The use of standards to ensure widespread use and interoperability of products and peripherals allows rapid enlargement of markets, increasing the incentive to invest in R&D (Albrecht, Dean, & Hansen, 2003; Heddergott, 2006; Kindleberger, 1983; Lecraw, 1987; Manivannan, 2008; Simcoe, Graham, & Feldman, 2009; WTO, 1995). Standards are not a pure public good, since companies whose proprietary technology is embedded within many of them benefit disproportionately. Thus developing and owning technologies on which widely used standards are based is extremely lucrative. Technology standards reduce uncertainty by creating a uniform technological platform on which any actor can develop new applications thus ensuring would-be innovators that a market for their products will exist when they complete their research. Where competing standards exist, firms may be forced to hedge their bets across several standards, increasing costs and manpower requirements and reducing the ability to concentrate resources and achieve breakthroughs.

International standards are debated and approved by various international organizations. The most active are the International Organization for Standardization (ISO), the International Association of Electrical and Electronics Engineers (IEEE), and the International Telecommunication Union (ITU). These organizations do not have enforcement capabilities and their standards are not legally binding. However, since the WTO included standards in the TBT

agreement, it made adoption of international standards a prerequisite for a member state (WTO, 1995). Members cannot knowingly use standards to discriminate against others or obstruct trade.³

In addition to international agreements and standard making bodies, market forces also determine the viability of different standards and so create many de-facto ones (Funk, 2002). Examples include Microsoft's Windows operating system and Intel's microprocessors. Market dominance is enhanced as more and more users or peripheral product developers adopt the platform. Through a network effect, these de-facto standards become increasingly entrenched (Cusumano, Mylonadis, & Rosenbloom, 1992; Kindleberger, 1983). Once a standard is entrenched, it becomes extremely difficult to challenge without a radical new displacing technology. De-facto standards nearly always involve proprietary technology, and thus, entail the payment of royalties or fees. As we discuss in our case studies, payment of royalties can be crippling to manufacturers who already operate under thin profit margins.

China in the World of International Technology Standards

China has a large and rapidly growing export-oriented high technology industry. Exports of high-technology goods totaled over \$415 billion in 2008, and accounted for over thirty percent of all Chinese exports in 2009 (NSBPRC, 2009, 2010). This industry juggernaut relies heavily on foreign proprietary technology (Breznitz and Murphree 2010; Cao, 2004; OECD, 2006, 2007). Consequently, China strongly feels the impact of international technology standards and their associated royalties.

³ Since 1995 there has only been one WTO arbitration case over a TBT standards disagreement. It involved use of the word "sardines" (WTO, 2003).

Since emerging as a player in the global technology trade, China's technology savvy and sophistication have grown (Ernst & Naughton, 2007; IHT, 2006; Kroeber, 2007; Naughton & Segal, 2003; OECD, 2006, 2007; Segal, 2003). It is therefore unsurprising that China would seek a commiserate voice in standards debates (Serger & Breidne, 2007). China's behavior, however, has been erratic, unpredictable and often seemingly counter-productive. Generally China's standards making efforts resulted in increased confusion and uncertainty.

China clearly benefits from conformity with the international system since adopting international standards enables manufacturers to secure overseas orders. It also aids companies to incrementally improve existing technologies, confident they will be globally accepted. Despite these advantages, influential voices in China's government and industry argue that although China benefits *absolutely* from international standards, the *relative* benefits disproportionately favor foreign standard holders. In response, China's central government made development of Chinese standards with indigenous intellectual property a national strategy (Linden, 2004; Suttmeier & Yao, 2004; Suttmeier, et al., 2006).

To understand why China benefits disproportionately less from the international technology standards system, one must understand the structure of China's high technology industry. Most of the activity is production of goods based on foreign technologies or the final assembly of products from components and sub-systems produced elsewhere. Looking at figures of added value in China, it becomes obvious that many Chinese firms are low-margin, high-volume manufacturing businesses (See Table 2).

<<**Table 2 – Value Added for Advanced and High Technology Manufacturing**>>

Furthermore, foreign companies produced eighty-three percent of China's high-technology exports in 2009. Much of their activity is also assembly of imported high value components for export (OECD, 2007; Xinhua, 2010). Such reliance on foreign standardized technologies and components places China at the low value-added end of the global production ladder. For example, Chinese analysts estimate the value-added by manufacturers in China for high-level color televisions is approximately two dollars per unit, while in Japan it is ninety dollars per unit (ZGJM, 2004).

Royalties, usually at a constant price per unit, have become one of the highest overall cost items for manufacturers. Furthermore, intense competition reduces the unit price while the cost of royalties per unit remains constant. Consequently, over time the relative cost of royalties increases while profit margins decrease. Chinese DVD manufacturers claimed that until 2008 their annual royalty payments of three billion USD were substantially greater than the industry's total profits (Cai, 2009; Chen, 2008; Ding, 2009). This situation makes the interest of the central government in promoting standards as a means of technological independence very understandable.

One of the most important accomplishments, if not officially declared, of China's technology standard policy has been its usefulness as an international trade negotiation tool for reducing royalty payments. By implicitly threatening that the large Chinese market and its multitude of manufacturers would be mandated to use only indigenous standards, China has successfully used the mere fact of indigenous standards development as a negotiation card with which to pressure foreign standards owners to lower royalty rates. As we later describe in the two case studies this strategy has proven to be the most effective one to date to achieve this goal, even in cases where all other attempts have failed.

State of the literature

The current understanding of technology standards in China uses political explanations to account for actors' behavior. The literature agrees, either implicitly or explicitly, that understanding the perspective and composition of the dominant political group is sufficient to predict the type of standard which will emerge and its likelihood of domestic approval (Kennedy, 2006, 2007a; Kennedy, et al., 2008; Kroeber, 2007; Lee & Oh, 2008; Linden, 2004; Liu, 2006; Suttmeier & Yao, 2004; Suttmeier, et al., 2006).

There are three main frameworks used to analyze Chinese standards debates: i) the spectrum of perspectives; ii) bureaucratic politics and iii) the logic of standards coalitions. At the micro-level each framework helps explain the results of specific standardization efforts. However, none of these frameworks deal with the macro level or tries to explain the systemic impact and the development of the standard policy as a whole.

The spectrum of perspectives argument analyzes the course and outcome of standards debates based on specific and knowable standpoints of different actors regarding international standards and their role in development (Kennedy, et al., 2008; Suttmeier & Yao, 2004; Suttmeier, et al., 2006). This argument proposes that by understanding actors' perspective it is possible to predict which standards they will support or try to block.

The most idealistic perspective is that of "instrumental techno-globalists" (Kennedy, et al., 2008). Techno-globalists hold that under globalization, scientists and engineers worldwide can be joined together in epistemic communities whose ties through mutual technological or empirical interests are foremost in their minds (Adler, 1992; Haas, 1992). Thus the results of debates at the international level are compromises based upon a dispassionate analysis of different standards and selection of the most technologically promising. Leaders who subscribe

to this perspective believe technology standards provide the most good for the most people and that political or economic arguments should not be introduced into debates over technological standards.

The most common position on the perspectives scale is “neo-techno-nationalism” (Kennedy, et al., 2008; Suttmeier & Yao, 2004). Neo-techno-nationalists argue that China should use state intervention, investment and planning to raise China’s level of industry and technology. However, China should do so working within the international economic system. Neo-techno-nationalists do not oppose the international standards system but seek to increase China’s share of relative gains within it. Consequently, they support creating Chinese standards, but desire for these standards to successfully compete and coexist with accepted international ones. Researchers and enterprises should grasp international linkages, cooperation, co-development and interaction where possible, but only to the extent that such cooperation advances China’s interests.

At the far end of the scale is techno-autarkism (often wrongly referred to as techno-nationalism).⁴ The techno-autarkist perspective holds that national interests should be paramount, even at the expense of many companies’ desires (Kennedy, 2006; Kennedy, et al., 2008; Lee & Oh, 2008; Linden, 2004; Qu & Polley, 2005; Suttmeier & Yao, 2004; Suttmeier, et al., 2006; Yoshida & Carroll, 1997). Techno-autarkists believe that for China to break itself free from dependence on foreign technology, it must have its own standards. In addition, they view technological-autarky as a security need, and argue that given China’s vast market, access-seeking foreign companies will acquiesce to unique Chinese standards (Yoshida & Carroll,

⁴ Techno-autarkism is commonly called “techno-nationalism.” Arguably a misuse of the term, “techno-nationalism” means different things in other contexts. For a useful definition of techno-nationalism, describing a coherent national strategy with regards to technology, science and innovation, rather than a singular drive for technological independence – autarkism – see (Samuels, 1994).

1997). Finally, techno-autarks hold that passing mandatory standards in consumer and other technologies will increase China's ability to force technology transfer from foreign partners (Kennedy, 2006; Kennedy, et al., 2008; Linden, 2004; Suttmeier & Yao, 2004; Suttmeier, et al., 2006).

A second approach used in explaining the outcomes in Chinese technology standards efforts is bureaucratic politics (Allison & Halperin, 1972; Clapp, Halperin, & Kanter, 2006; Kennedy, 2007b; Kennedy, et al., 2008). Bureaucratic politics argues that government action should be viewed as the result of internal negotiations and conflict between different units within the state. Each unit has predictable and relatively uniform interest. These interests are concrete objectives of increased authority and budget. Support for a given standard depends on whether or not it advances the interests of the bureaucratic unit.

Bureaucratic politics are very useful in explaining that outcomes of some specific standardization efforts, for example the Ministry of Industry and Information Technology's (MIIT) battle with the State Administration of Radio, Film and Television (SARFT) over the Audio-Video Standard (AVS) for digital media. Developed in an MIIT-affiliated research center, AVS was a successor to the MPEG-2 standard which might have been able to compete with the new international MPEG-4 standard. However, SARFT, usually one of the strongest promoters of unique Chinese standards, which has final authority over media content, sabotaged AVS's chances by announcing China would use MPEG-4, not AVS. SARFT preferred to preserve its authority rather than allow MIIT to encroach on its jurisdiction (Kennedy, et al., 2008; Suttmeier, et al., 2006). Bureaucratic politics also helps account for particular failures such as China's attempts to propose international standards (Kennedy, 2007b). In many cases Chinese

representatives act on behalf of their various ministries' interests rather than coherently advancing a national agenda.

Using elements from all these explanations, Scott Kennedy developed an integrated theory of political coalitions. Kennedy defines coalitions as formal or informal associations charged with examining, developing, promoting and ensuring compliance with a standard. Coalitions can also block standards which members believe detrimental to their interests. The supporting coalition's composition – government units, research institutes and enterprises (foreign and domestic both) – determines the viability of a standard. Kennedy found that for the twenty-four significant unique national standards adopted in China since the mid-1990s, those with a broad coalition are most likely to be developed, adopted, and implemented as official national standards (Kennedy, 2006; Kennedy, et al., 2008).

These approaches to standardization in China are powerful tools for examining individual standardization efforts. Nevertheless, each of these perspectives takes standards as independent episodes with an outcome – success or failure – which needs to be explained.⁵ In this worldview, standards creation is taken as given and the research puzzle lies in why some are adopted and while others are not. Therefore fundamental questions about why the development of indigenous standards has been pursued with vigor in the first place, and whether, or what, function they have in the Chinese political economy, are not asked.

The Logic of Chinese Technology Standards

We contend that only by realizing standards were initiated to accomplish goals critical within the context of the Chinese political economy, and that the dynamics unleashed by this

⁵ This is not to suggest the theory of political coalitions views the standards system as static. Earlier efforts' outcomes influence the behavior of later coalitions. Kennedy has found gradual improvement in the quality of China's standards, coalitions, submissions, and negotiating behavior at international standards forums (Kennedy, 2006, 2007b; Kennedy, et al., 2008).

policy have led to a self-reinforcing system of newly vested interests that now keep the system in place, can we understand why China's standards continue to proliferate. Thus, while research on the Chinese technology standards tries to understand their success (variously defined), we seek to understand the logic and driving force behind the technology standard policy, its overall systemic outcomes, and its longevity, not whether specific standards are successful or whether China becomes savvier in promoting its domestic standards worldwide.

The proliferation of standards in China occurs in a two-step self-reinforcing-sequence. First the central government initiated set of policies in pursuit of what its leadership's perception has been of the national interest. Following the particular implementation of that policy enterprises perpetuate standardization efforts through their rational responses to the new incentives and the political economic reality created as more domestic standards are developed and approved (Breznitz, 2009; David, 2001; Mahoney, 2000; Pierson, 2000a, 2004). The first step began with the central government's attempt to achieve its official goal: fostering indigenous innovation through promotion of domestic standards embodying self-owned intellectual property (Cao, Suttmeier, & Simon, 2006; Kennedy, 2006; Kennedy, et al., 2008; Kroeber, 2007; Suttmeier & Yao, 2004; Suttmeier, et al., 2006). It is hoped that indigenous innovation will reduce the royalty burden on Chinese manufacturers but this is not a techno-autarkist policy (Linden, 2004). As we will detail in the case studies, not even in the most critical technologies have China's leaders sought to cut off access to, and involvement with, foreign technologies and standards development efforts.

In order to promote standard creation the policy utilized a dual prong approach making technology standard development high social status activities, and supplying large financial incentives. To ensure both the creation of unique technology standards was enshrined as a major

innovation goal in the Tenth and Eleventh Five Year Plans and in the 15-Year Mid-to-Long Range Plan for Science and Technology (Cao, et al., 2006; StateCouncil, 2006). In addition, the state encourages standardization by recognition of technology standard development as a national innovation indicator, direct funding of development, and offering the possibility of a standard becoming nationally mandated which promises monopoly rents to the standard owners.

Official recognition as an innovation indicator means that organizations that develop standards receive preferential access to subsidized R&D financing, and enhanced national stature. Official recognition by itself acts as a strong incentive for organizations to participate in as many standards development projects as they can. For new enterprises in China's mixed economy, state recognition is also a powerful marketing tool as it attests to the firms' innovative and managerial strengths. This can help new firms overcome market inertia and improve their sales position vis-à-vis established firms. Enhanced status in the eyes of the state is important also for further improving access to finance and grants in the future.

The prospect of state financial support is significant as financial constraints are one of the major challenges facing Chinese enterprises which seek to conduct R&D (Fuller, 2005; Kennedy, 2006; Kennedy, et al., 2008; Segal, 2003). Last, since there is always the possibility that the government will certify a standard as a mandatory national one, both possible future gains from developing a standard as well as losses from not doing so have become immense.

After implementing these policies to stimulate technology standards development, unintended consequences have taken hold. Some early adopters begin development of and contribution to standards in targeted sectors. Then, in the second step of the SRS, enterprises and organizations, responding to the growing number of standards under development, produce more and more standards or portions of standards begun by others. As first mover organizations

produce standards, other companies and organizations working in the same space have been pushed to do the same or face a potential competitive disadvantage. An innovation arms race competitive game develops (Barnett, 2008; Baumol, 2004; Derfus, et al., 2008; Khalil, 1997; Schelling, 1960). Unsure which standards will be adopted, some companies join different alliances producing competing standards to ensure they are on the winning side. As more organizations follow this path the standards-creation arms race intensifies. Confusion in market and regulatory circles for the viability of different standards increases. Uncertainty leads to a systemic slow-down in innovation in the sector in question. Thus, while all actors individually behaved completely rationally, the systematic outcome is less than optimal – most notably a continued increase in uncertainty over the future of different standards. Actors which committed time, staff and resources to standards development seek to ensure the state continues to support and promote their standard. Lobbying for protection and even fighting against newer alternative innovations and standards ensues. This two steps SRS dynamic is graphically presented in the figure 1 below

<<Figure 1: Figure 1 – the Two Steps Self-Reinforcing-Sequence of Technology Standards Proliferation in China >>

An interesting question is whether technology standards were from the start, or have become in time a case of bureaucratic capture (Stigler, 1971). In the case of standards, while we surely can see a growing influence and more intense lobbying of economic actors on policy makers as the importance of the domestic technology standards grows, the capture of these policy makers has been, at most, partial. All of the major and controversial standards efforts have had a significant, if not exclusive, state role in their initiation. Indeed, the state pushes for standards often in spite of industry interests (Kroeber, 2007). However, as the economic stakes

grow and as in many cases the regulators are also the owners of the standard developer the system takes on some of Stigler's characteristics. Indeed, as many of the actors developing standards in academia or government research institutes are subject to bureaucratic rules of promotion, adhering to state policy and a desire to create more standards only makes even more sense (Zhou, 2001).

Since standards are now enshrined in the national plans, have been given the status of national indicators, and as many organizations and individuals have invested both their political and actual capital in these policies and in the promotion of domestic technology standards there is very little political will to rethink the system. Consequently, we predict that it would stay for at least the medium if not the long-term. This is especially true as the development of standards has accomplished several critical goals within the Chinese political economy, such as the reduction of royalties, that have nothing to do with promoting indigenous innovation, but are of significant economic consequences all the same.

With this two-step process in mind, we now move to analyze two key cases, fleshing out the above discussed mechanisms and motivations.

Mobile Technology: TD-SCDMA.⁶

In 1995, the Ministry of Science and Technology (MOST), the Ministry of Posts and Telecommunications (MPT – today's MIIT) and the State Planning Commission (today's National Development and Reform Commission) made development of a Chinese 3G mobile standard a key project of the Ninth Five Year Plan (Zhou, 2004).

⁶ Third generation (3G) mobile handles high levels of data transfer, enabling handsets to access voice, audio, video and Internet data. Although the ITU intended to have a single international 3G standard, three competing standards emerged. In the United States, the CDMA2000 standard is the most popular while Europe's prefers the locally developed W-CDMA.

Development of the new standard, TD-SCDMA, initially proceeded rapidly. Foreign participation, in particular from Siemens, was crucial to the development effort. Siemens saw cooperation with China as a means to further develop its then-largely rejected Time Division Duplex (TDD) 3G technology. Two hundred Siemens engineers worked with Datang, the commercial arm of the Chinese Academy of Telecommunications Research (CATT), which is in turned owned by MIIT on the integrated standard (3GNews, 2001; AsiaTimes, 2006; Linden, 2004). In terms of core patents for the standard, Nokia, Ericsson, and Siemens provided thirty-two, twenty-three and eleven percent, respectively, of the patent rights and thus, foreign technology actually constitutes the majority of TD-SCDMA (Sinocast, 2006; Stewart, 2009; Stewart & Wang, 2009). However, as development proceeded, Chinese firms, most notably Datang (which holds 7.3% of the patents), took the lead. In 1998, Siemens and CATT, with Datang Telecom acting as the representative for China's telecommunications industry, submitted TD-SCDMA to the ITU (PeoplesDaily 2007). The ITU approved the standard in 1999, making TD-SCDMA only the second case of international approval of a standard proposed by China.

Commercialization of TD-SCDMA has been slow. The task of developing and commercializing the standard fell mostly to Datang Telecom. Commercial viability for TD-SCDMA proved elusive. For example in June 2005, a field test of the TD-SCDMA system conducted by CATT failed when the handset chips were unable to support 3G applications, four years after such 3G services were offered using other standards on commercial basis in Japan (Li, 2005). In the end eight years passed between ITU approval and TD-SCDMA's commercial release. Only in April 2008, did China Mobile began selling 3G phone numbers for test networks in eight coastal cities – the first large-scale simultaneous commercial testing of TD-SCDMA (TD-Forum, 2008). Developmental delays caused MIIT to postpone launching *any* 3G services

in China until December 31, 2008 (Zhang, 2008a). In comparison Japan and the United States began commercial 3G services in 2001 and 2002.⁷

For Chinese companies, participation in TD-SCDMA's development provided access to hundreds of millions of dollars in state developmental funds under the five year plan and other national programs as well as subsidies for production of base stations and handsets (ShangwuZhoukan, 2007; Suttmeier, et al., 2006). Grant making began with a 1.986 billion RMB grant from CATT for the initial development of the standard (Chen, 2005). Spurred by potential profits suggested by the chance for a monopoly status, and guarantees of finance, companies, such as Datang, pushed to develop TD-SCDMA transmission technology. The prospect that it could become China's mandatory domestic 3G standard encouraged major MNCs, such as Philips and Samsung, to enter joint ventures with Datang, an enterprise with virtually no revenues at the time, for chip-sets and reference designs for TD handsets (BusinessWire, 2003; Linden, 2004). Datang benefited handsomely from state protection and subsidies in developing TD-SCDMA. In November 2008, Datang purchased 16.6% of the semiconductor manufacturer Semiconductor Manufacturing International Corporation (SMIC). This purchase allows Datang to secure the supply of TD-SCDMA chips. The deal also gives Datang significant influence over SMIC (China's largest pureplay chip fabrication company) including the right to appoint two board members and a vice president for TD-SCDMA chip fabrication (CTN, 2008, 2009; Lemon, 2008).

Since its market is nearly entirely domestic Datang does not concern itself with foreign reactions to a uniquely Chinese standard. Other companies, most notably ZTE and Huawei, have large vested interests in international standards. Indeed, only after the central government

⁷ Japan's NTT DoCoMo launched the first commercial 3G network in September 2001. Verizon launched the United States' first commercial network in January 2002 (CNN, 2002; Loney, 2001).

apportioned favorable spectrum for TD-SCDMA in 2002, did both companies decide to join the TD-SCDMA alliance and develop TD-SCDMA products. In tandem with the increasing specter of TD-SCDMA being announced as a mandatory standard, the TD-SCDMA alliance grew rapidly as many Chinese telecommunications firms joined it rather than risk being left out. Nonetheless, both leaders, Huawei and ZTE, continued to concentrate most of their efforts on developing transmission hardware and handsets for the two international 3G standards. Huawei invested 3 billion RMB from 1998 to 2002 on developing products for the WCDMA standard (Fan, 2006). Both companies hope to continue to expand their international businesses and thus fear that focusing resources on a technology with very dim prospects of ever being used abroad would diminish their ability to compete in the global market (Kroeber, 2007; Li, 2006). As part of its hedging strategy Huawei has become a major incremental contributor to international standards. Hedging bets by contributing to multiple standards provides benefits of financial access and state support even if the market for the domestic standard remains weak.

If the main commercial outcome of the TD-SCDMA effort was delaying the roll-out of 3G networks in China by eight years, it did prove very beneficial to China's telecommunication equipment industry as the ultimate tool with which to reduce royalty payments on the other two standards. After China developed the TD-SCDMA standard, nine companies in the WCDMA alliance capped the royalty rate they asked from Chinese companies at less than five percent of the sales price for hardware (Fan, 2006). This rate was far lower than for non-Chinese producers and represented a clear China-tailored boon. As the royalty fee was re-set as a percentage of the sale price and not as a constant sum, it ensured that the royalties paid fall in tandem with other costs. In a similar fashion Huawei used the threat of TD-SCDMA to negotiate lower royalty

payments for domestic and international CDMA products with Qualcomm technologies, the American holder of the standard (Sinocast, 2006).

Optical Storage Media: The Case of Competing Indigenous Standards

China has a long history of standards development efforts in optical storage media. Efforts to develop a standard began in the mid-1990s with two new standards for the Video Compact Disc (VCD) player called China Video Disc (CVD) and VCD 3.0. These emerged out of the initial VCD format first introduced in 1994. VCD 3.0 enjoyed strong state support. The Ministry of Electronic Industry (later merged into MIIT) strongly supported the standard as an alternative to the foreign-controlled DVD standard and as an indigenous technology. However, the rival CVD alliance moved to preemptively win market share by successfully pushing its products onto the market, without waiting for formal approval. The Ministry responded by integrating the original foreign VCD patent holders' standard with some elements from VCD 3.0 into a single standard – Chaoji VCD, known internationally as SVCD (Linden, 2004). It then successfully applied for SVCD's adoption as an international standard (IEC 62107) and forced the next generation of players to support both the mandated Chaoji VCD and CVD standards. Production of video compact disc players exploded in the mid- and late 1990s but was followed by a sharp crash – in 1999 over 200 manufacturers, out of 500 in total, went bankrupt (Kennedy, 2005).

By the late 1990s the DVD player and standard, developed by an alliance of Japanese, American and European companies, became popular and hundreds of Chinese manufacturers established production lines. DVD players enjoyed a larger export market and could play both DVDs and SVCDs, ensuring also a large domestic market. Production exploded from 3.5 million DVD players in 2000, to 70 million – seventy five percent of world output – by 2003 (Linden,

2004). Nevertheless, despite their production capabilities and large scale exports, profit margins for the Chinese companies remained thin, falling to one dollar per unit in 2004 (Kanellos, 2004). High royalty rates became a source of constant friction, and led Chinese manufacturers to take action, including filing a lawsuit in the United States accusing DVD's patent holders of abusing their monopoly power (ChinaDaily, 2005; Pyyny, 2005). None of these efforts proved successful at significantly lowering the royalty rates for the Chinese manufacturers; the case and appeal were dismissed in 2006 and 2008, respectively (Meisner & Lewis, 2008).

In 1999, China's government entered the fray and suggested development of a Chinese standard as an alternative approach to alleviating the financial trouble of DVD producers (Clendenin, 2006a; Zhang, 2008b). Under MII (the former name of MIIT), several government research institutes and DVD manufacturers formed an industry alliance under an incorporated entity called Beijing E-World Technology (Clendenin, 2006a; PeoplesDaily, 2003). MII and the State Trade and Economic Commission then provided \$1.2 million USD to begin development of the standard (Smith, 2003). In 2001, E-world released the Advanced High Density Disc System (AVD) – China's first red laser-based standard. The alliance paired the AVD system with a "basically compatible" Taiwanese system called Enhanced Versatile Disc (EVD). The Taiwanese partners, for reasons never fully disclosed, backed out of the arrangement shortly thereafter. The arrival of AVD-EVD was shortly followed by a royalty-rate concession from the DVD standard holders. The major patent holders for DVD players agreed to only charge full royalties (then twenty-one dollars) for exported DVD players whereas domestic market DVD players were only charged about twelve dollars (Linden, 2004).

In a repeat of the VCD scenario, competing alliances formed and initiated their own standards development efforts. Three months after AVD-EVD became commercially available,

nineteen IT consumer electronics manufacturers, including Skyworth, Changhong, and TCL who were also members of the E-World alliance, announced creation of another industry alliance to promote a competing standard (the High-clearness Video Disc, HVD) in April 2004 (CTN, 2004a). At the same time a third group led by Beijing K-City High Definition Electronic Technology Company formed an alliance to promote its own homegrown high definition DVD standard – High Definition Video (HDV) (AsiaInfo, 2004). In response to uncertainty over which standard would prove viable, Skyworth, Changhong, and TCL joined this alliance as well. As the Ministry debated which standard to adopt as the national standard, a fierce political battle between the AVD-EVD alliance and a joint front of the HVD and HDV alliances ensued, leading MII (the key force behind the AVD-EVD standard as well as the national regulator) to relent. While AVD-EVD was adopted as China’s national standard in 2005, it was neither mandatory nor exclusive (CTN, 2004b; Powell, 2006).

While being touted as China’s tool to free itself from dependency on foreign proprietary technology, AVD-EVD, like DVD and VCD before it, relied on foreign technology. The codecs – VP5 and VP6 – were developed and owned by On2, a US company; and the decoder was developed in cooperation between a US company, LSI Logic, Beijing Homaa Microelectronics Technology, and E-world (CTN, 2003; Frauenheim, 2004; McDonald, 2006; Powell, 2006; Yoshida, 2003).

While not a great commercial success these standard efforts had significant positive impacts on two fronts, they may have given one of the first extensive R&D and upgrading experiences to many of the Chinese companies such as Skyworth that have since routinized innovation activities (Nelson & Winter, 1982).⁸ Most significantly, by bringing China’s

⁸ Despite much lower royalties for the AVD/EVD system (two dollars per unit), the popularity and relative low-cost of DVD players meant that AVDs never gained appreciable market share (PeoplesDaily, 2004). Although able to

challenge to global standards into the spotlight, it quickly led to a substantial reduction in the royalties Chinese manufacturers had to pay – which was also a major motivation for companies like Skyworth (Einhorn, 2003). In 2004, while broadly announcing intentions to replace DVD players in China with AVD-EVD, the Chinese government pushed for a further reduction in royalties paid by Chinese companies per DVD player. Within a few months royalty fees were reduced solely for Chinese manufacturers. The rate decreased from over twenty dollars per unit for Toshiba, Matsushita, JVC, Mitsubishi, Hitachi, Time Warner, Philips, Sony, and Pioneer technologies to \$13.80 USD, (Linden, 2004; PeoplesDaily, 2004).

The third stage of these efforts started in October 2005 when China announced plans for a new violet laser high-definition disc player. With broad state support, a three-part alliance formed to develop a high definition, violet laser-based, optical storage technology – China Blue High-Definition Disk (CBHD). The main developers were the Optical Memory National Engineering Research Center (OMNERC) at Tsinghua University, the China High-definition DVD Industry Association (CHDA), and China Electronics Technology Group (CETC) (Ding, 2009; Yam, 2009). The standard took shape through subsidized research conducted at OMNERC and CETC. The leading commercializers of CBHD players, TCL and Shinco, enjoyed preferential state financing in their development and production efforts. In addition, other manufacturers have received state subsidies to accelerate their development of CBHD player models (CDRInfo, 2009b). Once again, first movers hoped to gain monopoly rents from the

generate higher quality images, the lack of high definition televisions meant the improvement was unnoticeable. Foreign movie studios refused to license content for the format. Arrival of the High-definition Digital Video Disk (HD-DVD) and Blu-ray high definition formats further eroded AVD/EVD's technology advantage. By 2006, it was clear the standard was commercially unsuccessful. Sales remained in the hundreds of thousands of units annually rather than the millions predicted (Clendenin, 2006a). By 2008, all three formats, AVD/EVD, HDV, and HVD, had proven market failures. Retailers removed the last AVD/EVD players by 2008 (Zhang, 2008b).

standard. As Lu Da, director of OMNERC stated: “China is a large potential market with more than one billion consumers, which is enough to support its own standard” (Ding, 2009).

CBHD was not universally supported within China. Zhang Baoquan of the Antaeus Group, which bought the rights to AVD/EVD fought aggressively against the new standard – accusing it of not only stealing some of AVD/EVD’s technology but also of not being truly Chinese and therefore undeserving of access to state developmental funds. Similarly to other efforts, while touted as an indigenous standard, up to ninety percent of the technology within the CBHD player is derived from Toshiba’s HD-DVD standard (Hsu & Hwang, 2008). Toshiba, in a bid to win its global standards war with Blu-ray, cheaply shared its HD-DVD technology (Hirooka & Nakajima, 2009). By adopting Toshiba’s technology, China’s CBHD developers also acquired established pools of talent and technology. Companies such as Memory Tech that worked on HD-DVD now support the Chinese standard and offer advice and research assistance to the 120 or so Chinese manufacturers interested in producing it (Hirooka & Nakajima, 2009).⁹

As with earlier standards in optical storage media, CBHD – and its related technologies – was not the only locally developed standard in this field. A noteworthy project was Guangzhou Digital Rise Technology’s development of an audio-video codec – DRA – for Blu-ray. China’s government was then able to force the Blu-ray Disc Alliance to adopt the Chinese DRA audio-video codec as part of the Blu-ray 2.3 package (CDRInfo, 2009a; ChinaSourcingNews, 2008).¹⁰ Adding the Chinese standard to the international standard was a quid-pro-quo for permitting the sales of Blu-ray products in China. Developing an alternative standard greatly enhanced China’s

⁹ Only two Chinese manufacturers produce CBHD players although eight more are interested and should release models by the end of 2010. Development continues; TCL and Shinco unveiled 3D capable models in July 2010 (Yen & Hwang, 2010a, 2010b).

¹⁰ In March 2009 Warner Entertainment group agreed to begin offering content for the CBHD standard (ChinaDaily, 2009; Wang, 2009). This was the first time a foreign content provider offered to support a Chinese standard, suggesting the increasing effectiveness of China’s standard-making as a trading tool tactic.

negotiating position for incorporating its technology. Development of CBHD as an alternative was sufficient threat to force the Blu-ray Alliance to bring in Chinese actors.

However, China did not only support the development of CBHD. The government also encouraged and abetted development of Blu-ray capabilities. CESI Technology, a subsidiary of the state-owned China Electronics Standardization Institute (CESI), opened the first Blu-ray certification center in Beijing in July 2008 (GlobalSources, 2009). By 2009, twenty two Chinese companies had licenses to produce Blu-ray devices and use the Blu-ray logo.

More significantly for the overall profitability of Chinese companies, the development of CBHD forced a two-part reduction in royalties. In the process of developing CBHD, the alliance secured the rights to the by-then defunct Toshiba's HD-DVD standard technology at fire sale prices, keeping licensing rates low. Manufacturers need only pay eight dollars per player in royalties. For manufacturers adhering to the international Blu-ray standard, the reduction was also significant, with royalties going sharply down to \$9.50 per player (Ding, 2009; GlobalSources, 2009).

Discussion

Both case studies illustrate the two-step SRS dynamics of standard creation in China as well as the perpetuating mechanisms underlying it that ensure continued standards creation even where innovation outcomes are less than optimal. Efforts to develop the TD-SCDMA standard created strong vested interests in the success and continuation of the standard, interests which assured its continued development even after alternatives proved more effective and internationally marketable. Initiated by the government in the mid-1990s, early adopters Xinwei and Datang, companies with strong connection to the ministries regulating the industry, poured resources – and received subsidies for doing so – into TD-SCDMA. In so doing they became

heavily reliant on the success of the standard for their long-term viability. By 2002, other companies such as Huawei and ZTE, seeing the central government's commitment to TD-SCDMA and the potential of losing competitive advantage, began developing technology for it even as they pursued alternative standards as a hedge. Even as it struggled commercially, TD-SCDMA accomplished large royalty reductions for China's telecommunications equipment firms, providing Chinese manufacturing with a considerable cost advantage over their competitors.

In optical storage media, the SRS dynamic resulted in repeated rival standards development efforts even as none ended with great commercial success. From SVCD through EVD to CBHD, the government initiated standards development efforts and provided financial incentives to participate in development. An alliance of early adopters formed to support the anointed project. A counter-alliance(s) then formed to develop alternative standards in order to block the primary standard from becoming mandatory. In addition, similarly to TD-SCDMA, all of the standards were largely based on foreign technology, thus not fully promoter of "indigenous innovation." However, all succeeded in forcing foreign standards-holders to lower their royalties for Chinese manufacturers, a unique and valuable advantage for Chinese firms given their position in international production chains. In all cases, again similarly to the TD-SCDMA standard the regulator also invested heavily in the commercialization of the standard and had significant vested interests in its continuous promotion.

Conclusion

This paper has argued that for a systematic understanding of the dynamics and outcomes of China's technology standard efforts we must understand both what are the various goals for the development of technology standards in China, as well as the particular political-economic

dynamics unleashed by the specific policy actions followed by the government. Existing scholarship has explored China's various standards development efforts but not in a systematic manner. It has provided strong and predictive theories which can be applied when studying standardization efforts in China and abroad by looking at the alignment of bureaucratic actors and the alliances which coalesce around different standards. However, in the social sciences we should not be content to examine the phenomenon of global standards regimes and their impact on domestic political economies on a case by case basis. For this reason, we have argued that a new theory which explains why standards are created and continue to proliferate is necessary.

We argued that this outcome is the result of a two-step self-reinforcing-sequence. First, standard creation was stimulated by the Chinese government's actions to foster it through various social and economic incentives. In the second stage, other organizations realized that standards might grant their competitors significant competitive advantage, including monopoly status, and began their own technology standard development efforts or joined others' efforts in alliances. This dynamic has transformed into a classic innovation arms race. The un-intended consequence of this dynamic is a systematic increase in uncertainty with its negative impacts on the behavior of economic actors. However, standard development serves many other useful goals, which are critical to the Chinese industry, such as royalty payment reduction. Furthermore, today many strong groups in academia, the bureaucracy, and industry have tied their fortunes to standards development. Consequently, we foresee that this situation will continue for at least the medium term.

Accordingly, we argue that if we want to understand technology standard development policy, we have to analyze both the particular political economy dynamics of countries like

China, as well as the structure and position of their industries within the global production networks.

A general lesson from the Chinese technology standard case is that international bodies' governance decisions, assuming they can reach a prescribed outcome by importing institutions from the advanced wealthy countries into emerging economies, such as the case of standards and TBT by the WTO, often end with very different market outcomes in different countries. Since the political-economic institutional framework significantly differs, imported institutional regimes for the regulation of intellectual property rights and creating platforms for free-market competition have different functional logics and strikingly different results.

Evidence can be seen outside of China as well. Other countries have used technology standards in unexpected ways. Most famously, Japan used standards policies and regulations to prevent rather than encourage trade throughout the 1970s and 1980s. It was largely due to Japan's creative reinvention of a Western political concept that the WTO made international standards conformity mandatory in 1994. Under global economic integration we can expect to see more such resourceful uses of existing policy to accomplish other goals. Accordingly, it is important that technology standards in different political-economic systems be further comparatively studied.

With debates about IPR regimes, such as patent laws, technology standards, and trademarks brewing in international trading bodies, it is important to remember that the immensely varied contexts in which these would be applied, should lead us to expect diverging, and not converging, outcomes and patterns of behavior. As such, theories which try to understand the influence of international governance agreements, should not necessarily rely on insight from economic theory, but instead opt to develop a political contextual understanding if

they are to offer relevant answers. A dogmatic belief in the universal meaning and working of theoretical concepts developed within specific institutional systems, by arguing that these systems embodies an optimal underpinning of a generally applicable free-market solution, only leads social science and policy makers astray.

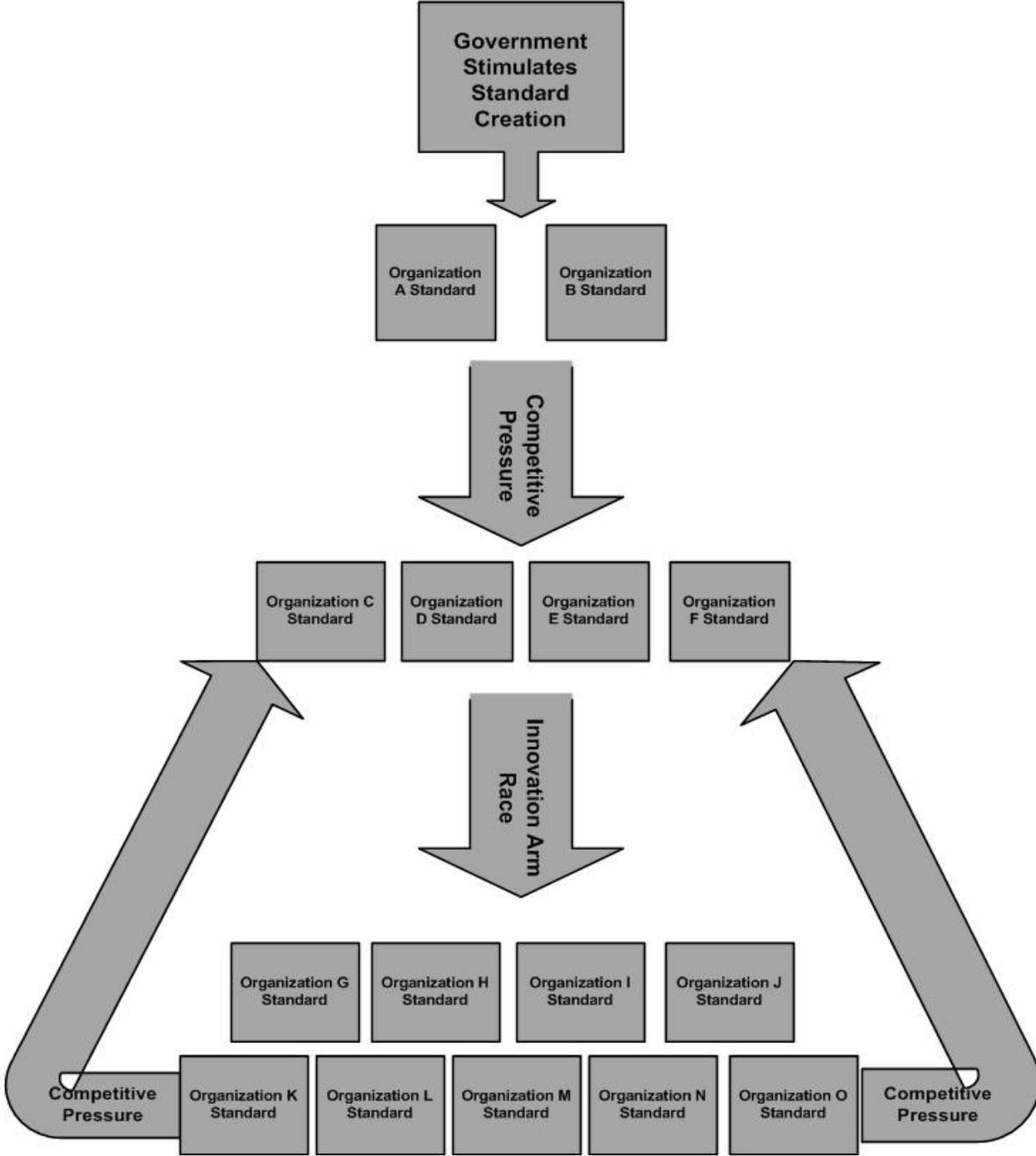
Table 1: China's Standard Development Projects - 2007-2009				
	2007	2008	2009	TOTAL
Total Proposed Standards	8617	2136	1877	12630
Projects to Develop New Standards	7703	1823	1528	11054
Projects to Revise or Amend Existing Chinese Standards	914	313	349	1576
Projects Comparable to International Standards (ISO, foreign national, etc)	2815	636	610	4061
Standards to be "Enforced"/"Obligatory"	1065	261	204	1530
Standards to be "Recommended"	7467	1862	1654	10983
Standards to be "Guides"	85	13	19	117

Table 2 – Value Added for Advanced and High Technology Manufacturing

Type of Product	Value Added in China (%)
General Purpose Machinery	2.94%
Electrical Machinery and Equipment	2.26%
Measuring Instruments and Machinery for Cultural Activities and Office Work	2.35%
Communication Equipment, Computers and Other Electronic Equipment	1.13%

Source: National Economic Census 2004 Cited in (Bi, 2007)

Figure 1 – the Two Steps Self-Reinforcing-Sequence of Technology Standards Proliferation in China



References

- 3GNews. (2001, May 28). Upset with Siemens TD-SCDMA 3G standard. *3GNewsroom.com*.
http://www.3gnewsroom.com/3g_news/may_01/news_0695.shtml
- Adler, E. (1992). The Emergence of Cooperation: National Epistemic Communities and the International Evolution of the Idea of Nuclear Arms Control. *International Organization: Special Issue*, 46(1), 101:145.
- Albrecht, C. C., Dean, D. L., & Hansen, J. V. (2003). *Market Place and Technology Standards for B2B. E-Commerce: Progress and Challenges*. Paper presented at the Standard Making: A Critical Research Frontier for Information Systems - MISQ Special Issue Workshop.
- Allison, G., & Halperin, M. H. (1972). Bureaucratic Politics: A Paradigm and Some Policy Implications. *World Politics*, 24, 40-79.
- AsiaInfo. (2004, May 10). Chinese HDV Alliance Established. *SinoCast*. Retrieved June 10, 2009 from Highbeam Database.
- AsiaTimes. (2006, January 26). Foreign R&D centers booming in China. *Asia Times*.
http://www.atimes.com/atimes/China_Business/HA26Cb01.html
- Barnett, P. W. (2008). *The Red Queen among Organizations: How Competitiveness Evolves*. Princeton: Princeton University Press.
- Baumol, J. W. (2004). Red-Queen Games: Arms Races, Rule of Law and Market Economies. *Journal of Evolutionary Economics*, 14(2), 237-247.
- Bi, J. (Producer). (2007, September 26) China's High-Tech Industry and Its Trade with the US. Power Point Presentation.
<http://www.carnegieendowment.org/events/?fa=eventDetail&id=1064>
- Breznitz, D. (2009). Slippery Paths of (Mis)Understanding? Historically Based Explanations in Social Science. In G. Schreyögg & J. Sydow (Eds.), *Hidden Dynamics of Path Dependency: Institutions and Organizations* (pp. 13-34): Palgrave MacMillan.
- Breznitz, Dan and Michael Murphree .(2010). *Run of the Red Queen: Government, Innovation, Globalization, and Economic Growth in China*. New Haven, CN: Yale University Press.
- BusinessWire. (2003, January 20). Datang Mobile, Philips and Samsung Form Joint Venture to Deliver Cellular TD-SCDMA Chipset & Reference Design. *Business Wire*.
<http://www.allbusiness.com/electronics/computer-electronics/5673690-1.html>
- Cai, W. (2009, April 28). Guochan Languang Gaoqing Dieji Dijia Jiaomai Guanwang Zhezhong. *Nanfang Ribao*. <http://tech.163.com/09/0428/10/57VU3123000915BD.html>
- Cao, C. (2004). Zhongguancun and China's High-Tech Parks in Transition. *Asian Survey*, 44(5), 647-688.
- Cao, C., Suttmeier, R. P., & Simon, D. F. (2006). China's 15-year science and technology plan. *Physics Today*, December, 38-43.
- CDRInfo. (2009, March 20). Chinese Audio Technology Included in the Blu-ray Specifications. *CDR Info*. <http://www.cdrinfo.com/Sections/News/Details.aspx?NewsId=25046>
- CDRInfo. (2009, April 23). TCL and Shinco Ship First CBHD Players in China *CDR Info*.
<http://cdrinfo.com/Sections/News/Details.aspx?NewsId=25238>
- Chen, H. (2008, June 18). Guanggu Jiang Zao Shijie Shoupi NVD 10 Yuefen Shangshi Jijie 1600 Yuan. *Changjiang Commercial Paper*.
http://www.hb.xinhuanet.com/newscenter/2008-06/18/content_13573016.htm

- Chen, Q. (2005). China Putian Promote Commercial TD-SCDMA Services. In Z. Wu, et al. (Eds.), *Lecture Notes in Computer Science: Embedded Software and Systems* (Vol. 3605, pp. 25-29). Berlin: Springer.
- ChinaDaily. (2005, February 2). IPR disputes highlight absence of law. *China Daily*. http://www.chinadaily.com.cn/english/doc/2005-02/02/content_414284.htm
- ChinaDaily. (2009, March 3). Warner Bros. Announces Plans to Support China's Domestic High Definition Format. *China Daily*. http://www.chinadaily.com.cn/showbiz/2009-03/03/content_7529855.htm
- ChinaSourcingNews. (2008, July 15). China DRA Passes Technical Evaluation for Blu-ray Disc Format. *China Sourcing News*. <http://www.chinasourcingnews.com/2008/07/15/16342-china-dra-passes-technical-evaluation-for-blu-ray-disc-format/>
- Clapp, P., Halperin, M. H., & Kanter, A. (2006). *Bureaucratic Politics and Foreign Policy, Second Edition*. Washington, D.C.: The Brookings Institution.
- Clendenin, M. (2006, February 16). China taps U.S. partner to keep EVD standards. *EE Times India*. http://www.eetindia.co.in/ART_8800407147_1800010_NT_32a4d728.HTM
- Clendenin, M. (2006, March 22). WAPI battle exposes technology rifts with China. *EE Times*. http://www.eetasia.com/ART_8800411320_499488_NT_0ceade42.HTM
- CNN. (2002, January 28). Verizon launches first U.S. '3G' network. *CNN.com*. <http://edition.cnn.com/2002/TECH/ptech/01/28/verizon.3g/index.html>
- CTN. (2003, November 18). VP5 And VP6 To Be Included In China's EVD Standard. *China Tech News*. <http://www.chinatechnews.com/2003/11/18/105-vp5-and-vp6-to-be-included-in-chinas-evd-standard/>
- CTN. (2004, April 30). HVD Alliance Established By 19 Enterprises. *Gadgets & Electronics*. <http://www.chinatechnews.com/2004/04/30/1201-hvd-alliance-established-by-19-enterprises/>
- CTN. (2004, December 8). HDV and HVD Hold Secret Discussions Over EVD's Fate. *Gadgets & Electronics*. <http://www.chinatechnews.com/2004/12/08/2113-hdv-and-hvd-hold-secret-discussions-over-evds-fate/>
- CTN. (2008, November 11). Datang Holdings Buys Stake in SMIC. *China Tech News*. <http://www.chinatechnews.com/2008/11/11/7964-datang-holdings-buys-stake-in-smic>
- CTN. (2009, January 12). SMIC Signs Cooperative Agreement with Datang. *China Tech News*. <http://www.chinatechnews.com/2009/01/12/8469-smic-signs-cooperative-agreement-with-datang/>
- Curtis, T. (1997). Japanese telecommunication reform and the standards-setting process. *Telecommunications Policy*, 21(2), 165-176.
- Cusumano, M. A., Mylonadis, Y., & Rosenbloom, R. S. (1992). Strategic Maneuvering and mass-market dynamics: The triumph of VHS over Beta. *Business History Review*, 66(1), 51-95.
- David, P. A. (2001). Path Dependence, its critics and the quest for historical economics. In P. Garrouste & S. Ionnides (Eds.), *Evolution and Path Dependence in Economic Ideas: Past and Present*. Cheltenham, UK: Edward Elgar Publishing.
- Derfus, J. P., Maggitti, G. P., Grimm, M. C., & Smith, G. K. (2008). The Red Queen Effect: Competitive Actions and Firm Performance. *Academy of Management Journal*, 51(1), 61-80.

- Ding, I. (2009, June 10). The Blu-ray Challenge in China. *China International Business*.
http://www.cibmagazine.com.cn/html/Print/Show.asp?id=950&the_blu-ray_challenge_in_china.html
- Einhorn, B. (2003, April 14). Master of Innovation? *Business Week*.
http://www.businessweek.com/magazine/content/03_15/b3828010.htm
- Ernst, D., & Naughton, B. (2007). China's Emerging Industrial Economy – Insights from the IT Industry. In C. A. McNally (Ed.), *China's Emergent Political Economy – Capitalism in the Dragon's Lair* (pp. 39-59). London and New York: Routledge.
- Fan, P. (2006). Catching up through developing innovation capability: evidence from China's telecom-equipment industry. *Technovation*, 26, 359-368.
- Frauenheim, E. (2004, January 29). Report: China's next-generation DVD faces hurdles. *CNET News*. http://news.cnet.com/2100-1041_3-5150373.html?tag=cd_lede
- Fuller, D. B. (2005). *Building Ladders Out of Chains: China's Technological Upgrading in a World of Global Production*. MIT, Cambridge, Mass.
- Funk, J. (2002). *Global Competition Between and Within Standards: the Case of Mobile Phones*. New York: Palgrave.
- Gao, P. (2007). Counter-Networks in Standardization: A Perspective of Developing Countries. *Info Systems J*, 17, 391-420.
- Gilley, B. (2008). Legitimacy and Institutional Change: The Case of China. *Comparative Political Studies*, 41(3), 259-284.
- GlobalSources. (2009, June 15). Blu-ray DVD players: industry on the rise, R&D in high gear. *Global Sources - Electronics*. Retrieved from
<http://www.electronics.globalsources.com/gsol/I/Blu-ray-player/a/9000000105354.htm>
- Haas, P. (1992). Introduction: Epistemic Communities and International Policy Coordination. *International Organization: Special Issue*, 46(1), 1:35.
- Heddergott, K. (2006). *The Standards Jungle: Which Standard for Which Purpose*. Berlin: Springerlink.
- Hirooka, N., & Nakajima, T. (2009, June 1). Next-generation DVD formats go head to head once again. *Nikkei Business*. <http://business.nikkeibp.co.jp/article/eng/20090601/196293/>
- Hsu, J., & Hwang, A. (2008, August 29). Hollywood Movie Studios Not Supporting China-developed CBHD, say Taiwan Optical Disc Makers. *Digitimes*.
<http://www.digitimes.com/news/a20080828PD215.html>
- IHT. (2006, December 4). OECD says China overtaking Japan in research spending. *International Herald Tribune*.
- Kanellos, M. (2004, August 9). DVD Player Profits down to \$1. *cnet News*.
[http://news.cnet.com/DVD-player-profits-down-to-\\$1/2100-1041_3-5302728.html?part=rss&tag=5302728&subj=news.1041.20](http://news.cnet.com/DVD-player-profits-down-to-$1/2100-1041_3-5302728.html?part=rss&tag=5302728&subj=news.1041.20)
- Kennedy, S. (2005). *The business of lobbying in China*. Cambridge, MA: Harvard University Press.
- Kennedy, S. (2006). The Political Economy of Standards Coalitions: Explaining China's Involvement in High-Tech Standards Wars. *Asia Policy*, 2, 41-62.
- Kennedy, S. (2007, April 19-20). *Capitalists in the Capital: Institutionalizing Informal Business Lobbying in China*. Paper presented at the International Conference on the State Capacity of China in the 21st Century, Hong Kong.
- Kennedy, S. (2007, February 28-March 3). *Paper Tiger: Mandarins in Geneva*. Paper presented at the 48th Annual Convention of the International Studies Association, Chicago.

- Kennedy, S., Suttmeier, R. P., & Su, J. (2008). *Standards, Stakeholders, and Innovation*. Seattle, WA: National Bureau of Asian Research.
- Khalil, E. L. (1997). The Red Queen paradox: a proper name for a popular game. *Journal of Institutional and Theoretical Economics*, 153(2), 411-415.
- Kindleberger, C. (1983). Standards as Public, Collective, and Private Goods. *Kyklos*, 36(3), 377-396.
- Krasner, S. (1991). Global Communications and National Power: Life on the Pareto Frontier. *World Politics*, 43(3).
- Kroeber, A. (2007). China's Push to Innovate in Information Technology. In L. Jakobson (Ed.), *Innovation with Chinese Characteristics: High-Tech Research in China* (pp. 37-70). New York: Palgrave Macmillan.
- Kushida, K. (2008). *Leading Without Followers: The Political Economy of Japan's ICT Sector*. Unpublished manuscript, Berkeley.
- Kushida, K. E., & Zysman, J. (2008). The Services Transformation and Network Policy: The New Logic of Value Creation *Review of Policy Research*, 26(1), 173-194.
- Lecraw, D. J. (1987). Japanese Standards: A Barrier to Trade? In H. L. Gabel (Ed.), *Product Standardization and Competitive Strategy* (pp. 29-46). Amsterdam: Elsevier Science Publishing.
- Lee, H., & Oh, S. (2008). The political economy of standards setting by newcomers: China's WAPI and South Korea's WIPI. *Telecommunications Policy*, 32, 662-671.
- Lemon, S. (2008, November 12). Troubled SMIC gets lifeline from China's Datang. *MIS Asia*. <http://www.mis-asia.com/news/articles/troubled-smic-gets-lifeline-from-chinas-datang>
- Li, C. (2006). China's Telecom Industry on the Move: Domestic Competition, Global Ambition, and Leadership Transition. *China Leadership Monitor*, 19.
- Li, W. (2005, June 22). TD-SCDMA insiders say trial went badly. *China Daily*. http://www.chinadaily.com.cn/english/doc/2005-06/22/content_453509.htm
- Linden, G. (2004). China Standard Time: A Study in Strategic Industrial Policy. *Business and Politics*, 6(3).
- Liu, X. (2006). *Path-following or Leapfrogging in Catching-up: the Case of Chinese Telecommunication Equipment Industry*. Paper presented at the CIRCLE Seminar Series. http://circle-lund.net/UploadedPublications/200701_Liu.pdf
- Liu, Y. (2005, February 25). ISO Meeting Fails to Back WAPI Standard. *China Daily*. http://www.chinadaily.com.cn/english/doc/2005-02/25/content_419204.htm
- Low, B. (2005). The Evolution of China's Telecommunications Equipment Market: a Contextual Analytical Framework. *Journal of Business & Industrial Marketing*, 20(2), 99-108.
- Loney, M. (2001, December 6). Europe's first 3G network goes live. <http://www.zdnet.com.au/news/communications/soa/Europe-s-first-3G-network-goes-live/0,130061791,120262215,00.htm?omnRef=http://www.google.com/search?hl=en>
- Mahoney, J. (2000). Path Dependence in Historical Sociology. *Theory and Society*, 29, 507-549.
- Manivannan, M. (2008, November 17-19, 2008). *Globalization of Technology - Imagine the possibilities Socio-economic, politics and cultural implications and thought leadership*. Paper presented at the IAJC-IJME International Conference, Nashville, TN.
- Mattli, W., & Buthe, T. (2003). Setting International Standards: Technology Rationality or the Primacy of Power. *World Politics*, 56(1), 1-42.

- McDonald, J. (2006, December 6). Chinese companies unveil video player with homegrown DVD technology. *International Herald Tribune*. Retrieved August 1, 2010 from Lexisnexis.
- Meisner, S. M., & Lewis, R. (2008, August 21). Patent Pool Can Provide Competitive Benefits. *Law 360: The Newswire for Business Lawyers*.
<http://www.mwe.com/info/pubs/iplaw082108.pdf>
- Naughton, B., & Segal, A. (2003). China in Search of a Workable Model: Technology Development in the New Millennium. In W. W. Keller & R. J. Samuels (Eds.), *Crisis and Innovation in Asian Technology* (pp. 160-186).
- Nelson, R. R., & Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Cambridge, Mass.: Belknap Press of Harvard University Press.
- NSBPRC. (2009). *2008 Nian Guomin Jingji He Shehui Fazhan Tongji Gongbao*.
http://www.stats.gov.cn/tjgb/ndtjgb/qgndtjgb/t20090226_402540710.htm.
- NSBPRC. (2010). *2009 Nian Guomin Jingji He Shehui Fazhan Tongji Gongbao*.
http://www.stats.gov.cn/tjgb/ndtjgb/qgndtjgb/t20100225_402622945.htm.
- OECD. (2006). *Information Technology Outlook 2006: Chapter 4. China, Information Technologies and the Internet*. Paris: Organization for Economic Cooperation and Development.
- OECD. (2007). *OECD Reviews of Innovation Policy: China Synthesis Report*. Paris: Organization for Economic Cooperation and Development.
- PeoplesDaily. (2003, October 28). China to issue home-developed EVD standard. *People's Daily*. http://english.peopledaily.com.cn/200310/28/eng20031028_127012.shtml
- PeoplesDaily. (2004, January 10). EVD players not selling as expected in China. *People's Daily*.
http://english.people.com.cn/200401/10/eng20040110_132291.shtml
- Pierson, P. (2000a). Increasing Returns, Path Dependence, and the Study of Politics. *APSR*, 94(2), 251-268.
- Pierson, P. (2000b). Not Just What but When: Timing and Sequence in Political Processes. *Studies in American Political Development*, Spring(14).
- Pierson, P. (2004). *Politics in Time: History, Institutions, and Social Analysis*. Princeton, NJ: Princeton University Press.
- Powell, G. (2006, December 1). Out DVD, in EVD. *China Economic Review*.
- Pyyny, P. (2005, January 2005). Chinese DVD Player Manufacturers Take Patent Owners to Court. *Afterdawn News*. <http://www.afterdawn.com/news/archive/5979.cfm>
- Qu, P., & Polley, C. (2005, December). The New Standard Bearer: China is now trying to set the rules for many developing technologies. *ieee Spectrum*.
<http://www.spectrum.ieee.org/computing/hardware/the-new-standardbearer/0>
- Samuels, R., J. (1994). *Rich Nation Strong Army: National Security and the Technological Transformation of Japan* Ithaca: Cornell University Press.
- Schelling, C. T. (1960). *The Strategy of Conflict*. Cambridge: Harvard University Press.
- Segal, A. (2003). *Digital Dragon: High-Technology Enterprises in China*. Ithaca: Cornell University Press.
- Serger, S. S., & Bredine, M. (2007). China's Fifteen-Year Plan for Science and Technology: An Assessment. *Asia Policy*, 4, 135-164.
- ShangwuZhoukan. (2007, October 5). Xinwei Shi'er Nian De Lunhui. *Shangwu Zhoukan*, 40-46.
- Simcoe, T., Graham, S. J. H., & Feldman, M. (2009). Entrepreneurship, Intellectual Property and Platform Technologies. *Journal of Economics & Management Strategy*, 18(3), 775-816.

- Sinocast. (2006, January 20). Chinese 3G Equipment Providers in Talks on IP Issues. *TD-Forum*.
<http://www.tdscdma-forum.org/EN/news/see.asp?id=2567>
- Smith, T. (2003, November 20). China unveils 'DVD killer' video disk format. *The Register*.
http://www.theregister.co.uk/2003/11/20/china_unveils_dvd_killer_video/
- Smith, T. (2004, April 22). China Agrees to Drop WAPI Wireless Sec Spec. *The Register*.
http://www.theregister.co.uk/2004/04/22/china_caves_on_wapi/
- StateCouncil. (2006). *Guojia Zhongchangqi Kexue He Jishu Fazhan Guihua Gangyao (2006-2020 Nian)*. http://www.gov.cn/jrzg/2006-02/09/content_183787.htm.
- Stewart, J. (Producer). (2009, December 8) Mobile Broadband: from 3G to 4G. *China European Information Technology Standards Research Partnership*. Power Point Presentation.
<http://www.china-eu-standards.org/press/stewart.pdf>
- Stewart, J., & Wang, C. (2009). *Final Report on Standards Dynamics in Domain of Mobile Telephony: Mobile Broadband from 3G to 4G*. Edinburgh: University of Edinburgh.
- Stigler, G. J. (1971). The Theory of Economic Regulation. *Bell Journal of Economics and Management Science*(2), 3-21.
- Suttmeier, R. P., & Yao, X. (2004). *China's Post-WTO Technology Policy: Standards, Software, and the Changing Nature of Techno-Nationalism*. Seattle, WA: National Bureau of Asian Research.
- Suttmeier, R. P., Yao, X., & Tan, A. Z. (2006). *Standards of Power? Technology, Institutions, and Politics in the Development of China's National Standards Strategy*. Seattle, WA: The National Bureau of Asian Research.
- Tang, A. (2009, August 13). Installation of Internet filtering software not compulsory: minister. *Xinhuanet*. http://news.xinhuanet.com/english/2009-08/13/content_11875099.htm
- TD-Forum. (2008, May 26). TD-SCDMA, Good Experience in Trial Use and an Uncertain Future. *TD-SCDMA News*. <http://www.tdscdma-forum.org/EN/NEWS/see.asp?id=5365>
- Wang, X. (2009, April 23). CBHD Entry May Escalate Disc Wars. *China Daily*.
http://www.chinadaily.com.cn/bizchina/2009-04/23/content_7706820.htm
- Wolchok, S., Yao, R., & Halderman, J. A. (2009). *Analysis of the Green Dam Censorware System*: University of Michigan.
- WSJ. (2009, June 8). Zhongguo Shoujin Hulianwang Kongzhi. *The Wall Street Journal*.
<http://chinese.wsj.com/gb/20090608/chw085100.asp>
- WTO. (1995). Agreement on Technical Barriers to Trade (1995).
- WTO. (2003). Dispute Settlement: Dispute DS231 - European Communities - Trade Description of Sardines (2003).
- Wu, I. (2009). *From Iron Fist to Invisible Hand: the Uneven Path of Telecommunications Reform in China*. Stanford, CA: Stanford University Press.
- Xinhua. (2010, March 16). China's trade surplus with US misread. *China Daily*.
http://www.chinadaily.com.cn/bizchina/2010-03/16/content_9598941.htm
- Yam, M. (2009, May 1). CBHD is China's Own Blu-ray Disc. *Tom's Hardware Guide*.
<http://www.tomshardware.com/news/cbhd-china-blue-bluray-disc,7681.html>
- Yen, E., & Hwang, A. (2010, April 19). China Market: 3D CBHD Players to be Available by End of 2010. *Digitimes*. Retrieved from
<http://www.digitimes.com/news/a20100419PD201.html>
- Yen, E., & Hwang, A. (2010, July 5). China Market: Shinco, TCL unveil 3D CBHD players. *Digitimes*. <http://www.digitimes.com/news/a20100705PD200.html>

- Yoshida, J. (2003, November 18). China unveils its own video format. *EE Times*
<http://www.eetimes.com/showArticle.jhtml;jsessionid=PENCN1RAJRG3KQSNL0SKH0CJUNN2JVN?articleID=18310016>
- Yoshida, J., & Carroll, M. (1997, November 24). China Flexes Standards Muscle. *EE Times*.
<http://www.eetimes.com/news/97/982news/china.html>
- ZGJM. (2004, May 9). Gaozengzhang Beihou De Fansi - Dangqian Gao Xin Jishu Chanpin Chukou Qiye Mianlin De Wenti Ji Duice. *Chinese Academy of International Trade and Economic Cooperation*.
<http://www.fiet.gov.cn:81/ReadNews.asp?NewsID=20040509141405&DWID=0&DWType=0&tbltype=1>
- Zhang, D. (2008, December 31). China to issue 3G licenses tonight. *TMT China*.
<http://tmt.interfaxchina.com/news/1158>
- Zhang, Y. (2008, March 8). Xiaoshou Yuleng EVD Dieji Niannei Yao "Tuishi". *Chengdu Shangbao*. <http://news.hexun.com/2008-03-08/104291325.html>
- Zhou, T. (2004, June 26). *China's Home Grown CDMA Systems: SCDMA/TD-SCDMA/LAS-CDMA*. Paper presented at the Monte Jade S&T Association Advance Program Workshop Newport Beach, California.
- Zhou, X. (2001). Political Dynamics and Bureaucratic Career Patterns in the People's Republic of China, 1949-1994. *Comparative Political Studies*, 34(9), 1036-1062.