BUILDING MARKETS: THE POLITICAL ECONOMY OF TECHNOLOGY STANDARDS

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BUILDING MARKETS: THE POLITICAL ECONOMY OF TECHNOLOGY STANDARDS

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For Nana, who fills my life with joy

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LIST OF ABBREVIATIONS

2G	Second Generation Mobile Telephony
3C	Content, Computers and Communications
AFNOR	French Standards Association
AMPS	Advanced Mobile Phone System
ANSI	American National Standards Institute
AQSIQ	State Administration of Quarantine and Inspection
AVC	Advanced Video Coding
AVS	Audio-Video Standard
BSI	British Standards Institute
CAS	Chinese Academy of Science
CATT	Chinese Academy of Telecommunication Technology
CBS	(Formerly) Columbia Broadcasting System
CCIR	Comité Consultatif International Pour la Radio
CCSA	China Communication Standards Association
CDMA	Code Division Multiple Access
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CESI	China Electronics Standards Institute
CFT	Compagnie France de Television
CNIS	China National Standards Institute
CTI	Color Television, Inc.
D-AMPS	Digital Advanced Mobile Phone System

DNI	German Standards Institute
DVD	Digital Video Disc
EC	European Community
ETSI	European Telecommunications Standards Institute
EU	European Union
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
FRAND	Fair, Reasonable and Non-Discriminatory
GATT	General Agreement on Tariffs and Trade
GB	China National Standard
GSM	Global System for Mobile Communications (Groupe Special Mobile)
HD-DVD	High Definition Digital Video Disc
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IGRS	Intelligent Grouping and Resource Sharing
IP	Intellectual Property
ISO	International Organization for Standardization
ITU	International Telecommunications Union
JS	Japan Standards
JTC1	Joint Technical Committee 1
LAN	Local Area Network
MII	Ministry of Information Industry
MIIT	Ministry of Industry and Information Technology
MNC	Multinational Corporation

MOST	Ministry of Science and Technology
MoU	Memorandum of Understanding
MPEG	Moving Pictures Expert Group
MPEG-LA	Moving Pictures Expert Group – Licensing Authority
NIST	National Institute of Standards and Technology
NTSC	National Television System Committee
ORTF	Organisation de Radiodiffusion et Television Francaise
OSI	Open Systems Interconnection
PAL	Phase Alternating Line
R&D	Research & Development
RAND	Reasonable and Non-Discriminatory
RAND-RF	Reasonable and Non-Discriminatory – Royalty Free
RCA	Radio Corporation of America
RF	Royalty Free
SAC	Standardization Administration of China
SDO	Standards Development Organization
SECAM	Sequential Color with Memory
SEP	Standards Essential Patent
SIPO	State Intellectual Property Office
TBT	Technical Barriers to Trade
TDD	Time Division Duplex
TD-SCDMA	Time Division-Synchronous Code Division Multiple Access
USB	Universal Serial Bus
VHS	Video Home System
WAPI	Wireless Authentication and Privacy Infrastructure

WCDMA	Wideband Code Division Multiple Access
WIPO	World Intellectual Property Organization
WLAN	Wireless Local Area Network
WTO	World Trade Organization

SUMMARY

This dissertation explains the causes of national differences in markets for technology. Different national approaches to intellectual property protection and use, market openness and market scope are the result of the process of creating technology standards in different countries. Technology Standards, in turn, are the product of two causal variables: the historically determined institutions of standardization - particularly the role of the state in the standardization process, and the position of a country in the fragmented global production system. The institutions of standardization determine the relative influence of different actors over standardization and market position. The position within the global economy determines these actors' perspectives on intellectual property and market scope. Using case studies of standardization and technology market creation in the United States, Europe and China, this dissertation reveals the mechanisms by which these two variables give rise to national differences in technology markets.

CHAPTER 1

THE THEORY OF POLITICS, STANDARDS AND MARKETS

Thought Game: A World without Standards

Imagine browsing the aisles of a grocery store in a world with no standards. While everything might appear unchanged, the world without standards is a very uncertain place. With no standards, it is impossible to know at what temperature or level of moisture fresh produce is and should be kept. How do the employees know how deeply to freeze ice cream? How can you as a customer determine the quantity of beans in a can? Do you compare the sizes of cans or how they feel in your hands? How certain can you be of the quality and safety of the foods you attempt to purchase? How do you know if a store has better or worse prices? There is no common basis to judge between one set of items and another set from a different store.

Imagine building a house in this world with no standards. How thick will the slab need to be for a foundation built on given type of soil? How does the builder know the correct mix of aggregate and cement for the concrete in the foundation versus the cement for plastering walls or building driveways? How do the carpenters determine which screws to purchase or use for given types of joints? Finally, even if the team were able to put the home together, how do regulators determine if the structure is sound and habitable? Against what standard, literally, can your newly built home be compared?

Given the complexities of navigating a grocery store or construction site without basic standards, imagine trying to build a cell phone, a task many times more complex given the need to integrate the hundreds of intricate components that make up a mobile phone. To make a mobile phone, at a minimum, a manufacturer needs to first ensure the phone is able to communicate with a set of towers and that these towers can interface with a broader telephone network. The phone's signal must be received, interpreted, converted and relayed and then the entire process reversed at the other end. How can a manufacturer ensure that all of the thousands of components in a phone are able to work together – especially as most are produced by multiple independent vendors? Without standards specifically governing the capabilities and interaction interfaces among components, as well as between the phone and the broader network, it would be impossible to make a phone which the user can expect to work reliably.

To continue this thought experiment, imagine how people in a world without standards would cope. Grocery store employees could be carefully instructed by experienced workers. Experienced workers would know by sight, touch or smell how cold freezers would need to be and how often to wet down the fresh produce. Construction workers would be subject to long apprenticeships which could impart the tacit knowledge needed to work without established standards. For mobile phones, a single firm could attempt to control all stages of production from components to final phones and base stations as well as all network equipment and broadcasting technology. Keeping all technology in house could ensure interoperability, but it would massively increase costs as well as decreasing the potential efficiencies from having multiple vendors solving the same problem or offering substitutable goods to drive down costs.

Even if workers could be trained to compensate for a lack of standards, customers would still lack this knowledge. Further, any group of workers could define and teach tacit knowledge in their own way. Every store's approach would be different; as customers moved from store to store, they would have to learn a new set of tacit information for selecting and comparing goods. Customers could overcome these obstacles through developing long and repeated relationships with a single vendor. However, the difficulty with comparisons would restrict the ability to substitute one set of goods with another thus undermining the basis for the price mechanism – the foundation of markets.

An alternative approach would be complete vertical integration within a firm – from resources, through production, to operation and sales. The phone example would require a total vertical integration. While this would solve the problems of coordination and transaction costs, it would produce an absolute monopoly: an economic arrangement well-known for yielding socially suboptimal outcomes in price, quality, choice, quantity, and innovation. Further, without comparability, each store would effectively be its own monopoly since goods could not be substituted. Without standards, market activity would be difficult at best and impossible at worst. A world without standards would be confusing. It would be uncertain. High technology goods without standards would be essentially unworkable – outside a vertically integrated monopoly context.

Fortunately, we do not live in such a world. Standards for metrics, safety, quality, and technology definition are ubiquitous. Some are codified formally as written documents, and others are implicitly accepted and established by different cultural norms and practices (Busch 2011). Standards mitigate the uncertainties which would plague a world such as that described above. Indeed, standards are so ubiquitous that their presence is generally treated as a background condition, always assumed to provide a politically neutral framework within which market activity – and innovation – can take place. Given the assumption that standards always exist, there has been insufficient research into the role of standards in building markets. The critical question of how politics shapes the standardization process – and thus shapes the basic foundations of markets – is underexplored through systematic comparative research. This dissertation addresses this gap in the literature, looking explicitly at the role of politics in standards formation and how political processes thus shape markets across countries.

Why Standards Matter

The thought experiment above illustrates a key principle. Standards are necessary for markets, as we understand them in the modern economy, to form and function. In the modern global economy, markets for goods and services involve the buying and selling of components, subsystems and final products across long distances by agents who do not intimately know one another. The tight relations and tacit knowledge from the examples above cannot be shared or absorbed in such arms-length relationships. Instead, economic transactions, from a visit to the supermarket to wholesale purchases of screws for an electronics assembly plant, rely on multitudes of standards. These standards act to reduce uncertainty, build implicit trust and thus lower transaction costs, smoothing exchange and facilitating the functioning of the "invisible hand" of supply and demand. Given their importance, we must look closely and critically at standards since these market-building institutions are themselves the product of political processes.

While standards are assumed as a background condition today, the historical record shows that standardization has long been considered a critical government task. Throughout history – from imperial China to revolutionary France to the newly independent United States – one of the first tasks of a new authority was to ensure it alone had the power to define and enforce standards throughout its realm. Indeed, the Book of Proverbs, King Solomon's collection of royal wisdom, declares that there should be a common set of standards: "Diverse weights and diverse measures – both are alike abomination to the LORD" (20:10, King James Version).

Newly minted governments do not neglect standards, even in their founding moments. In the United States, both the Articles and Confederation and the Constitution assign the power to set standards for weight and measure. Article Nine of the Articles of Confederation of the United States (1781) gave the national congress the sole authority to fix standards for weights and measures. In the later Constitution (1787), the ability to fix weights and measures was the fifth power delegated to the national congress. From 1790 – George Washington's first report to Congress – to 1838 the United States worked to establish a single system of metrology standards, a project considered of critical importance by Presidents Washington, Jefferson, and John Quincy Adams. These early centralized standardization efforts led to creation of the forerunner of today's National Institute of Standards and Technology – a body still charged with developing efficient and standard units of measure and measurement instruments. For the early United States, the goal of common standards for weights and measure was to facilitate trade among the states. To enable a ton of South Carolina rice or Georgia Sea Island cotton to be sold efficiently in the warehouses and exchanges of New York, it was necessary to set common units to which all the states would adhere. Later, common standards of weight would be complemented by official standards for grading the quality of such commodities, allowing traders to purchase goods sight-unseen and know what they were getting, further reducing transaction costs (such as the need to have experts examine every individual shipment) and facilitating exchange.

Standards of weight and measure facilitate trade in all types of goods and services, but the importance of standards has only increased as technologies have become more sophisticated. The increased importance includes traditional standards for weights and measures as well. One of the most famous failures stemming from incompatible standards was the loss of the Mars Climate Orbiter due to the use of imperial units by ground based instruction software and metric units by the on-board computer software. As the systems shared numbers, the differing units of measurement resulted in faulty calculations which caused the orbiter to pass too close to the upper Martian atmosphere, causing the probe to de-orbit and burn up entering the Martian atmosphere (NASA 1999).

High technology goods and services today generally rely on a specific subset of standards: technology standards. *Technology standards are protocols defining the necessary functions and capabilities of different components and how these are to interact with one another to work as a single unit in the final product.* Technology standards also define how technology products connect to and communicate with one another and with the broader networks through which interconnection takes place. These protocols are essential for the functioning of markets in technologies. In this dissertation *markets for technology and technology markets refer to the markets for high technology based goods*. This differs from the definition in Gambardella, Arora and Fosfuri's work on markets for technology which are defined as efficient systems for exchanging intellectual property rights (Arora, Fosfuri et al. 2001; Gambardella 2002; Arora and Fosfuri 2003).

Since technology goods are generally made from hundreds of components which are themselves produced by tens or hundreds of different supplier firms before being integrated, standards are necessary to ensure the final product works as intended. Final users do not know the providers of components such as the memory or digital signal processing chips for their phone, but users expect the phone to work smoothly. Technology standards are the means of coordinating such a variety of components and the vast array of vendors. In the absence of standards, hierarchy within a single vertically integrated monopolistic firm is an alternative, but one without the innovation and competition benefits of standardization.

Changes in the global trade and production system mean technology standards are more important than ever. With the rise of global markets and the fragmentation of production, the need to maintain arms-length economic exchanges has only grown. While this truism applies to all types of standards, advances in technology mean standards now go far beyond those traditionally made for definition and metrology. Technology standards, far more complex than traditional standards, are a major area of state and firm interest today. Technology standards define products, components, and their integration. Technology standards make it possible to reliably source goods and services globally, from multitudes of suppliers, confident in their ability to work together.

While standards-conforming components and products may be sourced from any number of firms, technology standards themselves are based on key underlying technologies, embedded as standards-essential patents (SEP). Standards-essential patents provide the contributing firms with royalties, the ability to limit market entry, and intimate knowledge essential for defining subsequent developments of a standard. Taken together, contributing to the definition of technology standards, and controlling their content, is a source of market power.

The importance of standards for globally-organized production is not in dispute. However, standards are not black boxes or irreducible variables to be taken at face value. Since markets are the basis of economic activity – and economic activity the root of wealth and hence political power – there are interests from both firms and governments in appropriating the greatest returns from market activity. If standards are essential to market operation, it stands to reason that standards will be highly political. Therefore, taking a political economic approach to studying standards can illuminate the means by which different technology markets arise around the world.

Dissertation Goal and Significance

The goal of this dissertation is to introduce a theory accounting for the differences in technology markets in different countries. As a first introduction of a theory using technology standards as the primary mechanism through which features of technology markets are determined, this dissertation is not attempting hypothesis testing. However, the mechanism presented here will be illustrated in case studies from different countries which show that the predicted outcomes from the theory are indeed born out in various technology markets shaped under different standardization systems.

The process by which standards are formed shapes the distribution of gains among participants and implementers of the standard. Both government and business actors actively seek to shape the standardization process to their own benefit. As market power – going back to the work of both free market champions like Smith and developmental statists like List – is considered the source of national wealth and power, control over technology standards is a means of seeking, grasping and controlling that power (List 1841 (1991); Smith 1937).[1] With so much at stake, the development of standards is a highly contentious and politicalized process. Accordingly, the actors with the greatest influence over the process of standardization will have the greatest ability to mold or even control markets for technology.

This dissertation looks at the politics of technology standardization by examining the processes by which standards are created in different countries. The institutions of technology standardization, both formal organizations and traditional practices and inclinations, privilege certain actors over others. Privileged positions in standardization afford advantages and influence in technology markets. By studying the politics of standardization, we can come to understand how politics can shape markets and different avenues for control exercised by states and firms.

This is not the first research to claim markets are subject to political influences. However, the existing literature emphasizes the importance and role of formal government structures (locus of control, degree of federalism, autocracy versus democracy), government economic policies, or the structure of the world economy itself. There is also a rich literature dating back to the 1970s and 80s which argues that technology standards have strong market impacts (such as shifting the mode of competition from product differentiation to price) (David 1985; Besen and Johnson 1986; David 1986; David and Greenstein 1990; Besen and Farrell 1994). A related but disconnected stream of research also argues that political forces determine much of the outcomes in standardization. However, the literature does not engage with the question of how the political influences on standards are a vector through which politics shapes technology markets. This dissertation expands our understanding of the role of politics in markets by explicitly examining the role of politics in shaping standards and how this

[1] Adam Smith's "Wealth of Nations" argued that the exercise of free trade and limited government intervention in the economy would ensure greater economic development and wealth. List, on the other hand, argued that open markets were insufficient to ensure national wealth and that state intervention, protection, and sponsorship of critical segments of the economy – particularly industrial development – were essential to ensuring national wealth and power.

translates into differing technology markets across countries. For scholars to understand the emergence and divergence of markets for technology, and their salient features such as pricing for intellectual property, openness and scope in different countries, we must look at the politics of standardization and how this then determines these markets.

Argument and Theory

The puzzle being addressed in this dissertation is why technology markets have different features across countries. If science and technology were universal, there should be great similarities in markets based on them. Yet we find that technologies are created, bought, and sold very differently across countries. This dissertation accounts for the differences in technology markets through the mechanism of the process of technology standardization. Influences on technology standards in different countries determine the content of standards and thus the form and operation of national technology markets. While it may seem strange to speak of "national technology markets" in an era of globalization and global production networks, national features still strongly influence the development of technology standards and their influence on final markets for technology. Salient national features – historical institutions of standardization – remain greatly influential, even as firms are increasingly subject to globally determined pressures.

It is important to note that this dissertation and theory are not attempting to propose a normative ideal for standardization or technology markets. The reality is that there are coexisting approaches to standardization and types of markets. No single approach has proven over time to be universally more successful than others. The US, European and Chinese cases examined in this dissertation all show evidence of relative, or absolute, successes in creating highly lucrative markets through their standards. All three cases also have standardization efforts which failed to result in viable markets. Indeed, the same institutions and position in the global economy which yield spectacular successes in certain standardization efforts have also yielded protection, fragmentation of markets and obsolescence of technology in others. Accordingly, the theory proposed here, unlike much of the standardization and markets literature, does not take a normative position comparing the relative merits of different approaches. It only seeks to account for why differences emerge.

My research finds that two salient variables – historically derived national institutions of standardization and the position of firms and national-level industries in the fragmented global production system – determine differences in the characteristics of national technology markets. These two variables shape the three defining attributes of technology markets as derived by standards: IP policies, openness and scope. Technology standards are intermediate variables between the causal variables acting on standards and the final technology market. Historical institutions and position in the fragmented global production system explain the arrangement of actors and distribution of power in a technology market – and hence the differences among countries. A simplified version of this model may be outlined as shown in Figure 1:

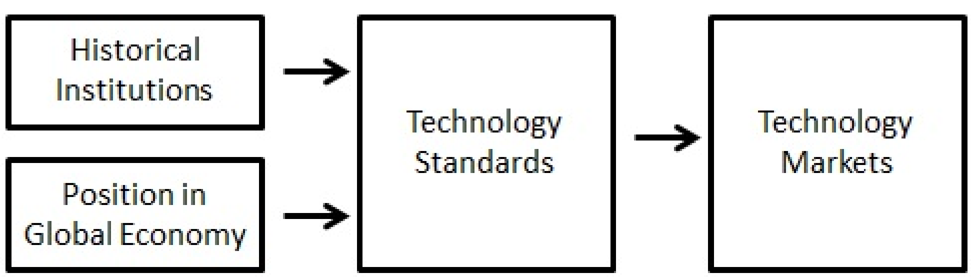

Figure 1: Basic Model

The combination of national institutions of standardization and the position of firms and industries in the fragmented global political economy determines the content of technology standards. As the intervening variable, the corresponding characteristics of standards determine the final values in the technology markets which emerge. Standards determine the distribution of power for various actors in the market, thus setting the values for treatment of intellectual property, the openness of the market, and its scope.

This is not a static unidirectional model. It must be acknowledged that the model has a degree of reverse causation and feedback as well. For example, technology markets dictate the profitability of different firms which will in turn shape their relative position in the global economy and their perspective on future generations of standards. Similarly, national institutions are not static but are subject to the pressures of the global market – as well as rapidly changing innovations and technologies. National institutions thus adapt to meet changes in global markets, even as they seek to shape these markets through standardization.

How does this model work in practice? A technology standard becomes the framework for the technology market. First, the standard sets the legally mandated requirements for technology licensing and royalty payments for a given standardized technology. This dictates the terms under which actors will be able to utilize the embedded intellectual property within the standard. The terms of this access determine pricing and profit positions of different actors and the viability or profitability of different business and innovation strategies. Where standards require that all technologies be included on a free basis, the market which emerges will favor firms with product development or manufacturing capabilities as such firms will be able to extract profits in the market while would-be technology licensors will struggle to earn returns. On the other hand, where firms are allowed to independently determine their licensing fees and practices, IP licensors will have great market advantages. Large IP contributors will pay less in licensing fees as they may be able to arrange technology sharing or cross-licensing agreements with other contributors to the standard. This will enable them to offer standards-compliant products at lower prices – holding profits steady – than competitors. Further, where commitments to "reasonableness" or "non-discriminatory licensing" are weak, strong IP contributors may be able to shape the final market by limiting the number of participating firms. If a firm refuses to offer non-discriminatory licensing, it may choose which firms are allowed to produce standards-compliant goods. This undermines the price-reduction advantages of standardization and builds oligopolistic markets.

Thus, the IP policies and practices of standards have real impacts on the viability of different firm's business models. In recent debates over intellectual property and standards, leading corporations such as Apple and Qualcomm have vehemently disagreed over norms for intellectual property in standards.

Second, the openness of a standard is written into its protocols. Inclusion or exclusion of actors from a standard determines which actors are even allowed to participate in the market. Some standardization efforts are restricted to firms in a single industry, polity or industrial alliance. A wholly closed standard bars potential entrants from the market simply because the IP in the standard is not available for license to outside parties. Actors who were not party to the development of the standard are thus locked out of the market. They may consume technology goods but will be unable to become providers of these goods or to improve upon the standardized technology.

The degree of openness in a standard is a function of the type of standard being developed – whether formal or de facto – and the means by which it is developed. Openness is a measure of the number and breadth of different actors involved in the creation of the standard and the terms under which actors not directly involved in creating the standard can utilize the standard in their own products. In certain countries, standardization efforts are initiated by governments to serve strategic purposes. Depending on the goals of the standard, the standard which results may be highly restricted. Chapter four discusses the case of the WAPI wireless network security standard in China which was legally closed to all but a small group of contributing firms. Other firms were not permitted to take part in development or license the core technology. Standards created by de facto processes – that is without formal organizations developing, approving and publishing the standard – may be highly restrictive or open depending on the desired outcome of the firm which created the would-be standard. Openness in de facto standards depends on the developing firm(s) strategy. If it seeks maximization of immediate profits by commanding royalties for a chosen set of intellectual property, it may keep the standard closed and charge any would be adopters. In other cases firms will opt for very open standards allowing as many other firms as possible to license and utilize a technology – often at very low cost – in order to preempt the emergence of a competing technological alternative.

In markets, openness matters for two reasons. First, openness helps determine which firms have early access to and knowledge of the standard. This helps provide early or first mover advantage in the market. First movers tend, all else being equal, to earn greater returns and market share. Thus, being included in the development of a standard is important and may afford a sustained competitive advantage. Second, where standards are restricted based on nationality, firms from the sponsoring country have great advantages – such as free technology access, lower licensing fees, or access to state subsidies and procurement markets – over outside firms.

The openness of a standard relates to the conception by firms and states of the ideal final market state. If the desired market is a protected one, participation and enforcement restrictions are likely to be onerous. However, as firms and states may not have the same interests in the nature of enforcement, the relative power of these actors will be important in determining how open a final standard will be.

Finally, the scope of a standard determines the geographic and industrial range over which a market will operate. The same market holds sway as widely as a standard is implemented; yet where incompatible standards are adopted, there is a different market.

When standards are set at the national level, the scope may be limited to the national borders of a state, particularly where the dominant actors setting the standard desire protection of the technology and market. Scope is also a factor of the decisions made by other states to adopt the same or other incompatible standards. If other countries adopt the same standard, the market extends across the broader range. Ensuring broad market scope is a major impetus behind the European Union's project to ensure compatibility and uniformity of standards across all member states. Having a single standard makes the ideal of a single integrated pan-European market a reality.

Scope is a function of the degree of state involvement in standards creation and the firms or other actors given priority of voice in the development process. More statist standards will often have limited scope as protectionism is often a goal in creating national standards. Standards with limited scope are generally effective at providing the creating firms with a protected market but also limit these firms' ability to sell goods and services in a broader global market based on incompatible standards. Indeed, the fear of facing higher compatibility costs is one reason when major Chinese firms often reject the central government's attempts to impose standards with a limited national scope.

Once finalized, these attributes of standards lay out the conditions for markets for technology. The initial independent variables being presented here are thus national institutions of standardization and the position of a country in the fragmented global production system. Technology standards are the intervening variable which in turn shapes the dependent variable – technology markets.

Technology markets can be measured via the same defining characteristics as technology standards: intellectual property, degree of openness, and market scope. These three factors differ widely across technology markets both among and within countries. For example, both Korea and Japan are known for having highly interventionist governments, active in the development and promotion of indigenously developed technologies. However, the degree of protection in their markets for technologies such as mobile telephony hardware differs widely. Japan's markets have traditionally been closed to outside technology while Korea's high technology industries are highly integrated with foreign developers of technology and open to international cooperation. The end result is that Korea's technology market is open and globally integrated while Japan's has long been highly isolated. What accounts for this difference?

Treatment of intellectual property, degree of openness, and scope in standards are the product of both the national institutions of standardization and the position of a national firm or industry in the global economy. These aspects of standards go on to influence the same characteristics of technology markets. However, as mentioned above, standards are also shaped, particularly in their later revisions and updates, by the same markets they initially helped mold.

The national institutions independent variable is dichotomous – having two idealized categories into which a country may fall: statist or non-statist. Position for firms in the global economy can be reduced to one of three conditions: IP Creator-Licensor, IP Creator-Manufacturer, or IP Taker. The orientation of an actor between the six possible combinations of these different variable values determines the content of standards and their relevant technology market shaping aspects.

National institutions of standardization are the product of historical path dependent processes in which economic ideology, historical accidents or unique emergent conditions and motivations are strongly influential. These historically determined institutions shape the standardization process by giving more influence and power to certain actors (Hall and Taylor 1996). Accordingly, in different standardization systems, the state or firms, or certain sub-sets of firms such as large or state-owned enterprises, have differing degrees of influence. Therefore, national institutions of standardization can be categorized as either statist or non-statist. This characterization as statist or non-statist is based on the technology standardization literature which emphasizes the role of governments or firms as the leading actors in the standardization process. Although government is involved in standardization in all countries, the nature of this involvement varies from ex ante definer and creator to ex post adopter and regulator. The differing levels of involvement by the state strongly determine which actors are involved and influential in the standardization process – and thus which actors are able to define the critical market-defining characteristics of technology standards. The statist versus non-statist distinction is based on whether or not the national government has a leading role in the standardization process.

The role of the state is a function of when a state began its industrialization and the conditions under which it did so. Using Gerschenkron's logic of relative backwardness, the later a state began industrializing, the more active the government will be in shaping the industrialization process to achieve national political goals. As the varieties of capitalism literature has shown, the differences in relative state intervention in the economy continue long after the initial conditions of backwardness have been addressed. This historical role for the state means that reforms are unlikely to significantly alter the state's role in the economy. While the nature of state intervention will change, the government remains an active – even leading – actor in the economy.

In standardization, the role of the state is similar to that throughout the broader economy. Where the government is not actively involved in managing or intervening in the economy, the government similarly takes a "hands-off" approach to technology standardization. Government will thus have a limited role in the direct operation or behavior of technology markets. On the other hand, activist staves have the tools and institutions with which to mold standardization and technology markets.

In non-statist cases, firms determine the outcome of the standardization process and thus wield greater influence over final markets. The state has a less prominent role – usually taking the position of basic regulator to ensure fair competition in the economy and to ensure that standardization processes do not become avenues for inter-firm collusion. Firms develop technologies and push these as standards, either independently or through building coalitions of like-minded firms. This largely “market-based” approach to standardization, as discussed in the literature, tends to be faster than state-led standardization but can result in a condition where a standard fails to emerge or where a suboptimal standard becomes entrenched.

While two countries may have “statist” approaches to standardization, this does not mean the actions of the state will be identical. There are real choices available to states in standardization. Firm-led standardization will also not necessarily follow the same patterns. The role and policies that states or firms will adopt and push in standardization is constrained by the second independent variable – the position of firms in the fragmented global production system.

The power that different actors have over standardization – whether state or firms – affords them with the ability to push through their strategic normative vision for markets. This vision is a product of the actor’s position in the fragmented global economy. This vision determines the policy and strategy choices of actors in the standardization process and sets the stage for the conditions which will materialize in technology markets.

Firms can exist in one of three states in the fragmented global production system: as an IP creator-Licensor, IP creator-Manufacturer, or IP taker. A firm’s position in the fragmented global production system shapes its approach to standardization. Position in the global economy determines the approach to standardization by molding the normative views of leading actors on the value of intellectual property, approach to licensing of technology, and the openness and scope of standards. With certain actors being empowered by their country’s statist or non-statist standardization institutions, they will then employ these perspectives when setting standards, thus defining their technology markets.

This three-part division takes into account that not all firms adopt the same business strategies even when their R&D, human resource, or capital capabilities are similar. There is a commonly held belief that advanced economies with robust R&D sectors will all converge to a common set of interests, yet the empirical data reveals that firms primarily interested in manufacturing – even with strong R&D capabilities – push for different standardization policies than those more interested in earning revenues by licensing technology. IP Creators must be divided between those whose worldview is shaped by their licensing or manufacturing emphasis in the global economy.

The IP Creator-Licensor has robust R&D capabilities and is able to produce new or recreated and improved technologies readily. The IP Creator-Licensor seeks to set technology trends over time through ownership and control of access to IP. The firm in question is more concerned with technology independence and perpetuation of dominance over the highest value-added end of the production chain – architecture and definition.[2] The IP Creator-Licensor also sees licensing fees as the major source of revenue. It does not emphasize manufacturing; indeed manufacturing may be seen as a lower value-added activity which should be outsourced. The goal behind standardization is to enhance the ability to extract royalties from other firms and ensure sustained technology dominance over time.

An IP Creator-Manufacturer, on the other hand, sees the real value of technology primarily in its incorporation into final products which can then be sold. Actors in this category still have robust manufacturing capabilities and view manufacturing as a strategic asset worthy of support and investment. In this instance, the firm will actively seek to develop technology but does so not to license but rather to improve the value added, profits, or desirability of its goods and services. It is important to note that this distinction between licensor and manufacturer is not necessarily predicated on the actual

[2] Stan Shih, founder and CEO of Acer proposed the concept of the "smiling curve" in 1992 to account for why certain production stage activities were more profitable than others. Assembly and manufacturing lay at the bottom of the curve while patenting, definition and architecture for whole systems lay at the top of the curve. Technology standards, as long term determinants of market characteristics and technology trends, may be seen as the ultimate peak of the smiling curve – affording the most value added and strongest competitive advantage to firms.

production of goods. Due to its emphasis on products rather than monetization of intellectual property, Apple is decidedly an IP Creator-Manufacturer while Qualcomm is an IP Creator-Licensor as its revenues are entirely based on licensing fees.

The IP Taker is a firm with little independent R&D capability, particularly for definition of architecture and basic capabilities of a technology – the exact types of research which becomes the basis for technology standards. IP Takers are thus reliant on other firms – typically foreign – to produce the IP they will use in producing or utilizing goods and services. IP Takers are in a disadvantageous position when it comes to contributing to or setting international standards or attempting to improve their profitability in the face of mandatory licensing fees. IP Takers thus have very different perspectives on the value of intellectual property and the normatively "proper" role for technology standards. However, their ability to realize these normative goals is limited by their relative power. Relative weakness means the IP Taker will be forced to accept its position in the global standardization system – and disadvantaged market status. A stronger state, or globally influential firms by market share or production capacity, can help counteract this disadvantaged position by lobbying for better licensing terms.

Taking these two independent variables, we can construct a 2 X 3 matrix (See Figure 2). This matrix shows six possible conditions for countries to occupy in the standards and market creation ecosystem. The following paragraphs detail the possible outcomes before briefly noting how certain national cases fit into this typology. It should also be noted that these categorizations remain somewhat ideal. There are individual cases and specific technologies for which a country may appear to cross over – particularly on the Licensor-Manufacturer distinction. For example, while the United States generally de-emphasizes manufacturing, there are companies for which the licensing of technology is not part of their core business strategy – such as Apple.

Position in global economy			Historical Institutions: Statist	Historical Institutions: Non-Statist (Firm-led)
	IP-Creator-Lisensor	IP-Policy	Strong IP Protections; state promotes indigenous IP for national, regional or global standards; State sponsors IP development by favored firms	Strong IP Protections; firms have the right to dispose of IP as they see fit; limited state enforcement of RAND norms; state supports IP rights of indigenous firms internationally
		Openness	Closed to outsiders; state protects indigenous technology and market	Open; government regulatory action limited; firms – including foreigners – dominate standardization process; multiple standards co-exist
		Scope	Limited; standards adopted strategically	Broad; firms create standards seeking universal application
	IP-Creator-Manufacturer	IP-Policy	Strong IP Protection, state promotes domestic firms' IP implementation for products; state support for RAND	IP Protected; firms emphasize production rather than monetization; firm alliances share technology among suppliers
		Openness	Open so long as domestic manufacturers have an advantage - otherwise state can intervene	Open so long as firms able to reach agreement on common standards for manufacturing
		Scope	Limited; standards adopted strategically	Standards adopted as needed to support manufacturing; otherwise adopt or adapt foreign
	IP Taker	IP-Policy	State cultivates indigenous IP but aggressively seeks low-cost foreign; state support for RAND-RF, technology sharing and mandatory licensing	IP protected to secure foreign orders; firms adopt international standards and pay for IP as needed
		Openness	Development closed, otherwise open	Open, accepts foreign standards to encourage domestic access to foreign markets and the global economy
		Scope	Generally open to rest of world but very closed in targeted sectors	Universally open; new standards adopted with little debate

Figure 2: The Impact of Historical Institutions and Position

The first category of country in this matrix is the Statist IP Creator-Licensor. The combination of strong R&D capabilities with a less manufacturing intensive strategy for a firm means there are strong incentives to support hard intellectual property rights protection in technology standards. In the presence of a strong state, this means that the government will use its authority to ensure the success of indigenously produced technology on the national, regional and international stage. The state will aggressively promote international cooperation utilizing the indigenous technology in order to increase licensing returns for national enterprises. The strong state also means that technology markets will frequently be closed. The strong state is able to protect the interests of domestic IP holders and may bar foreigners from participation in standardization activities so as not to dilute domestic firms' IP contributions and may discourage adoption of international standards. At the same time, however, the scope of the market will depend on the reaction of foreign markets to the indigenous technology standard. Where foreign partners adopt the national technology, markets will be broad and internationally integrated. However, national markets may be restricted if alternative technologies are adopted.[3]

The second category of country is the Statist IP Creator-Manufacturer. Such countries take a different approach to intellectual property. As firms active in the standardization process emphasize the value of physical production of goods versus just the production of licensable intellectual property, IP rights are treated flexibly. The state protects firms' IP, but the firms seek to include this technology in products or use IP strategically to increase the acceptance of their products versus those of other countries. The strong state will promote the Reasonable and Non-Discriminatory (RAND) licensing norms for intellectual property embedded in technology standards. Enforcement of the RAND norm will facilitate development of products incorporating proprietary technology and encourage production and sales of goods. In this case, standards development will be open to foreign participation and markets will be open to all comers – except in cases

[3] In China, the TD-SCDMA 3G mobile telephony standard was successfully promoted by the state and developed sufficiently to receive international certification by the International Telecommunications Union as one of three international 3G mobile telephony standards. However, foreign regulators did not offer licenses to their telecommunications operators to use TD-SCDMA technology with the result being the market for TD-compliant goods is restricted entirely to China.

where the country's manufacturers find themselves at significant competitive disadvantages. In such a case, the state may intervene to protect domestic industry. The state will also promote the development of standards it considers strategically important, using incentives to encourage firms to develop and utilize indigenous standards – but with a focus on products rather than IP licensing.

In the third case, the leading firms involved in standardization are largely IP Takers, albeit in the context of a strong state. Firm strategies emphasize the production of actual goods and services. Weak indigenous innovation capabilities limit the ability of the country or its firms to develop technologies capable of earning royalties or challenging existing standards. The country also has a strong tradition of state involvement in the standardization system and the economy more broadly. Here, the state must take an active role in shaping markets for technology in order to ensure what it considers to be favorable outcomes. The state will be inclined to promote indigenous technologies – even technologically inferior ones – especially if they are cheaper than foreign alternatives. The state will also encourage adoption of international technology standards in order to increase the potential market size for exporting firms but will seek the best possible licensing terms on behalf of firms. The state will use its influence to try to reduce or eliminate royalty rates for domestic firms and to secure access to foreign technology at nominal rates. Where indigenous standards are proposed, they will be open and even royalty free. The position as IP Taker means firms will seek to minimize IP costs in order to maximize their profits and enable them to seize greater profits and market share at constant low price points. Although the government will promote indigenous IP wherever possible, on the whole, technology markets will be open and conform to international standards. This is because the IP Taker needs access to foreign technology and will produce goods for foreign markets.

The fourth category of country is the Non-Statist IP Creator-Licensor. Here, the country has no tradition of strong state involvement in standardization or the economy. In this case, technology markets will be dominated by firms. Technology standards governing the market will arise through de facto processes rather than formal ones. The state will largely limit its role to ratifying what firms have already put into practice. Indeed, firms will resist state attempts to intervene in technology development and standardization. State intervention will be ineffective due to a lack of state capacity for such actions. Where IP Creators dominate the standardization process, however, the country will have strong IP protection and property rights norms, giving firms the right to dispose of their intellectual property as they see fit. In extremis, the lack of state intervention may enable firms to flout RAND licensing norms. Technology standards, and hence markets, are generally open due to limited government regulatory action and the desire of firms to produce standards rapidly – frequently requiring cooperation with foreign firms. Without a strong state to select standards, however, firms may produce multiple incompatible standards, thus forming separate fragmented technology markets. In terms of scope, firms will seek to promote their standards as broadly as possible. However, these countries will occasionally fail to produce efficient technology markets as they will be plagued by excess inertia – where firms would be better off adopting a common standard but are unable or unwilling to agree upon a single standard from a given firm or alliance.

The fifth possible category is the combination of an IP Creator-Manufacturer with a weak state. As in the IP Creator-Licensor case, intellectual property is protected by the state legally but there is no push for the firms to license or manufacture. By tradition, firms emphasize deploying their own technology for product creation rather than licensing. Firms seek to build broad coalitions among themselves to facilitate access to IP on favorable terms so as to encourage high value products. Markets are generally open so long as firms are able to reach agreement on common sets of technologies underlying their products. However, without state coordination, the possibility remains for no single standard to emerge, thus creating competing blocks of firms with closed standards. The scope of the market will generally be as broad as possible as firms seek to market their products worldwide. Without state support, protection is largely unavailable so firms will try to set or influence whatever standards are most widely adopted.

In the final case, leading, or simply globally oriented, firms have weak IP creation capabilities and no statist heritage or possesses a weak state due to disruptive historical events (like the fall of the Soviet Union or PRI governance in Mexico). The state is unable to dictate technology choices or to lobby for favorable licensing agreements on behalf of local firms. Firms must accept the licensing conditions of foreign IP holders as they lack the power to negotiate lower rates. At the same time, these countries will consistently seek to adopt international standards as this offers access to foreign technology markets. Firms emphasize adopting the broadest standards possible and do not challenge international standards. While firms are thus able to rapidly and efficiently scale up production and sales internationally, they lack the ability to influence the technology trajectory of standards or to push for alternative norms on IP pricing.

Using this model, it becomes possible to predict the form technology markets will take after different standardization efforts across countries. For example, France is known to have a strong government and a political economic tradition of state guidance in the economy and science and technology institutions. French firms are also producers of new technologies in an array of fields. According to this model, France would frequently belong in the first case: Statist IP Creator-Licensor. In France, we find that the state has a major role in shaping the technology standardization process. The country has strong respect for intellectual property rights but tries to use state power to encourage regional or global adoption of French technologies. The country licenses broadly to encourage adoption of French technology and return of royalties to French firms. On the flip side, however, where French technology is not internationally adopted, the state uses protection to ensure a market for French technologies. French technology standards are often closed, in the interest of promoting French firms and technology.

At the other end of the spectrum, Mexico is known to have a weak state with very limited intervention in the internationally-oriented economy.[4] Arguably, the lack of state intervention and direction makes Mexico an inviting place for foreign direct investments. At the same time, in technology-intensive industries, Mexican firms have little indigenous R&D and indeed remain low-value added manufacturers of foreign-designed goods. The result is that Mexico is resolutely an international standards taker. Its technology markets follow global trends and support whatever technologies have the largest global share. It contributes little to new standards development and does not oppose the licensing terms of existing foreign technologies.

Naturally, as the position in the global economy is firm specific, the results of this 2X3 can vary for a country depending on the industry in question or which firms are participating in standardization. Accordingly, there are many countries for which their position in the global economy is neither completely as an IP creator nor as an IP taker. Similarly, there are many subtle levels of state involvement in the economy. A country's position in this typology is also not static as it can change over time. For example, as recently as the 1980s, South Korean firms were technology takers, with low indigenous R&D capabilities and little ability to contribute sophisticated core technology to technology standards. However, South Korean firms have since become IP Creator-Manufacturers. The legacies of earlier positions in the global economy remain influential, however. In the case of South Korea, firms and the state agree that intellectual property is important and the rights of IP holders should be considered inviolable. At the same time, however, Korean firms tend to view IP as secondary to production of goods and services. Hence Korean firms do not seek to monetize their IP through licensing or transfer of ownership so much as through the sale of actual goods and services, more like the approach of "IP Taker" countries. The heritage of being reliant on foreign technologies

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[4] Mexico effectively has two economies. The domestic economy is highly regulated and statist but the export-oriented sectors of the economy operate largely free of state intervention or heavy regulation. Some scholars attribute Mexico's limited technology upgrading capabilities to this the laissez-faire approach.

and keeping their firms plugged into global markets continues; South Korea is disinclined to promote exclusionary standards.

As developed in greater length in chapter four, China is a rapidly progressing technology power. It has a very strong tradition of state involvement in the economy and institutions of standardization geared to ensure reliance upon the state for funding and strategic direction. It is also plugged into the global economy as an IP Taker. This means that even where the state is interested in promoting indigenous technology as a complement or replacement for foreign technology, many Chinese firms are disinterested, given their reliance upon global technology trends. Thus we see China as falling in the Statist IP-Taker category but with tendencies trending toward the Statist IP Creator-Manufacturer as firms' technology development capabilities become more sophisticated. Like South Korea, Chinese firms value production and seek means of producing at the lowest possible costs while also ensuring the broadest possible markets for their goods.

Approach and Cases

To illustrate how this theory accounts for different technology market outcomes in different cases, this dissertation looks at the processes by which standards are created and the political influences on those processes in three countries and regions. I adopt a comparative political economy methodology approach to studying standards. To enable compatibility across cases, I narrow my observations to a sub-set of technology standards: information and communication technology (ICT). This set of standards provides a rich base of different cases to compare as the world's major economies are all involved in the research, development, production and commercialization of ICT goods and the technology standards on which they are based. Further, ICT is a critical industry, both for its economic contributions but also as the infrastructure which binds together the global economy and has facilitated the rise of the information society. Based on field research and primary and secondary source documents, this dissertation proposes a model for standardization and market formation which links politics to market outcomes through the lens of standardization.

This dissertation examines this model by considering the standardization processes and markets for technology in the United States, Europe and China. These cases provide rich comparison as all three are active in the ICT industry, and all seek to influence, set, and control the standards underpinning these technologies. These cases provide variation on two key causal variables: historical institutions and position within the global economy. In terms of historical institutions, China and Europe actually share more in common than they do with the United States as both have strong statist traditions. For economic position, however, the US and Europe are more similar as both are decidedly IP Creators. These overlapping positions on these two variables enable us to isolate the relative impact of each variable on the four aspects of standards and hence market outcomes. Where US and European technology markets differ, it may be attributed to different historical institutions. Where China and Europe differ, it results from different positions within the global economy.

Technology standardization in the United States is a product of historical institutions determined during the late 19th and early 20th century as well as a political economy with a traditionally weak state, particularly during the period of rapid industrialization (Cochrane 1966; Dunlavy 1994; Shapiro and Varian 2003; Russel 2009). Technology standardization institutions in the US thus evolved to emphasize voluntary association, leadership by firms and firm representatives and a minimum of state involvement. This means firms tend to be the most active agents in standardization and their interests are reflected more or better than those of the state. In terms of position within the global economy, US information technology firms are often innovative leaders, specializing in the generation of new technologies. US firms tend to support strong intellectual property rights in standards, and emphasize these rights over other interests such as dissemination. American firms have also become increasingly interested in treating IP as a major, if not the predominant, source of income and wealth. This means firms are strongly inclined to create technologies and then license them rather than seek to incorporate the technologies in their own final products.

Europe's institutions of standardization evolved at the same time as the United States but did so in a very different political economic climate. European governments during the late 19th and early 20th century – particularly France and Germany – were heavily involved in their economies (Gerschenkron 1962; Dunlavy 1994). European governments sought to use the forces of industrialization to build national wealth and power through strategic efforts (List 1841 (1991)). Even the United Kingdom opted to follow the German model for standardization by creating a single government-licensed body to coordinate standardization activities. This historic role for the state means standards do not necessarily reflect only the interests of firms. State interests in "ideal" or "fair" markets and competition are successfully voiced in standardization. Like the US, Europe is a global leader in innovation and technology generation. Thus, the major differences in technology markets with the United States arise due to the role of the state and the emphasis on either licensing or manufacturing. Countries such as Germany and Sweden emphasize manufacturing while France emphasizes protection and promotion of French IP. Across Europe, firms remain committed to strong intellectual property rights, albeit tempered by state and regional (EU-level) government desires for broad technology dissemination and access.

China's standardization system is much more recent, having only been formed in the 1950s under Soviet tutelage. The Chinese standardization system was explicitly and legally mandated to be state-led (Wang, Wang et al. 2009). Firms had little role in standardization as efforts to develop standards were explicitly the responsibility of government industrial ministries. Under this system, standards had the force of legal regulations, thus being the polar opposite of the American "voluntary" ideal for standards (Ernst 2011; Ernst 2013). Although the Chinese system has been significantly reformed, the changes made primarily in the 1980s still reflected state leadership and involvement in standards (NPCPRC 1988; SAC 2008-2010). Firms in China tend to resist taking positions in standardization without first being prompted by the state (Author's Interviews). Firms in China also are mostly manufacturers of established or commodity technologies rather than technology creators (Cao 2004; Cao, Simon et al. 2009; Breznitz and Murphree 2011). As a result, Chinese standards tend to emphasize the importance of broad dissemination of technology for free or nominal royalties. Chapters three and four explore in detail how these different standardization systems emerged, the countries' positions within the fragmented global economy, and how this determines the structure and operation of their technology markets.

Defining the Terms: Markets and Standards

For the mechanism proposed here to make sense, it is necessary to define markets, institutions and standards. The description and definition of technology standards in this section serve as a brief overview of the material discussed at length in chapter two which offers an in-depth look at technology standards, the politics of standards, and the role of standards in market formation.

Markets

To describe the influence of politics on markets through technology standards, we must first clarify what is or is not a market. In doing so, we must remember that markets are not self-generating but are, as Trigilia notes, "simply one out of many historically specific ways to arrange institutions of exchange" (Trigilia 2002). As there have been other non-market-based modes of exchange at various periods in human history, the market mechanism itself is a human creation. Since they are creations of human society, markets can be reformed or molded into different patterns of distribution. This is important when considering the relationship between technology standards and markets.

If markets are human creations, creating a market affords actors with opportunities to influence aspects of those markets, especially the distribution of gains, losses, and power.

Since the 18th century, economists have wrestled with the concept of a “market.” Smith defined the market as the set of human interactions governed by a price mechanism set by the “invisible hand” (Smith 1937). A market exists where there are multiple interchangeable goods so that buyers must compete with one another to gain the business of customers who are seeking the best price for their desired goods or services. Other scholars have looked at markets differently; they emphasize certain necessary attributes of markets. Cournot emphasizes in his “Researches” that:

> “It is well known that by market, economists mean, not a certain place where purchases and sales are carried on, but the entire territory of which the parts are so united by the relations of unrestricted commerce that prices there take the same level throughout, with ease and rapidity” (Cournot 1838 (1897)), Ch 4., Paragraph 23).[5]

Scholars emphasize that a market is the geographic region throughout which the price mechanism achieves uniformity of prices for goods and services – mediated by competition and substitutability. Jevons argued that there was a certain amount of information necessary for a market to form: the stocks of the actors and their intentions to exchange and the ratio of exchange (price) had to be known to all (Jevons 1871 (1970)). Only so far as this knowledge is available can there be said to be a “market.”

More recent sociologists such as Fligstein have used a relatively simple definition of “market” – a “situation in which some good or service is sold to customers for a price that is paid in money” (Fligstein 1996). Fligstein continues, saying the market is an “abstract space of exchange in which frequent intercourse among buyers and sellers

[5] Anyone who has ever purchased gasoline knows, however, that this range can be very small indeed – often limited to a single street intersection. Only a few hundred yards away – but out of sight – the prices will differ. Consumers require information in order to compare and thus induce competition. The advent of mobile “apps” which identify which gas stations have the lowest prices may – if they become widely used – increase the size of this “market” where prices are identical.

determines prices." Menard argues that "a market is a specific institutional arrangement consisting of rules and conventions that make possible a larger number of voluntary transfers of property rights on a regular basis, these reversible transfers being implemented and enforced though a specific mechanism of regulation, the competitive price system" (Menard 1995).

The sum of these scholars' definitions is a series of descriptive attributes which define a human institution as "market" or "not market." If these attributes are present, however imperfectly, there is a "market." Once the most basic elements of a market are clearly delineated, it is possible to describe how a market form and can be molded. This clarifies the role played by standards as the means of fulfilling these necessary attributes. There are at least two basic attributes necessary for a "market" to exist: presence of multiple buyers and sellers and trust among actors. When these features are present the "market" can be said to exist as Smith's mechanism of the "invisible hand" will be able to function.

The most basic element of a market is the necessity of having two or more buyers and sellers. With only one buyer, there is no market as the price mechanism does not work. The buyer is able to dictate the price. Similarly, with only one seller, a monopoly condition exists and price is not determined through competition. For this dissertation, a monopolistic market is acknowledged. Indeed, these are often the results of de facto standardization where alternative technologies are completely eliminated or formal standards legally mandating the use of a single technology from a single or narrow alliance of firms. Monopolistic markets do not yield the sought after benefits of standardization and market competition – that is falling prices and arguably increased innovation. This further increases the political stakes in technology standardization. When done well, standards result in competitive technology markets, but they can also be used to create closed monopolies. Before the integrated development of GSM in Europe, different states each created national technology monopolies by only permitting the use of indigenous mobile telephony standards. These national monopolies retarded the development of mobile telephony in France, Germany and Italy in particular (Funk 1998).

Arguably most importantly, there must be trust among agents for there to be market exchange. Granovetter's research found that embeddedness of institutions and actors was intended to increase trust among them and therefor enable exchange to take place (Granovetter 1983). Where buyers and sellers have neither faith in the medium of exchange (ie: will the money hold its value? Is the money being used counterfeit?) nor that the seller is not trying to cheat, there will be impediments to exchange. Although trust can be built over time and through repeated interaction, to even begin a market, there must be some degree of trust and hence certainty against cheating. Without a mechanism for certainty, the probabilities of different outcomes cannot be determined making it impossible for agents to exist as conscious utility maximizers (Beckert 1996). For a market to form, therefore, there must be means of mitigating uncertainty. Economists, sociologists, and political economists usually prescribe a set of "institutions" as the means of reducing uncertainty and building the trust necessary for markets to function. This dissertation lies within this strain of the research as standards are a form of uncertainty-reducing institution which enables market formation and operation.[6]

A primary means of mitigating uncertainty and hence enabling markets is through rules and conventions. These constrain the behavior of would-be market actors to ensure they compete fairly. While there are sanctioning mechanisms possible without formal rules and conventions such as the loss of demand for a seller's goods or services after they are revealed to be defective or deceptive, society must first face injury before the mechanism self-corrects. To prevent such ills, and to draw lines around what sorts of pricing, marketing, production, and service practices are considered acceptable, a market

[6] Standards are not the only institution able to furnish these attributes. Other institutions noted in the risk and uncertainty literature such as rule of law and property rights, and interpersonal trust as researched by Granovetter are also critical to market formation and function.

requires rules and conventions. Rules and conventions help agents to understand the rules of competitive games ex ante and to reduce the uncertainty over the intentions and behavior of other actors. Standards are on such trust-building institution.

Institutions

Standards are a product of historical institutions and are also an institution in the formation of markets; hence it is important to clarify what is meant by "institutions". Institutions for markets are formal and informal means of ensuring that agents have the confidence they need to enter exchange relations with one another. I take the Northian definition of institutions – formal and informal routinized patterns of behavior (North 1990). This definition necessarily includes formal laws and regulations as well as established practices for which there are no written guidelines. Institutions can include cultural norms of behavior, established but informal channels through which influence or information are transmitted, as well as legally established hierarchies, rights and responsibilities. Some standardization scholars have argued for a broad definition of standards, such that would encompass informal but established institutions, defining these instead as a type of cultural or social standard instead of just as institutions (Busch 2011). For market formation, institutions are critical as they reduce uncertainty. Standards also set the rules of the competitive game in technology markets by establishing the positions and relative power of different actors. This helps determine market outcomes.

One of the difficulties with using institutions as a causal variable in research is that institutions themselves emerge through political processes involving other institutions. For this reason, I take a historical institutionalist approach in this dissertation (Steinmo and Thelen 1992; Hall and Taylor 1996). Historical institutionalism emphasizes that the formal and informal routinized patterns of behavior discussed by North are embedded in the organizational structure of the polity or political economy and often reflect the long-term influence of historical accidents or crises. For my primary causal variables, this is important as standards in different countries are the product of these embedded pressures coming from the position of firms or states in the global economy as well as the different historical circumstances in which they emerge. In discussing technology standardization and market formation in different countries, it is essential to consider the pathways through which institutions governing standardization were created. This helps explain the different values placed on intellectual property, openness and scope – the variables which determine technology markets.

Historical institutionalism emphasizes the asymmetries of power within and among institutions in their formation and operation. This is important for this dissertation as different levels of power shape the standardization process and the final position of actors. Where a state, or state sub-unit such as a ministry or even research group, has significantly more power than other actors, a standardization effort will reflect their interests to a greater degree than other actors'. It is these imbalances of power and influence that determine different patterns in standardization and, later, market formation.

Historical institutionalism argues institutions are the product of historical processes. This means the creation of institutions may be the result of specific historical conditions or crises, yet through path dependency these historical events shape the way organizations and individuals behave long after conditions have changed. It is extremely difficult to change historically derived institutions and power relations among agents within them, even with reforms. Thus institutions are an enduring force. For instance, in China, institutions of standardization were created when the planned economy was still dominant; thus the state remains the key actor in standardization. In the United States, however, standardization institutions developed during a time of weak central government. Government attempts to assert itself in standards have usually failed.[7]

[7] The one major exception to this rule is in the area of telecommunications policy. As the national regulator, the FCC has the ability to impose standards through its control over the allocation of spectrum for use by broadcast industries and mobile telephony operators. At different times the FCC has been an active promoter of one standard or another, but it has also chosen in many cases to allow the enterprises to

What are Technology Standards?

Building on the definitions of standards used by international standards development organizations such as the International Organization for Standardization (ISO), the International Telecommunication Union (ITU), and national standards bodies including the American National Standards Institute (ANSI) and the Standardization Administration of China (SAC), **standards are formal written protocols, developed by consensus or a modified consensus principle in a formal or ad hoc body, that serve as a platform for interoperability, comparability and on which other applications and innovations can be built.** This definition encompasses both the most basic metrological standards (standards of weight and measure) – developed by scientific consensus with political support – and highly complex and detailed technology standards defining the capabilities, qualities and functioning of high speed computer networks.[8]

A defining feature of standards is that once they are established, other firms – even those unrelated to the development and adoption of the standard – are able to use the standard as the basis for products or as the basis for development of related goods and services. Standards are thus a public good insomuch as one firm's use of a standard does not diminish its value or availability to others (Kindleberger 1983). To make such a platform for competition, standards must define specific dimensions or capabilities. Where the specifications are sufficiently detailed, all a firm needs do is make sure their products or services conform to the standard and the firm – and its customers – can be confident that it will work with other components and networks in the same standard. However, although standards are public goods, they are more rightly considered "semi-public" goods as the benefits of standardization accrue unevenly. As discussed above, the

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decide for themselves whether or not to support one standard, or any standard, for their industry (Besen 1986).

[8] Metrology is the science of measurement. Metrological standards are the formal agreements on values and conversion ratios for mass, weight, distance, volume, and time. Standardization bodies such as America's National Institute for Standards and Technology (NIST) and Germany's Imperial Physikalisch-Technische Reichsanstalt were originally created to develop standards and values for metrology.

IP policies of a standard in particular determine the profitability of different business strategies – IP licensing versus products. Thus, the degree of benefit a firm receives from a standard will vary depending on the standard's content and the firm's business strategy. While all firms have access to a standard, the benefits are not even.

Standards also have the effect of "freezing" the development of technology at a certain level, thus enabling peripheral innovations to be built around it (Kindleberger 1983; Besen and Johnson 1986; Ernst 2009; Ernst 2011).[9] This freezing of technology also effectively precludes development of alternative technologies as these have no market. Setting the standard for a new technology offers firms a major long-term technological and competitive advantage over others. As the masters of the core technology, they also have intimate familiarity with it which often translates into further innovations laying the groundwork for the next generation of standards. So long as a firm continues in this vein, they may be able to preserve a competitive advantage through multiple generations of standards. The challenge, however, for states seeking to normatively or strategically shape markets to achieve goals other than the smooth exchange of goods and services, is how to prevent control over standards from creating monopoly power or preventing the emergence of superior alternative technologies.

Standards are also highly dense. States interested in using standards to normatively mold markets in their desired form also face a difficulty from the relative impenetrability of standards which makes them incomprehensible to non-experts. The formal documentation for a standard usually consists of hundreds of pages of technical specifications defining terminology, outlining protocols and specifying the technologies necessary to make the protocols deliver the necessary performance as defined by the standard. This documentation makes standards dense and difficult for non-engineers to

[9] The term "freeze" comes from the standards literature. It does not mean that technology development stops but rather that standards codify the state of knowledge and state of the art in a field up to that point. Standards thus lock technology at a certain level. New developments are then made on top of this locked-in platform leading to the next major upgrade or development.

understand or analyze for potential impact. The meetings for standards development working groups and technical committees use similarly obtuse language, making it difficult for non-experts to follow the discussions or understand the implications of various measures being debated.

Impenetrability enhances the influence of actors such as corporate IP lawyers and engineers while inhibiting the ability of untrained government experts or civil society representatives to influence the path of standardization. The complexity of standards makes it difficult for states to fully appreciate the implications of a given standard as well as the technologies incorporated in it. This complicates the political process of standards development.

Technology standards can be classified as de facto or formal (de jure) standards. De facto standards are set through competition where the winner pushes competitors out and acquires a technology monopoly. A technology monopoly forms when a standard pushes aside all alternative approaches. The backers of alternative approaches abandon their chosen technology and adopt the common standard. Most de facto standards are still open insomuch as firms are free to adopt and utilize the platform for their own innovations. This means that once the standard has been established, there will be competition, usually price-based, within the standard among firms confirming to it.

Formal standards are developed by institutionalized technology standards bodies whose decisions are based on consensus or majority vote. Formal standards development organizations can be non-governmental organizations, such as the Institute of Electric and Electronics Engineers (IEEE), or state membership-based bodies like the ITU and ISO.[10] At the national level, formal standards bodies include non-governmental bodies, such as ANSI or the European Technical Standards Institute (ETSI) that define national or regional standards. These bodies may or may not actually make the standards for which

[10] IEEE is a professional organization made up of electrical engineering experts and sets standards for electronics. It has no independent enforcement capability. ISO and ITU membership is limited to representatives of different countries. These organizations also have no formal enforcement capability.

they are responsible. Some national standards bodies such as the German Institute for Standardization (DNI) and the French Standards Association (AFNOR) draft, adopt, and certify national standards. Others such as ANSI are administrative bodies that only certify standards and represent their states in formal inter-governmental standards organizations.

The type of standards organization used to create a formal standard has significant impact on the market which will emerge. De facto standardization is decidedly led by the private sector. It privileges established firms able to independently produce complete or nearly complete technologies. Small firms are often excluded from the developmental process or may only participate at a cost disadvantage as they must pay to license the leaders' technologies. In contrast, formal standardization offers smaller firms, civil society, and government ministries an opportunity to voice their opinions and make submissions. Formal standardization may also include specific rules regarding the inclusion of technology, degree of openness in licensing and limits on costs. Thus different state preferences for de facto or formal standardization practices will determine the performance and nature of the technology markets in that state. If a state prefers de facto standardization, corporate interests will dominate. Formal standardization has the potential to constrain corporate interests in setting up a market to incumbents' advantage. Nonetheless, even formal standardization is often criticized as beholden to the interests of incumbent large firms. Part of the reason is the cost involved in sustaining involvement in standardization – a process that takes years and is beyond the reach of smaller firms.

To develop standards, standards development organizations establish technical committees to draft the protocols for a given technology or area of interest. Some technical committees are disbanded after developing a standard while others become institutionalized organizations which continue to improve standards or draft new ones in the same industrial sector for years. Under technical committees, working groups of experts – sometimes based in single firms – propose, test, debate, and adopt protocols to incorporate into the final standard. Inclusion of technologies or approval of protocols is accomplished through consensus and/or simple majority vote in the technical committee.

How Standards Shape Markets

The development of the modern PC industry provides a simple illustration of how standardization shapes technology market conditions. Before 1984, there were no fewer than four competing personal computing standards: Apple, UNIX, CSIS, and IBM. At this time, the different approaches effectively constituted closed monopolies where a single provider sold to a captive group of customers. Software was limited to one platform and the range of hardware available was limited to a single company provider. This meant a consumer became a captive to whichever standard he or she adopted as parts and software were not interchangeable. Each standard effectively constituted a closed monopoly where users were bound to the parent company whose standard they utilized.

IBM's PC took an alternate approach by accident, but the resulting open standard created a fiercely competitive PC market resulting in rapidly declining prices and increased market size. Although the IBM BIOS was proprietary, IBM decided to utilize an operating system from Microsoft rather than one developed in-house. By not requiring the use of its own software operating system, it was possible for other vendors to build IBM "clone" computers by reverse engineering the BIOS and shipping copies of the Microsoft operating system with the computer hardware. Ironically, the same Taiwanese firms that IBM sued for illegally copying its BIOS helped popularize IBM's platform. Using Microsoft's operating system also made it easier for software developers to create programs which worked on any PC clone. This effort at standardization was the first step to creating an international competitive personal computing market. With multiple vendors supplying effectively identical machines able to run the same software, consumers now had the freedom to choose among substitutable goods. Price competition began, rapidly driving down the costs of personal computers. As costs fell, mass demand further increased which encouraged more firms to begin computer production and more vendors to develop software for the IBM platform. With IBM's open platform, there were multiple vendors and buyers, thus creating a market. The act of setting a standard created a competitive market.

The standards literature often discusses competition between standards. There is a theory that a standard "wins" when it gains sufficient market share that there is a bandwagon effect and new adopters choose one standard over the other. Before a common standard emerges, there are separate fragmented monopolistic markets. Victory occurs where a standard creates the largest market through its openness and availability as a platform for other firms to build upon – or simply when it becomes large enough that potential customer base entices late adopters away from alternative standards.

As discussed above, a major challenge for market creation is the reduction of uncertainty to allow agents to enter exchange relations with one another. Standards help reduce this uncertainty. For example, safety standards ensure products or services are not injurious to consumers. Standards for heat resistance in wire coatings for electronics will enable manufacturers to know in advance which wires they may source that meet regulatory requirements on fire prevention. Quality standards facilitate trade through lowered transaction costs (via decreased information asymmetry between sellers and buyers). The grading system for meats (Grade A, etc) allows buyers to know the quality of their purchases without having to visit the supplier's factory or painstakingly inspect every shipment. Standardized measures of quality enable potential buyers to acquire goods or services sight unseen with a measure of confidence. At the same time, however, non-uniform standards can actually have the opposite effect. All international travelers know well the irritation of being unable to use different electronic devices due to different standardized voltages and plug styles. Non-uniform standards fragment markets and raise transaction and conversion costs undermining market formation and expansion.

It is important to note that standards are not the only means of reducing uncertainty – that is lowering transaction costs. As Williamson (1983) argued, hierarchy – vertical integration within a single enterprise – is a means of facilitating clarity and understanding. Where a single firm conducts all R&D, manufacturers the components and declares its own internal standards by fiat, a formal external standard is not necessary. However, using single firm hierarchy produces suboptimal outcomes compared with using standardization as a means of reducing uncertainty. Hierarchy reduces uncertainty by at a cost to innovation – and usually higher costs to consumers due to less competition.

In Information and communication technology, technology standards are essential for market formation as ICT standards enable devices to communicate. Once multiple devices become compatible, products from multiple vendors can become interchangeable with ease. This even applies where the standard developing body is entirely private. For example, the Universal Serial Bus (USB), developed by a consortium of US computer firms including Intel, IBM, and Microsoft, has become the global standard for interfacing computer peripherals with the main system. The USB standard has eliminated the need for multiple incompatible jacks which had made it difficult to design peripheral products for any and all types of personal computers. Readers may recall the multiple ports necessary for attaching mice, keyboards, speakers, and other devices. USB makes it possible to guarantee compatibility, reduce space requirements, and simplify design. USB has helped alleviate market confusion and increased the market for peripherals. Buyers can confidently purchase hardware from different vendors and be assured of its compatibility.[11] Attesting to the power of the standard, there have been subsequent updates and improvements to the capabilities of USB but no serious challenger has yet emerged – with the possible exception of the much higher speed HDMI standard for

[11] The market success of USB is such that both Apple and PC-brands use it as the basic connection interface.

inter-device media transfers. The technology standard (USB) thus created a competitive global market in computer peripherals, one with greater choice and lower prices for consumers as well as ease of market entry by vendors and producers.

For firms, there is great value in creating a standard. Some firms, such as Microsoft, have invested heavily in technology development and lobbying in standards development organizations in the hope of having their technology established as a standard – and thus creation of a new market (particularly OOXML). Setting the standard can result in technology lock-in. For example, although there are competing software options including free open-source and online tools, Microsoft's Office suite dominates the global market in word processing, spreadsheets, and presentation software. This effective monopoly enhances Microsoft's brand value and makes it difficult for competing technologies to take root in the market.[12] Firms whose technology is incorporated into a technology standard stand to earn massive returns, while those who supported a losing standard might find their R&D investment wasted. An illustration of the power of standards victory and defeat can be seen in the battle between Sony and Toshiba over high-definition optical disc players. The victory of Sony's Blu Ray over Toshiba's High Definition-Digital Video Disc (HD-DVD) was so complete that Toshiba exited the HD market. Facing significant losses, Toshiba licensed its technology at very low rates to Chinese firms in order to cut these losses. Chinese firms went on to use this technology as the basis for the indigenous China Brand High Definition violet laser disc standard. Expert analysis estimates 90% of the technology for the Chinese standard came from HD-DVD (Hsu and Hwang 2008). Firms without contributions to a standard are able to utilize the standard but must pay licensing fees for the right to do so, thus placing

[12] Through the "network effect" in which more users adopting a given technology can exponentially increase that technologies' value due to the number of compatible partners. As such standards such as Microsoft Office become deeply entrenched. Known as "Metcalfe's Law", this method of valuation has been used to explain the value of social networks, computer networks and the Internet.

them at a price disadvantage vis-à-vis the firms which successfully continued technology to the standard.

The Role of Politics in Standards

Technology standards development is neither apolitical nor necessarily technologically rational. Politics, the apportionment of scarce resources by non-market mechanisms, is very much part of the standards development process. As technical standards shape markets, control over the standards development process offers significant competitive advantages. Firms with controlling interests in standards (or major intellectual property contributions to them) earn licensing fees, brand recognition, and a price advantage in competition. Existing research also shows that control over essential core technology in standards grants firms an advantage in controlling the trajectory of technology development in future generations of a standard. This affords potentially long-term sustained competitive advantage. Thus firms and states have a strong incentive to take an active interest in standardization and attempt to control the standardization process or steer discussions and technology development toward a favored set of technologies or firms. Control over essential intellectual property also privileges licensing-heavy business strategies.

Control of technology standards has real sustained market impact, meaning firms and states have a strong incentive to seek control over standards. On the other hand, state involvement in technology standardization can also backfire. In the 1970s and 80s, the Japanese government famously used standards to protect its domestic market. Japanese standards were frequently mandatory and opaque. It was extremely difficult for foreign companies to receive the “JS” stamp certifying them as compliant with Japanese standards. While protection was effective in building a dedicated home market for Japanese firms, in globally oriented industries, it may have had a long-term negative result. Japan’s insistence on using unique technology standards for mobile telephony in the 1990s arguably prevented the emergence of Japanese mobile phone firms as global leaders (Funk 1998; Funk 2002; Kushida 2011).[13] While Japanese technology had been world beating in the 1980s, and many innovations in the 1990s were far ahead of foreign competitors, these were based on technology standards only used in Japan. As a result, Japanese firms were forced to divide their resources between producing for their domestic market and making a separate set of devices for the global market. This helped undermine their long-term competitiveness against firms able to concentrate solely on one standard. Despite the potential risks, states and firms increasingly understand the stakes involved in international technology standardization and take an active role in promoting and protecting their interests.

Since the 1990s, the incentive to shape standards has only grown. Enforcement of adherence international standards is accomplished through the World Trade Organization (WTO). In response to the use of technology standards as a trade barrier in the 1970s and 1980s, the Uruguay Round of the trade negotiations incorporated language regarding technology standards into the Technical Barriers to Trade (TBT) agreement.[14] Under the WTO, the TBT agreement's preamble notes that standards encourage and facilitate trade and that harmonious standards are to be encouraged wherever and whenever possible. The preamble states:

> "Recognizing the important contribution that international standards and conformity assessment systems can make in this regard by improving

[13] Today, it appears Japanese mobile telephony firms (including Sony) are at their nadir of international influence. In the internationally dominant FDD-based 4G Long term Evolution standard for mobile telephony, only one Japanese company – NEC – has any standards essential patents. In contrast, the United States and Korea control 42% and 34%, respectively, of the standards essential patents.

[14] Since standards determine the terms of competition, they can easily be used as a protectionist device. If the terms of the standard restrict the ability of certain firms – whether foreign or just non-incumbents – to license necessary technologies or receive certification as compliant (necessary to reduce uncertainty when a user considers a new vendor), the standard fosters a market with limited participation. This will raise prices within the market but also ensure higher revenues per sale for protected participants. It can also limit adoption and retard technology dissemination and innovation. These negative impacts, however, are not the focus of standards developers or implementers whose primary focus is on creating markets to the benefit of specific interest groups.

> efficiency of production and facilitating the conduct of international trade; Desiring therefore to encourage the development of such international standards and conformity assessment systems" (WTO 1995).

However, the experience with unique and incompatible standards also showed how standards could be used as highly effective barriers to trade. The preamble continues:

> "Desiring however to ensure that technical regulations and standards, including packaging, marking and labelling requirements, and procedures for assessment of conformity with technical regulations and standards do not create unnecessary obstacles to international trade" (WTO 1995).

To prevent the emergence of protectionist standards, the TBT agreement states that where international standards have been established, member states must adopt international standards as their national standards. In effect, the WTO requires member states to join the international market under an existing standard, not to create alternative protected markets using incompatible technologies. According to the 1995 TBT agreement text:

> "Where technical regulations are required and relevant international standards exist or their completion is imminent, members shall use them, or the relevant parts of them, as a basis for their technical regulations" (WTO 1995).

Stated directly, the TBT agreement requires WTO members to use internationally accepted standards. WTO members who adopt non-conforming technology standards may face retaliatory action by offended parties through the WTO's arbitration apparatus. Unique compulsory standards can be used as trade barriers and are banned under TBT rules. Offenders can also be brought into WTO arbitration.

While the TBT agreement makes compliance with international standards enforceable, the WTO arbitration mechanism is rarely used. The arbitration mechanism is universally agreed to be too slow and cumbersome to have meaningful enforcement ability. To date, only a single standards-based case has been brought for arbitration, concerning a European attempt to restrict use of the word “sardines” (WTO 2003). Under this case, the market for sardines was to be limited to fish sourced in the Mediterranean. Control of the supply for the market in sardines would raise the price for the fish in Europe but support the livelihoods of fishermen. The WTO courts agreed with the countries bringing the suit that the standard was deliberately protectionist. Accordingly, the WTO ordered Europe to repeal the standard.

Despite the ineffectiveness of the formal WTO arbitration mechanism, the TBT has created strong norms against exclusionary standards. These norms mean that more often than not, a single standard will emerge worldwide. Actors controlling this standard will have enormous economic and political power. This greatly increases the incentive to use all of the means available to ensure ones technology becomes the global standard. In such a winner-take-all environment, political pressures increase. To return to the sardine example, a standard mandating that sardines were only Mediterranean fish would grant market power to European fishermen and states.

A final aspect of technology standards, and one that differentiates them from standards more generally and contributes to the political wrangling in their development, is the incorporation of proprietary intellectual property. As a technology standard is developed, participating firms and organizations suggest specific approaches and technologies which address the general needs and requirements of the standard. Once written into the protocols of the standard, these technologies become essential. If the technologies are protected by patents, then conforming with the standard means that a firm will infringe upon the existing patent. The patent then becomes a “standards essential patent” (SEP). Contributing firms are expected to make good-faith declarations of relevant patents that relate to proposed standards and to make the patents available for licenses under Fair, Reasonable and Non-Discriminatory (FRAND) terms. This means the firm will not restrict the firms which would like to license their SEP and will make their SEP available at reasonable royalty rates. Control over SEP, however, yields great influence in the market created by a technology standard. When SEPs are protected, licensing becomes a viable business strategy – and one affording a firm the ability to largely control a standard. At the same time, however, standards which mandate free or low-cost licensing privilege product firms at the expense of firms using licensing strategies. This means there is a strong incentive for firms – whether licensors or product firms – to control the IP system of a standard.

With the terms and background of the debate on standardization and technology markets thus defined, the remaining sections of this chapter outline the research methodology used in this research and summaries of the remaining chapters.

Research Methodology

This dissertation uses two methodological approaches. First, it follows the tradition of inductive theory-building (Ragin 1987; Eisenhardt 1989; King, Keohane et al. 1994; Ragin 1994; Yin 1994; Van Evera 1997). This methodological tradition argues that the best way to develop rigorous and empirically sound theories is to first openly examine empirical reality and then through an iterative process going back and forth between theory and the field develop a theory. Rather than first deductively determine a theory and then check if it effectively describes empirical reality, this approach requires theory to grow from observation (Glaser and Strauss 1967).

This research also makes use of the comparative case study approach (King, Keohane et al. 1994; Van Evera 1997). Rather than a purely in-case study of a single well developed and deeply researched instance, the theoretical implications are drawn from systematically examining the similarities and differences between cases. Using multiple cases helps to show which variables are actually significant and thus likely causal. To do so, this dissertation has made use of Mill's method of difference for inductive theory development, also known as Most Similar Systems Design (Mill 1843(2002)). The dependent variable – technology markets – differs between the three cases. I then looked back across a range of variables, noting the areas where the three cases differed, thus showing the likely causal source of this variance.

For data gathering, this dissertation used both field and book research. The China case is based primarily on inductive field research through semi-structured interviews supplemented by primary and secondary source material on Chinese standardization. It follows in the tradition of institutional-industry studies. This research tradition assumes that in order to understand industry practices – such as standardization, researchers must analyze regular patterns of behavior, interactions, competition, and cooperation that constrain and support certain capabilities, as well as the forces that motivate economic actors to behave in particular ways (Zysman 1983; Piore and Sabel 1984; Fligstein 1990; Powell and Dimaggio 1991; Lundvall 1992; Nelson 1993; Zysman 1994; Herrigel 1996; Kenney 2000; Lester and Piore 2004; Breznitz 2005; Berger 2006; Breznitz 2007; Breznitz 2007; Breznitz and Murphree 2011; Breznitz and Zysman 2013). The field research took place over 30 months in China between 2007 and 2012. In total, 307 semi-structured interviews, site visits, and meetings were performed, not counting repeats. The research was conducted across China but primarily in Beijing, Shanghai, the Pearl River Delta region (Shenzhen, Dongguan, Guangzhou, Hong Kong), Xiamen, and Jinan. As the center of China's political system and home of most standards-making bodies, the majority of interviews were held in Beijing. Some interviewees were interviewed multiple times – as many as six – over the course of the field research period which provides a dynamic picture of their changing perspectives regarding the structure, performance, and role of standards in China's technology markets over the period.

Interviewees included all of the actors involved in technology development, commercialization, regulation, and standardization in China. Eighty-one interviewees were from small and medium-sized enterprises. These interviewees were the founders, general managers, and chief technology officers of these firms. Seventy-seven interviewees were government officials representing levels of administration from townships (the rural equivalent of a county in the US administrative system) to central government ministries. Government officials included department heads and vice-heads, middle managers and bureaucrats working in specific functional areas such as technology transfer promotion. Forty-nine academics including university professors, university presidents, and lab directors also participated. Thirty-eight representatives from large-scale and state-owned enterprises also participated in the research. For this project, a large-scale enterprise was any firm employing more than 500 workers. These interviewees included department managers, lab directors, government-relations managers, and technology officers. To gain the foreign perspective on technology development and standardization in China, thirty-four representatives from foreign invested enterprises were also interviewed. Representatives from foreign-invested enterprises similarly included lab directors, department managers, and government-relations managers. Finally, twenty-eight industry and standards development association interviews were conducted. These provided direct insights into the daily operations of standards development and the business of lobbying for and against standards and government regulations in China.

The interviews were “semi-structured” allowing the interviewee to speak freely on topics in which they had greater expertise and interest. Each interview was structured around 8 themes. Unlike an oral survey with specific questions that are asked of each interviewee, the theme-based semi-structured approach allows the researcher to spend more time gaining insights from the areas where the interviewee has the most knowledge. The interviews, which lasted from one to three hours in length, were conducted in

English or Mandarin Chinese according to the participant's comfort level. Roughly 60% of the interviews were conducted in Mandarin.

Interviewees were selected using public records of leading firms and agencies from which lists of interview targets were selected. Interviewees were also selected through contacts made at conferences, industry and trade association meetings. In each interview, the participant was asked to recommend other firms or specific contacts. Thus using a "snowball" approach, a large pool of critical and knowledgeable interviewees was constructed. While this approach may induce "success bias" as interviewees are likely to only recommend others with positive stories or with whom they agree, the large number of interviews as well as triangulation through other primary and secondary source documents mitigates this risk.

The time period during which the field research was conducted was particularly important for the study of standards in China as it reflected the final year of the post-WTO succession boom (the era of 10-14% per year economic growth – by 2011, the Chinese economy was 2.5 times larger than it had been in 2000), the 2008 Financial Crisis, and the ongoing reforms attempting to reorient the Chinese economy away from reliance on commoditized manufactured exports and investment and towards knowledge intensity and value-added goods. Standardization and the development of standards, as will be detailed in the empirical chapter, are policy areas central to the planned and desired reorientation of the Chinese economy. The research was thus able to see the evolution of Chinese standardization practices and their relative impacts on technology markets over time.

The semi-structured interviews were supplemented with data gathered from public resources, conferences, industry associations, archival resources, and secondary literature. Information provided by the interviewees was substantiated wherever possible both by other interviewees and through the available literature. To protect the privacy of interviewees, all citations from interviews will be made as "Author's Interview" or

“Author’s Interviews.” In accordance with the IRB protocols for the research grants which facilitated this research, all interviewees had to be guaranteed anonymity. Further, in the context of field research in China, privacy concerns are often paramount and participation by many interviewees was contingent on preserving their anonymity.

For the European and US cases, data was gathered from primary source documents including policy statements, strategy documents, plans and standard documents supplemented by secondary source material and peer-reviewed literature. These were supplemented with targeted questioning of specific authors and participants to ensure understanding and provide depth and context. Europe and the United States were selected to provide comparison and contrast to the Chinese case. The literature holds Europe as the archetype for state-managed and formal standardization while the US is considered the ideal-type of de facto standardization where companies take the lead and government plays little if any formal role in the technology standardization process. Both perspectives are necessary in order to highlight the relative market impacts of these two approaches. As China uses an awkward combination of state-led and non-state standardization, it is necessary to see the general market outcomes from each approach before considering how the hybrid system shapes markets. Further, the European and US cases provide a clear test for the theory that politicized standardization determines market outcomes since both regions are highly developed capitalist economies.

Plan of the Dissertation

The rest of this dissertation is structured as follows. Chapter two offers an in depth review of the state of the literature on the political economy of technology standards and the role they play in market formation. Chapter three examines the cases of the political economy of standardization in the United States and Europe. Examination of these two cases side by side enables the reader to see two ends of a hypothetical spectrum for how to use standards to influence markets – one where the effort is systematic and strategic and the other where the self-interest of agents is allowed to lead. The two standardization approaches create very different markets for technology, market structures, and distribution of gains. The comparison thus illustrates how standards shape markets.

The fourth chapter examines in depth the political economy of standards in China, developing the overall theory of the role of politics in standards as a market determining force. It emphasizes the different approaches to and types of standardization in creating markets as China attempts to move from being a Statist IP Taker to a Statist IP-Creator/Manufacturer. China presents a special case of a country that is both heavily bound by existing institutions and practices while also being flexible and attempting to incorporate new ones, producing a highly complex standardization system. The final chapter draws conclusions and implications for future research into the evolving role of technology standards as the means for creating and sustaining viable global technology markets.

CHAPTER 2

STANDARDS AS MARKET SHAPING INSTITUTIONS

This chapter looks in depth at technology standards and the social science literature on technology standards. It provides a detailed background on standards and the role they play in market formation. It also illustrates the current understanding of the process of standards development and the various political forces acting on standardization in the hopes of shaping market outcomes. This chapter thus provides the theoretical background context for the empirical chapters which will show the different political influences on technology standards in the US, Europe and China and how these have translated into their national markets for technology. After reading this chapter, the reader will understand technology standards in greater detail and thus be able to see how political influences on standards in different countries translate into market outcomes.

The chapter first offers a historical background on the origins of standards in the pre-modern world and the role they played in pre-industrial markets. This is followed by a detailed definition of technology standards as developed during the industrial revolution and still in force today. The chapter then looks at the purported benefits and potential drawbacks of standardization. These benefits and drawbacks help account for the political importance attached to standards by many countries and firms. This is followed by a theoretical discussion of how standards actually form and the actions that firms or states can take to facilitate the development and shaping of standards. With this background, the chapter then turns to a discussion of the two different types of technology standards: formal and de facto. This section emphasizes that the different development paths for formal and de facto standards privilege different actors and thus create different competitive features in markets. It further shows how certain national institutional arrangements encourage use of one form of standards or another. It then discusses the question of intellectual property in technology standards – a critical concern when examining technology markets and the distribution of gains within those markets. The chapter concludes with a brief discussion of the literature on "successful" standards showing the necessary conditions for standardization to take place. The section shows the potential role for the state in ensuring that standardization succeeds but shows, as will be developed in the empirical cases, that different regions approach this role from differing ideological and institutional perspectives.

This dissertation contributes to the political economy literature on institutions and markets by emphasizing the central role politics plays in standardization and how this shapes market formation. Standardization plays a critical role in facilitating the integration of national economies and promotion of trade. Indeed, as discussed in the first chapter, standards are essential for market formation. For the global organization of production systems, standards enable the fragmentation of production and arms-length relations among thousands of vendors and clients seeking to produce a final functioning good. With standards being so critical to markets and the global economy, standards and standardization is highly political and contentious for the actors involved. As their economic importance has grown, the potential gains from controlling standards have increased, as have the costs for supporting "losing" standards.

The processes by which states develop, adopt, and utilize standards are not the same. These differences are the product of the dual factors of national historical institutions and the positions of agents in the global economy. Divergent standards development processes become the basis of divergence in national markets. Knowing how different markets form and why markets differ has implications for economic policy development and the study of comparative capitalisms. Standards should be a new and vital area of research into market formation and the comparative economic performance of firms and countries.

Historical Origins of Standards: the Importance of Metrology

As noted in chapter one, setting standards was often one of the first tasks of a sovereign state. The standardization efforts in the ancient and pre-industrial world show that there has long been recognition of the importance of standards. The earliest conception of standards comes from the development of metrology – the study, creation and maintenance of units of measure. Declaring and maintaining a common set of standards for measurement has long been a focus of governments. Reliable metrological standards lower transaction costs and so facilitate exchange. Economic agents need reliable knowledge of units of weight, measure and volume in order to determine the value of the goods they seek to purchase. Lack of reliable metrological standards historically inhibited trade, particularly when different regions used different systems of metrology or the same system but with different values for given units (Hoppit 1993).

Governments require uniform measures in order to assess goods for taxation or, in societies where tax was paid in quantities of commodities rather than currency, to receive quantities of goods as tax. If peasants, for example, are required to provide payment in quantities of grain, it is essential that governments clearly stipulate these quantities and provide clear references (or standardized containers) for the collection of that tax. Without standard units, this process would be significantly more complicated. Having diverse weights and measures complicates exchange and leads to disagreements and a breakdown in exchange (Stampa 1949).

Beyond weights and measures, standardization of the purity and composition of metals was also important for controlling currency. In ancient China, the debasement of metals in currency during the Tang and Song dynasties – usually through the gradual decrease in the amount of copper in coins – undermined the value of the currency and led to unproductive economic behavior – such as hoarding of older coins or melting them down (Cohen 2000). Rather than spending money, it was more profitable to hoard and melt down old standard coins to make even greater numbers of new coins. Lack of standardization of the purity of silver in ingots similarly plagued trade in later Ming Dynasty (Hansen 2000).

The importance of standardization has long been linked to the idea of state building and unification. In 221 BC, Emperor Qin Shi Huang unified China and established truly centralized rule and administration. Although mostly remembered for his military prowess and accomplishments in forcibly bringing China into a coherent centralized polity, arguably his greatest accomplishment was not the political unification but rather the economic integration of his empire through imposition of standardized weights, measures, writing, and currency (Cohen 2000; Hansen 2000). Where formerly the area known as China had a wide array of differing systems – each of the seven major states issued its own currency and used its own system of metrology – the Qin unification made long distance exchanges of goods predictable. Unified writing facilitated communications throughout the empire – and among distant merchants speaking radically different dialects.[15] Common standards throughout the empire greatly reduced transaction costs for long-distance trade. Throughout the history of China, maintaining an integrated economy and networks for long-distance internal trade would be major goals of the state. Although written in the terms of modern diplomacy and technology standards, the European Union's standards harmonization project is essentially a continuation of the policies and practices imposed by Emperor Qin. The goal in both places remains the integration of a continental polity under a single set of trade-facilitating standards.

[15] The reader will do well to remember that while there is only one official Chinese language, it is divided into at least seven mutually unintelligible dialects that use a common written form for communication. Even today, speakers of different dialects can communicate in written Chinese as it adheres to a single standard, regardless of spoken dialect.

In more recent history, foundational documents of state creation have paid specific attention to standards as well. In England, the Magna Carta proclaimed a single system of metrology for the whole of England:

> There shall be, through our Realm, one Measure of Wine, and one of Ale, and one Measure of Corn; that is to say, the Quarter of London; and on breadth of dyed cloth, russets and haberjects; that is to say, two yards culne within the lists: And it shall be of weights as it is of measures (1215).

Magna Carta called for unity in weights and measures according to a single centralized standard. Even for regional lords looking out for their parochial interests, enforcing common standards was important. As will be discussed below, however, England struggled to enforce common metrological standards until the 19th century.

In Renaissance Florence, cloth merchants' guilds tightly controlled standards for measurement in their industry. Production and use of yard sticks was closely monitored to ensure fair sale of cloth (Kindleberger 1983). At a time where cheating would be easy and convertibility between non-standard systems of measure exceedingly difficult, having a reliable and honest system of measure greatly facilitated exchange in cloth. To ensure a good reputation for Florentine merchants, the guilds controlled the yard sticks to prevent short sticking and bad reputations. Being known for reliability in sales afforded Florentine merchants a competitive advantage in the cloth trade.

The Spanish Empire would similarly attempt to use common measurement standards as a means of economic integration. Showing the importance of clear metrological standards, in 1524, only three years after the conquest of the Aztecs and assertion of Spanish control over Mexico, Hernando Cortes declared the first metrological ordinance for New Spain. According to Cortes's decree, each town was to maintain a standard set of weights and volume measures sealed with the town stamp. Further, each town was to have a formal sealer of weights and measures whose duties included enforcing standard weights and measures, preventing merchants from selling goods without using approved weights and measures, and certifying the scales and measuring sticks used by merchants (Stampa 1949). As in imperial China, imposition of standard weights and measures was considered a critical part of the state-building process and essential for the operation of the polity and economy. It was also state-building in that stamping out traditional non-Spanish metrological systems would further cement Spanish authority.

Uniform standards yield real benefits, as shown in the case of China, but failure to enforce existing standards can undermine their intended good. Cortes's ordinance was never fully implemented. During three centuries of Spanish rule, the colonial government repeatedly issued decrees and ordinances to unify metrology in New Spain. Insufficient control by the government over local merchants' standards meant the Spanish never succeeded in eliminating the use of unique regional or trade-specific systems of measurement. Unofficial measures such as arms-lengths and hand-widths remained in common use. In 1831, an observer noted that:

> "The same diversity as always persists, not only in the different provinces but also in different paridos or districts of the same province and even, perhaps, within the same town, producing inconveniences, injuries, dissensions, and lawsuits in business" (Stampa 1949, 9).

Adding to the difficulties with metrology in New Spain, the broader Spanish Empire also had differing metrological systems in the Viceroyalty of Peru, the Caribbean colonies and the Philippines. Incompatible systems vastly complicated trade, taxation and integration, certainly perpetuating "inconveniences" to market formation and sustenance.

As the case of metrology in New Spain suggests, despite the promulgation of a single system of weights and measures throughout a region or country, standards require enforcement in order to be effective. Indeed, using common standardized terminology but non-standard bases for measurement such as hollow weights, short yard sticks or non-standard conversions such as five quarts per gallon is arguably worse than having no standard at all. Inconsistent standards increase uncertainty and risk since the agents involved believe they are communicating but are, in effect, using different languages.[16]

To illustrate, different regions and townships with the United Kingdom continued to use diverse and non-standard bases for measurement and conversion up through the mid-19th century (Hoppit 1993). In keeping with the dictates of Magna Carta, the British typically used a common set of terminology for their weights, measures and volumes, but the actual amount measured by these terms varied greatly. In 16th century England, a "bushel" could be 8, 10, 12, 16, or 20 gallons – depending on which town a merchant happened to visit. Such differences would, as noted in New Spain, complicate exchange as each merchant would believe their measure or conversion to be accurate and others' to be either to large or too small. Further, before metrological standards in the 19th century took general effect, the value for a bushel could even vary by commodity: a bushel of oats, wheat or rye could use a different number of gallons within the same marketplace. Commenting on the problems of non-standard and uniform measurements, Sir John Riggs Miller noted in 1790 that:

> "(Bad weights and measures are) detrimental to our Commerce, disgraceful to our policy and injurious to our people…We cannot go…from one parish to another, or from one market town to another, without learning a new language, which no grammar or dictionary will enable us to acquire" (Hoppit 1993, 91).

Such conditions stifled inter-regional trade and made national-scale markets for goods much more difficult. Although by the 18th century royal edicts required each town

[16] The same problem remains today in technology standards. Where there are multiple standards in use, consumers are confused and comparisons between products and the relative advantages become more difficult. For this reason, it is usually ideal for a single standard to emerge to which all agents agree and conform. When this occurs, standards realize their full potential for minimizing uncertainties and transaction costs.

keep a standard set of weights under lock and key, enforcement officers tended to seek out hollow weights or short sticks rather than attempt to eliminate non-standard unit conversion such as the number of ounces in a pound – which ranged at the time from 16 to 36. As late as 1816, the Times of London was compelled to note the imperative of achieving uniform metrological standards:

> "We have observed, that the law, in fixing a standard of weight or measure, creates a language; but to create a language is to create mind. A language that is obscure, that is inconsistent, that is unintelligible, stupefies and confounds, as much as a clear, consistent, systematic mode of developing the ideas enlightens and animates the national intellect" (Hoppit 1993, 91).

Without standard weights and measures, the economy and market remain fragmented; uncertainty increases and transaction costs become prohibitive. In effect, different incompatible standards work like tariffs by imposing opportunity costs on agents seeking to enter into exchange. These higher opportunity costs inhibit the ability for long-range commerce and arms-length economic exchange to take place.

In the 19th century, European states began to unify their domestic systems of measure as part of their centralizing state-building projects. Many adopted the Metric System as their metrological standard – at times imposed by Napoleon's armies. The Metric System was formally developed by French scientists during the 1790s. Development of the Metric System was a government project envisioned as a means of rational metrology that could also help integrate and unify France (LNE 2013). Before this attempted common standardization, France – like the other countries and empires described above – had a highly fragmented metrological system. In 1795 there were at least 700 different units of measure in use across France. The First Republic and First Empire invested significant resources developing standards to knit the country together including standards for language, education and measurement.

One of the earliest non-metrological standards was the Bavarian Reinheitsgebot or beer purity law. This standard mandated that only water, barley and hops could be used in the production of beer. The Reinheitsgebot was intended to regulate competition for resources by restricting brewers to a single grain, thus reducing demand from brewers for the main bread grains wheat and rye. In terms of market, this would prevent beer makers from competing with bakers for the use of wheat and rye grain. It would also clarify for consumers exactly what they were purchasing when a brewer tapped a cask of beer. Use of hops was a safety measure to prevent the use of potentially poisonous plants as preservatives. Adopted in 1516, the Reinheitsgebot is arguably the oldest quality and health standard developed (Geitber Forthcoming). As a health standard, the Reinheitsgebot was legally enforceable. Those found violating the law's precepts by selling beer made with non-standard ingredients could have their stocks seized without compensation. A second market influencing aspect of the standard was that its strict definition of what could be considered beer effectively protected the Bavarian and later German beer industries. Within Germany, imposition of the Purity Law across the empire was a prerequisite demanded by the Bavarian government before it agreed to join the German Empire in 1871. Widespread adoption of the purity law would help protect Bavarian brewers from competition by brewers in other Lander that used non-standard ingredients. In force until struck down by the European Court in 1987, the Reinheitsgebot later obstructed the import of many Belgian, English and American beers as these contained non-standard ingredients. Through two mechanisms – limitation of competition for commodities and barring of non-standard goods – this standard was able to shape markets in Germany.

To sum up this historical examination of standards, metrological and purity standards even in antiquity and through the pre-industrial age served to lower transaction costs and encourage market formation. Without standards, markets are restricted to the narrow ranges in which there is tacit agreement upon metrology. However, with widely accepted standards, goods are mutually compatible and interchangeable. Writ large, this can enable a global-scale market. Historical evidence testifies to the importance of attaining and maintaining unified standards to enable economic exchange.

Technology Standards

The most commonly discussed standards today define the protocols and capabilities of specific technologies in various industries or circumstances. The principles of facilitating market integration, reducing transaction costs, and advancing state interests remain central to modern technology standardization efforts. Indeed, because of their breadth and detail, technology standards can define critical aspects of markets as well. Studying technology standards, which are constantly being developed, allows researchers to study how the politics and process of standardization shapes market outcomes.

Technology standardization at the national and international level began with the development of mechanized international trade, transport and communications in the late 19th century. The initial impetus for establishing common standards was the practical need to bring order to the chaotic and then-unprecedented growth of technology and industry in the late 19th century (Cochrane 1966). To enable efficient transport of goods, for example, railroad gauges had to be standardized. Without standardization of gauge, goods need to be transferred from one set of trains to another in order to continue on a different set of track. In the 19th century, the United States alone had no fewer than six different incompatible standards for railroad gauge, largely because of the dominant influence of state governments (rather than the national government) in alliance with private capital in promoting the development of railroads (Dunlavy 1994). As late as the 1990s, Europe had not yet fully harmonized its track standards and the fact that Russia continues to use a unique narrow railroad gauge remains an obstacle to its international overland trade (Puffert 1992; Murphree and Breznitz 2013).[17] As science-based industrialization proceeded in the late 19th century, new fields such as telecommunications and electricity (both generation and transmission) required codified protocols which were common to both companies and countries (Russel 2009). From these demands arose the quest for uniform and widely accepted technology standards.

Definition of Technology Standards

There are several definitions for standards in current use. The international definition of a standard is established and maintained jointly by the ISO and IEC. Guide 2: 2004, Definition 3.2 defines a standard as:

> "A document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context…(Standards moreover) should be based on the consolidated results of science, technology and experience, and aimed at the promotion of optimum community benefits" (ISO/IEC 2004).

This definition has achieved widespread acceptance by formal national standardization bodies. ANSI adheres to the current ISO/IEC standard (ANSI 2013). The European Parliament and Commission accept the basic premise but add two concepts, continuous application and voluntary compliance. Specifically, EC Directive 98/34/EC defines a standard as: "A technical specification approved by a recognized standardization body for repeated or continuous application, with which compliance is not compulsory" (EC 1998). The Standards Administration of China also adheres to both the ISO/IEC definition and the note concerning the primacy of science, technology and experience for its definition of standards in GB/T 20000.1-2002 (SAC 2002).

[17] At the Sino-Russian border, for example, special facilities have been built to lift train cars off their carriages and place them onto alternate carriages which meet the Chinese or Russian railroad gauge standards. This process adds time and cost to trade between the two countries.

The common theme for definitions of standards is that they include the following:

1. Formal written documentation
2. Use of consensus for drafting, adopting or amending standards[18]
3. Approval by a “recognized body”
4. Science and technology basis
5. Repeated, common and consistent use and application
6. Voluntary compliance

It is important to differentiate standards from laws, regulations and policies. While they may appear similar, standards are distinct. First, although not included in the formal ISO and IEC definitions, the World Trade Organization, ETSI and many other standards development and approval bodies add the requirement that compliance with standards be voluntary. This distinction formally separates standards from regulations and laws as compliance with these is compulsory. It is possible, however, to cite standards in laws and regulations, thus making compliance effectively mandatory even though the standard itself is voluntary. Second, while standards must be based on consensus principles, regulations and laws have no requirement to reach consensus among stakeholders in their development and approval. Third, the definition of standards also differentiates them from government policies. Policies may encourage economic behavior through the provision or withholding of resources. Standards, in contrast, incentivize action through the creation of markets. Adherence to a standard provides access to the market for that standardized good while failure to adhere means an actor must create an alternate market using a different standard. Failure to conform to a standard effectively bars an agent from a market.

[18] While ETSI does not explicitly adhere to consensus and instead uses a modified supermajority for adoption and amendment of standards, consensus is the generally accepted goal of standardization since it affords buy-in by all participants and should yield the best technology, not just the one with the most powerful backer. The United States Technology Transfer and Advancement Act mandates that the National Institute of Standards and Technology (NIST) coordinate activities to encourage the adoption of private-sector created consensus standards rather than unique proprietary standards by different government units.

The voluntary compliance principle enshrined in the WTO Technical Barriers to Trade Agreement arose out of the increasingly widespread use of mandatory unique technology standards as non-tariff barriers to trade in the 1970s and 80s. Mandatory standards, opaque certification methods and secret details of national standards obstructed trade. Where compliance with a standard is mandatory, non-compliant goods may not be sold. If certification of compliance is done through unclear or biased methods – such as mandating goods be certified by an agency located in the target country – then it becomes difficult to export goods. The most famous case of such obstructions was the use of the Japan Standards label on goods. Japanese consumers considered the label to be a mark of quality and avoided goods without the label. Foreign companies would need to send their products to Japan for certification, a process that was slow and was widely held to be biased against foreign products (Kushida 2008). This added costs and difficulty for foreign goods trying to enter the Japanese market. Adding to the difficulties, some countries made the contents of standards secret. Without knowing requirements, it was impossible for foreign firms to make goods compliant, thus effectively barring them from the target market.

These obstacles were created by design as the standards in question were intended to foster closed markets in which only domestic firms could compete. In response to the increasing number of trade distorting standards, the WTO's TBT agreement requires today's standards to be voluntary and not create unnecessary obstructions to international trade. To ensure members' standards do not obstruct trade, WTO members are expected to be highly transparent in their development of standards (WTO 1995). Member states are to make proposed standards available for comment by other WTO members and offer sufficient time for WTO members to review the proposed standards. WTO members must then make good faith efforts to address the comments they receive from foreign parties. The idea is to allow foreign countries to study proposed standards looking for provisions that could add extra costs or difficulties for their goods. Further, the WTO certification of compliance with a standard – whether national or international – should be as easy as possible and ideally based on a principle of mutual recognition where member states acknowledge that certification of compliance made by a certification body in another state is legitimate. Under the mutual recognition principle, states will not include, or withhold, marks or other identifiers to discriminate against foreign manufactured or certified goods.[19] The understanding is that such openness and transparency will mean standards result in markets open to broad participation and competition.

With this discussion in mind, for this dissertation, standards will be defined as: **formal written protocols, developed by consensus or a modified consensus principle in a formal or ad hoc body, that serve as a platform for interoperability, comparability and on which other applications and innovations can be built.** This definition deliberately omits the "voluntary" principle as well as the concept of a "recognized body" as both of these terms are subject to controversy. The selective use of mandatory standards and standards development through different bodies are often strategic moves intended to shape the markets which emerge from standardization. For example, while generally supportive of the ISO and IEC as standards development organizations – and their adherence to voluntary compliance principles, European standards organizations and member states reserve the right for regulations, laws and policies to reference formal European technology standards and thus effectively make compliance mandatory (EC 2012). In China mandatory standards are officially enshrined in the standardization law as a possible type of national standard (NPC 1988).[20] Under Chinese law, mandatory standards have the same effect as law or regulations. Mandatory standards in theory should be restricted to health and safety or environmental standards

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[19] The inclusion of alternative certification marks for goods certified as standards-compliant overseas but not by the domestic certification agency is a contentious issue. Japan was notorious for its refusal to allow the use of the Japan standards mark unless goods were certified as compliant within Japan. This meant goods produced and certified abroad, even if compliant, would appear different to Japanese consumers, thus making it easier to discriminate against foreign goods.

[20] As will be detailed in the China chapter, until the reform of the standards system in the 1980s, standards and regulations were synonymous. All technology standards were mandatory for industry.

but China's standardization system leaves open the possibility of mandating standards defining particular technologies for consumer or commercial products. Setting such standards results in a highly protected market for the products where participating firms, most likely indigenous Chinese ones exclusively, face little competition.

The definition for this thesis also avoids the concept of a "recognized" body because there is intense disagreement over whether certain standardization bodies are "recognized" or not. In some states, only formal organizations with state charters (such as the BSI) – or that are part of the government bureaucracy itself (such as China's SAC) – can make standards. In other states – most notably the United States – ad hoc industry bodies which publish a standard for industry use are equally legitimate and their standards can become national standards with little or no revision. There are also professional associations such as the IEEE which publish many critical industry standards although their status as a "recognized body" is not universal. Although IEEE publishes standards, these standards do not have the legal status as national standards in all countries. In some countries – including Europe and China – IEEE standards still need to be introduced, debated and adopted through the formal standardization system before they become national standards.

Due to the wide array of organizations from which standards may arise, this thesis treats standards born of formal SDOs, professional societies and industry consortia as standards for comparison purposes. Whether a state accepts standards from different bodies as legitimate, and why, will be addressed in the individual empirical chapters. The legitimacy, or not, of different SDOs has a major impact on the way in which standards shape markets. The different developmental paths for standards – statist and non-statist – exert significant influence over the market which emerges. Standards developed by industry consortia can be captured and controlled by incumbent firms which attempt to structure standards to privilege their technologies and preserve their competitive advantage. Formal government sponsored standards can similarly bias market outcomes through requirements on technology contributions or licensing rules.

This thesis mainly addresses a specific sub-category of technology standards known as “compatibility standards”. Compatibility standards are defined protocols that enable different equipment or components to work together in predictable ways, most commonly for use in telecommunications or information technology. Compatibility standards enable communication – that is the ability for devices or people to exchange information. For the modern economy, compatibility standards ensure that different communication networks and technologies will be able to exchange data. For communication technologies in particular, compatibility is critical to market formation as it increases the size of the potential user base. Through the network effect, compatibility also increases the value of that market to users and firms.

Given the economic interests at stake in standardization, potential market size is important. Furthermore, compatibility standards are among the most contentious standards in policy debates as these lie at an uncomfortable crossroads where international trade regulations such as those of the WTO are unclear. The WTO allows for countries to make unique standards where national security interests are at stake but whether this exclusion includes standards for information and network security is a contentious area. For these two reasons – economic heft and vague norms – the empirical chapters of this thesis concentrate mainly on compatibility standards.

The actual process by which technology standards are developed has some variation. When standards are developed by individual firms or small consortia, the standardization process can be as open or closed as the developing members wish.[21] The development process may or may not be formalized into clearly delineated steps. In most

[21] Here “open” and “closed” refer to the degree to which firms are able to freely join and actively participate in standard development.

established standards development organizations (SDO), the standardization process takes several steps and involves at least three levels of administration.

First, a call for a new standard is made in the secretariat or governing organ of the SDO. If members decide by vote to pursue development, the task of administering the development is passed to a relevant technical committee. Technical committees are groups of experts with a specific technological focus. For areas of interdisciplinary interest such as information technology, there are entities such as the Joint Technical Committees between the IEC and ISO. In the ISO, proposals are made directly in one of the 287 permanent technical committees. In the technical committee, the expert representatives divide the work by specific sub-discipline or task. These tasks are passed to working groups. Working groups negotiate and draft the protocols. Proposals are vetted by the working group and compromises reached. Different technologies need to be either harmonized or else certain technologies are removed from consideration – a difficult task as the submitter may have a strong vested interest in seeing their technologies included in a standard. Once a working group has agreed upon its protocols, they are sent back to the technical committee for deliberation and approval.

Once the full draft of the standard has been agreed via consensus, it is published for comment. After the comment period, the technical committee considers the comments and may make amendments to the standard proposal. It is then published a second time for comment. After a third (usually) round of comments and revision, the standard is ready for final submission to the SDO's secretariat for final approval – usually by member vote – and adoption (ISO 2013). The formal standards development process does not vary significantly among formal SDOs in different countries. The official rules for standardization are thus quite similar. However, as will be shown in the empirical chapters, there are other administrative rules and, more importantly, effective institutions in practice which change the dynamics of standardization significantly in different countries.

Standardization and Markets

As mentioned in chapter one, standards are necessary for the formation of markets. This section discusses the mechanisms by which standards shape markets as shown in the existing literature. The reader will see how these mechanisms increase the political importance of standards and the avenues though which political forces may determine market outcomes through standards. Since standards are created through political processes, they offer opportunities for strategic action by states and firms to influence market outcomes. To see how standards shape markets, this section explores the formative role played by standards in decreasing transaction costs and ensuring compatibility among products. It then discusses the way standards shape the structure of markets through influencing the size of the potential market, influencing the type of competition in the market, providing opportunities for collusion, and creating market orphans. Through these mechanisms of standards, the political influences on standards can be turned into market reality.

First, standards shape markets through the reduction of transaction costs (Carlton and Klamer 1983; David and Greenstein 1990). Transaction costs are difficulties and obstacles which complicate or interfere with economic exchange. There are three basic types of transaction costs: search and information costs, bargaining costs and policing costs. Standards can help reduce all three and thus facilitate the formation of markets. For information costs, standards reduce uncertainty. If a good or service conforms to a standard, would-be buyers can know its capabilities and quality ex ante. Standards reduce the need for consumers to investigate firms or goods. For consumers, standardization facilitates information accessibility, making it possible to compare products with confidence. In bargaining costs, standards ease the challenge of finding an agreeable price. It does so by enabling substitutability of goods which forces comparable goods to converge to a common price. Finally, the act of certification of goods or companies as compliant with standards acts as a policing force. Non-compliant firms can be known ex ante (Dahlman 1979).

The second causal impact of standards on market formation is in the ability of standards to ensure compatibility. Compatibility shapes both the supply and demand sides of markets. For supply, Farrell and Saloner (1986) note standardization ensures compatibility and hence interchangeability of complementary products. Rather than allowing dominant firms to sell bundles of products which reduce consumer choice, standardization makes it possible to combine goods from multiple vendors (Braunstein and White 1985). Different component technologies can be sourced from vendors offering the best price, quality or features. Consumers can confidently recombine the products knowing they will work so long as the goods conform to the same standard.

For enterprises and would-be market entrants, this means that a standard opens new avenues and opportunities for investment. A firm does not need to be able to produce every technology or component for a standardized system in order to jump into a new industry. They can specialize in a sub-system or component knowing that it will be compatible with the whole. This changes the competitive dynamics of a market by encouraging more competition through wider participation.

As a simple illustration, the Universal Service Bus standard interface for computer peripherals made it easier for firms to specialize and produce peripherals such as mice, keyboards, headsets, speakers and other devices. These could now be used with computers of any brand. Hitherto, the myriad plug interfaces meant a product would need to include multiple adapters in order to work with different users' incompatible systems. This increased final prices, or decreased profits at a constant price point, or else limited producers to manufacturing for specific computer models, thus locking in a manufacturer to a given brand. With USB, a single plug interface could work with any device. The consumer benefits from ease of use and certainty in purchasing a device while manufacturers are able to specialize in peripherals, knowing their output enjoys a market the size of the complete worldwide installed personal computer user base.

On the demand side of markets, compatibility standards increase the size of the potential and actual user base for a market. Compatibility standards facilitate communication – the ability for devices or people to exchange information. Industries defined by exchange of information exhibit the network effect. The network effect simply means that a good's value increases exponentially as the number of compatible users increases. This is because information sharing goods need other compatible goods with which to share information. The more compatible goods there are the more potential connections and hence greater value. Through standardization, the value of the good to a user increases as others have compatible goods (Farrell and Saloner 1985). A phone network or computer is more valuable when there are more devices with which it can communicate. A phone without compatible devices is useless but each new user increases the number of potential connections and hence value to all other users. As more users become available, the number of potential connections increases. This increases the value of the product. Greater value increases the demand for the product which encourages more adoption in a virtuous circle.

Further, the communication and businesses built upon the sharing of information are often far more valuable than the standardized goods themselves. It is in the interest of agents to adopt technologies which are compatible and useable. For later adopters, standards yield even greater benefits as there is already a substantial user base available which may consume a firms standards-compliant goods or services (Arthur 1985). The value of late adoption is greater because the stock of knowledge of a product and its use is a function of the size of the earlier existing user base. Hence, the marginal value of a product for later adopters is greater. This stock of knowledge is not reduced even if early adopters switch to a different system. Standards can thus be self-sustaining.

Standardization thus increases the size of the user base through both increased demand and increased availability of complementary products (Katz and Shapiro 1985). This applies both for final consumers and for firms operating or selling to networks. Standardization ensures there will be a large potential user base for goods and services compliant with that standard. This reduces market uncertainty and thus incentivizes R&D investment (See also: (Kindleberger 1983; Lecraw 1987; WTO 1995; Albrecht, Dean et al. 2003; Heddergott 2006; Manivannan 2008; Simcoe, Graham et al. 2009).

Standards help set the terms of competition in a market. Research finds that all else being equal, having a standard should be better than not having a standard. Without a standard, each firm offers a unique incompatible approach or technology. When this happens, each proprietary approach effectively creates a small fragmented monopoly. Unless adapter technologies are added, goods from different firms cannot operate together. The market effects of lower prices through greater competition and firm entry described above fail to materialize.

Before a standard is established, firms compete on the unique features of their technology. Firms can also, by virtue of their mutually exclusive systems, force customers to purchase bundled services and products since they have no choice but to stick with a given vendor. Standards turn these forces on their head. Standardization shifts the nature of competition from features and uniqueness to price (Farrell and Saloner 1985; Berg 1988; Berg 1990; Berg and Schummy 1990; Ozsomer and Cavusil 2000; Yoo, Lyytinen et al. 2004). Once a general standard emerges, a single market also emerges. Firms now compete with similar goods targeting similar consumers. The result is intense price competition. To illustrate, consider basic voice telephony. Since the basic product is the same, there is really no advantage for a user to select one firm over another – since calls can be competed to any user with any carrier. Thus, there must be price differentiation in order to win customers. This enhances consumer welfare through lower costs. Even for proprietary technologies, standardization will lower the prices that consumers will have to pay due to the increased number of competitors offering comparable and interchangeable products.

While firms may seek to limit price-based competition, the increased demands for their goods at a lower price point make standardization still beneficial. Even though the profits per unit decline, standardization increases the overall market size which makes standardization attractive even for firms which stand to lose some of their per-unit profitability. Further, under price-based competition, firms able to wield larger economies of scale will be more successful than firms which cannot. This may benefit incumbent firms and thus give an incentive to participate in and actively seek standardization. At the same time, however, since the basic technology is common to all vendors, new entrants can offer niche services or products built around this technology. They do not need to have the resources to develop the whole system but rather can work around its fringes. This also increases consumer choice and competition.

Adopting a common standard also changes competition dynamics throughout a supply chain. Standardization creates cost savings for manufacturers (Farrell and Saloner 1986). Standardization of components or processes facilitates the development and expansion of mass production through building economies of scale by enabling supplying firms to amalgamate customers (Berg 1984). A similar dynamic has been noted in Breznitz's work on the global fragmentation of production (Breznitz 2007). It is standards that make this fragmentation possible. The economies of scale are facilitated both for the production of components and complementary products (Berg 1984; Farrell and Saloner 1985; Katz and Shapiro 1985). Standardization increases the availability of replacement parts and services which reduces some of the risk from building a large production base. Lack of common standards makes it difficult to realize these beneficial economies of scale. Additionally, standardization facilitates the entry of smaller niche market players (Berg 1990; WTO 1995). Standardization enables broader competition and innovation by defining a technology in such a way that all would-be agents are able to participate. Where enterprises set their own standards or have proprietary formats, competition can be stifled as fewer actors are able to develop new goods and services.

In the analog era of mobile telephony, there were no fewer than seven competing mobile telephony standards. This meant there were seven different markets of various sizes for which producers could make compatible goods. A producer of transmission or terminal equipment or receiver chips would be limited to working with a single standard for a given dominant operator (usually a state monopoly). They would be reliant on the incumbent's market – and marketing practices – including whatever prices the incumbent would be willing to pay. It also would increase costs by making it difficult to achieve economies of scale given the relatively limited market size for any given standard. In Japan, for example, manufacturers faced difficulty lowering the price of their equipment as there was little scale. The national telecommunications operator deliberately made mobile telephony prohibitively expensive in order to prevent the development of a large market (Funk 1998; Funk 2002; Funk 2006). On the other hand, in the 2G mobile era, there were only two major standards. Firms could produce for one standard or the other knowing both had global-sized potential markets. The lower costs from such competition helped facilitate global adoption of mobile telephony.

Standardization can shape the competitive dynamics of markets by facilitating anti-competitive collusive behavior as well. When this occurs, the markets formed by standards may fail to yield the lower prices, greater entrepreneurship and higher innovation that standards ostensibly foster. If one takes a highly pessimistic perspective, standards development organizations which permit corporate membership or representation are little more than institutionalized venues for collusion. In standards development, where core technology is shared and debated, the development of a standard is, in effect, the division of a market among stakeholders such that they all can benefit without having to compete with each other. Firms outside the standards development effort are likely to benefit less; firms which do not contribute or fail to have their technologies incorporated see their technology or alternative products excluded from the market without having had the chance to compete for consumer acceptance. Among participants in standardization, the inclusion or rejection of submissions from different parties can appear to be anti-competitive. Standards development organizations can look much like the sorts of backroom anti-competitive behavior that much regulation is designed to prevent. As Adam Smith noted:

> "People of the same trade seldom meet together, even for merriment and diversion, but the conversation ends in a conspiracy against the public, or in some contrivance to raise prices. It is impossible indeed to prevent such meetings, by any law which either could be executed, or would be consistent with liberty and justice. But though the law cannot hinder people of the same trade from sometimes assembling together, it ought to do nothing to facilitate such assemblies; much less to render them necessary" – (Smith, 1776).

The potential for collusion can be seen both in terms of the products which can be developed and sold and the licensing of essential embedded intellectual property. By explicitly defining technology, a standard limits the range of products which can be sold. Firms with experience in these areas will be better placed to compete than others. As the technologies to be developed and sold, or not, are determined through discussions and debate in working groups, this may be considered collusion. The case of standards as avenues for collusion is even clearer for the inclusion of proprietary technologies. Firms which are able to have their proprietary technology included as essential IP benefit from standards more than firms which do not. Competition in the market is determined partly by the inclusion of essential IP. In some standards alliances, firms which contribute large portfolios of IP arrange technology sharing agreements with other large contributing firms. These technology sharing arrangements are facilitated in the context of standardization, often as part of the agreement on terms for including proprietary technology in the standard. These patent sharing agreements give participants royalty-free access to one another's technology. Firms which contribute little or no technology will not be part of these sharing arrangements. These firms must pay for licenses placing them at a competitive disadvantage vis-à-vis firms with royalty-free access through patent sharing agreements. In some cases, firms with large portfolios may be unwilling to license their technology to firms without patent sharing agreements. When this occurs, the standard – which mandates the use of that firm's technology – effectively bars certain firms from participation in the market while granting exclusive access to others. In this way, incumbents can shape the structure of the industry which emerges from standardization to their advantage while limiting the ability of other firms to compete.

Standards may thus pose a very real challenge for encouraging and sustaining competition. With the opportunities for collusion and using standards to limit competition, standards can foster markets which are far from fair and open. Standards development organizations, both private and state sponsored, are the "assemblies" Adam Smith warned about. Their mandate to seek a cooperative solution to technical problems necessitates the reliance on negotiation for setting a standard, but this means the type of market which emerges from the standard is established by non-market or competitive means so SDOs are at pains to avoid appearing to be colluding or anti-competitive (Besen and Johnson 1986). This is particularly challenging when there are participants within the standard development organization with strong interests in a given technology approach that the majority no longer favors. As a standard usually necessitates a single technical solution, the standards development process necessarily eliminates technology options without allowing market forces to determine the fate of a given technology. This appears close to anti-competitive behavior designed to limit consumer choice.

To prevent the coordination efforts in technology standardization from creating anti-competitive and restrictive markets, states must be vigilant in policing standards bodies. As Berg (1990) notes, ensuring that standards do not become a venue for collusion, price fixing and other anti-competitive behavior is a major function of state policy in technology standards. This is a delicate balancing act, however. While guarding the public interest, it is important for standards bodies not to be overly taxed by state supervision. Where anti-trust laws are rigidly enforced, would-be participants in standards development may be discouraged from participating for fear of attracting unwanted regulatory attention. This reticence impedes standardization and, hence, market formation for new technologies (Besen and Johnson 1986).

A second area of concern for market formation through standardization is the risk of sub-optimal technology lock-in and creation of technology orphans. Although the literature argues that standardization is typically better than fragmented markets for incompatible technologies, technology standardization can result in a single market based upon an inferior technology. When this happens, all actors are actually worse off than they would have been had an alternative standard, or no standard, been chosen. Emergence of technologically sub-optimal standards is possible when there is a standard (or set of specifications able to become a standard) that has no originator with proprietary interest or specific sponsor but which through serendipity becomes established. This occurred in the case of the QWERTY standard for keyboards (David 1985; David 1986; David and Greenstein 1990). Although the QWERTY keyboard is ergonomically inferior and yields a slower typing speed than alternatives such as the Dvorak keyboard, it remains the industry standard for all typing devices. This is because the size of the user base is so large that the standard has become effectively “locked in”. Changing the standard will require retraining hundreds of millions of typists, a cost which industry is not willing to bear in the interests of improved typing efficiency. Thus, despite the sub-optimal outcome, the standard remains. Further, with so many typists using the same standard, a manufacturer which produced a non-QWERTY keyboard would have difficulty attracting customers.

Although standardization usually results in market integration which creates a single market for a technology, there is also the possibility in standardization of creation of “technology orphans” (Ozsomer and Cavusil 2000). Orphans are early adopters of one standard that are left isolated when an alternative standard is adopted more broadly and thus enjoys a larger real and potential consumer base and a larger ecosystem of participating firms making compatible goods and services. Technology orphans can emerge when there are multiple competing options for a standard which are different enough to make their integration into a single compatible standard difficult or impossible.

In the pre-standardization phase of an industry or technology era, there are usually multiple technologies or systems from which to choose. At this early stage, it can be difficult to know which standard is more likely to be broadly adopted, especially where the technologies have similar capabilities. Firms or consumers with strong interest in adopting a technology will make early selections. Their choices lock them in to one or the other of the fragmented markets for the different incompatible technologies. Should a single standard emerge, those early adopters who chose the alternate formats will become technology orphans. Orphans are left in an isolated niche market with limited growth potential and usually higher costs. However, due to switching costs, it can be difficult for orphans to get out of their isolation by switching to the alternate standard (Matutes and Regibeau 1987). The innovation, scale, cost, and complementary goods benefits accrue to adopters of the dominant standard but not to the “orphans” in their isolated markets.

Orphans may eventually switch to the dominant standard as happened with the victory of Sony Blu Ray over Toshiba’s HD-DVD. However, firms which must switch face higher costs and are thus at a competitive disadvantage versus firms which developed the winning standard or adopted it from the beginning. Further, any capabilities the firms had developed while using the now orphaned standard may not be transferrable. Governments and firms, thus have an incentive to avoid adopting the “wrong” standard or allowing the “wrong” standard to be developed.

Politically, this means governments have the option of allowing standards to be selected through competition between their markets or to proactively try to pick winners and thus ensure early selection of a single standard without orphans. Successfully picking winners is difficult even for the most sophisticated government sponsors. For choosing a standard, the overall market size for the chosen standard must be initially large enough to get global attention. When this occurs, other countries and firms will be attracted to the protected standard. A protected standard without sufficient market gravity will become an orphan by political choice. Such was the case with many Japanese standards, particularly in telecommunications, throughout the 1980s and 1990s (Kushida 2011).

The potential for becoming or creating technology and market orphans contributes to the problem of "excess inertia." There is likewise the opposite problem where a standard emerges so quickly that suboptimal technologies become dominant. This is a situation of "excess momentum." The next section looks at how standardization takes place and the potential market impacts of different speeds of standardization.

Process of Standardization and Market Impacts: Excess Momentum and Inertia

Economics, business and policy analysts studying technology standards have postulated several circumstances under which standardization is likely, or not, to take place. By standardization, the literature means the selection of one technology solution. The literature emphasizes the importance of information, signaling and market guidance for the emergence of technology standards. A review of the literature finds four conditions under which standardization can be expected to take place:

1. Clear industry demand for standardization
2. Rates of technological change have stabilized, slowed or plateaued
3. Options for standardization are clearly differentiated
4. A strong industry or government actor clearly favors one technology over another

When these four conditions are met, early adopters will cluster around different technologies in separate markets. When one standard achieves a "critical mass" of users, suppliers or third parties, it usually is considered the victor. It has the largest potential consumer market and ecosystem of participating and producing firms. Agents which adopted alternate technologies then switch to the winning standard or become orphans. While the literature agrees that there is a tipping point after which a single market becomes dominant compared with others, there is no clear indication of what level of adoption for a standard amounts to a tipping point. For example, in the early years of the PC industry, the standards war arguably ended in 1984, the year IBM (and clones) achieved 26.4% of the PC market (Ozsomer and Cavusil 2000). At this point, software developers and hardware manufactures began gravitating toward the IBM standard. Alternate standards were abandoned or became niche markets.

The next standard shift will only take place once technology has clearly leapt to a new level. This can be seen in the case of the VHS-Betamax war. Once VHS achieved critical mass, Betamax users were orphaned, restricted to an increasingly limited variety of difficult to access content. The VHS standard was so entrenched from the 1980s that until the advent of inexpensive DVD players, none of the alternative technologies including laser disks and VCDs, managed to build a large market.[22] Only the clear sound and image quality improvements of DVDs managed to change the standard.

In order for standardization of an industry – and creation of a single market to occur, a bandwagon effect must be initiated. To get a bandwagon started, however, certain conditions must be met. As noted above, if there is universal attraction to one technology – or a lack of alternatives – then any actor will adopt the default standard. If, however, there are different options or different levels of interest, information becomes important. Where actors know the interests of others they can easily decide whether to move forward with standardization or not. Since perfect information is only possible in

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[22] There are exceptions. VCDs were widely adopted in Southeast Asia and China where VHS had never established itself since mass markets for consumer electronics in these countries only began developing rapidly in the 1990s. In countries such as the United States where VHS was broadly adopted in the 1980s, alternate technologies did not establish significant challenging markets.

abstract, firms actually must act under uncertain conditions of incomplete information. This can yield excess inertia or excess momentum.

Excess inertia means standardization fails to take place even though all actors would benefit from creation of a single compatible market. Excess inertia can occur where the technologies from which to choose are not clearly differentiated or none of the firms has a particularly strong desire for standardization. Even though all of the firms in an industry would benefit from standardization, none have sufficient interest to take the risk of acting first without certainty that other firms will follow. Here firms fear making an early market choice and becoming orphans if others do not follow their lead.

If there is no clear difference between technologies, it becomes difficult to choose. Unless a firm has a strong interest, usually due to proprietary technology, in one standard over another, it will most likely not act. Since firms fear being orphaned, they may only be willing to adopt a technology if they feel confident that other firms will follow suit and adopt the same standard. This signaling can be accomplished by prompting from a large dominant firm. Large firms may feel they are able to act independently of others – particularly if they have vertically integrated production and marketing capabilities. Their move will bring their allied companies into the new standard. This may be sufficient to start the bandwagon effect and form a standard (Besen and Johnson 1986).

Companies may not always be able to independently overcome the problems of excess inertia. Here, politics can again play a role as government can push firms onto a bandwagon and overcome excess inertia. Governments do so by adopting a standard through a formal standardization process or establishing a binding regulation that in effect mandates the use of one standard or another. For example, although the US government had no official preference for standards in stereo television, the radio spectrum allocated for stereo would only work with one of the competing standards. This provided the clear signaling necessary for the bandwagon effect to take over (Besen and

Johnson 1986). Only one standard was legal and thus firms adopted it. This created a market in stereo-capable televisions as the common standard had been set.

The opposite problem of excess momentum is also possible. This can create market outcomes that are both socially and individually (for firms) suboptimal. If technology is still rapidly developing, early selection of a standard may not be ideal as this could stifle other potentially better avenues for innovation. If a dominant firm pushes for a standard they can start the bandwagon effect and produce a standard even though all actors would have been better off with an alternate standard. Where firms have differing levels of commitment to a technology – or to standardization in general – the strong early adopter can produce excess momentum as even disinterested parties will adopt rather than remain outside the standard. Excess momentum is also likely to yield unequal distributions of benefits as late adopters will have a difficult time establishing their presence in the market once early switchers have established themselves.

Attempting to start a bandwagon for creating a single market to the advantage of one firm versus another can also lead to anti-competitive behaviors. One of the most effective strategies for firms attempting to start a bandwagon is predatory pricing. Predatory pricing is purposefully undercutting alternative technologies even to the point of selling at a loss for a time. By underselling their competition, a firm can build a large enough market to produce critical mass. Once the alternatives have been pushed out of the market, however, the standard-setter – which now controls the market – is free to demand high royalties from other firms or charge high prices to consumers. Although a standard has been set which creates a desirable single market, the outcome is socially sub-optimal as the market has higher costs for all participants and privileges some firms more than others. For firms to achieve this level of dominance, however, takes significant commitment and willingness to take losses. Research has shown that in order to create a monopoly through standards, a firm needs to charge prices that are even lower than would be necessary just to drive out the competition by encouraging competitors to purchase licenses. To preserve a monopoly, alternatives must be completely removed. In order to keep competing firms from developing alternative technologies, a monopolist needs to set their prices even lower. This level of commitment is difficult for firms to sustain unless they have significant resources. As a result, predatory standardization privileges established incumbents or firms with significant and consistent state support over all others.

Categories of Technology Standards

Technology standards can be divided into two general categories: formal (sometimes called de jure) and de facto (also called market). These categories are significant as their different developmental processes privilege different actors and give varying degrees of influence to governments, firms and other non-state actors. It is therefore important to clearly define these categories of standards. In the empirical chapters, we discuss specific standardization efforts in the case study countries and look closely at the political influences on standards of both types.

Formal standards closely follow the general definition of standards as established by the ISO/IEC. Formal standards are those established by recognized standards development bodies. These development bodies use consensus or modified consensus procedures to amend and approve standards and their various protocols. With very few exceptions, compliance with formal standards is voluntary as most formal standards organizations have no independent enforcement powers. In addition to general consensus principles, formal standards bodies have policies governing the inclusion of IPR and the means of settling disputes over IPR inclusion or use. Generally, formal standards bodies utilize the (F)RAND principle (detailed below) for technology inclusion. Formal standards can be further divided into government formal standards and organizational formal standards.

Government formal standards are set by national and regional standards bodies – usually with the sole right to develop or publish such standards in a given polity. At the international level, government formal standards are developed by the ISO, IEC and ITU as these standards development bodies have national representation. Different states appoint their own organizations to represent their interests in the ISO and IEC. These organizations include ANSI (United States), BSI (United Kingdom), DNI (Germany), AFNOR (France), and SAC (China). A state's telecommunications regulatory body or ministry (sometimes foreign affairs ministry) sends delegations to the ITU. These international formal government standards bodies have existed since the 19th century (the ITU was created in 1865). Throughout much of the 20th century formal government standards were considered less important or influential, particularly in major network industries like telecommunications and broadcast media. Until the 1980s, many countries had national state-owned or private monopolies in these industries. A monopoly operator is able to dictate national standards by virtue of whatever technology it chooses to adopt with or without the involvement of formal standards organizations (Berg and Schummy 1990). Vendors must also adopt the same standards in order to sell compatible equipment to the monopoly operator. Formal standards development organizations in ICT began gaining influence and attracting scholarly attention in the 1980s and 90s as regulatory authorities introduced competition in these national markets. Only once regulatory authorities introduced competition in various industries did formal standardization become necessary. Multiple firms would need to be able to interconnect their networks and ensure compatibility of goods. This necessitated coordination. The mission of government formal standards was to accelerate the development and approval of national or regional standards in the absence of firms able to set these standards by default (Berg 1990; Berg and Schummy 1990; Bogod 1990; Rankine 1990). Under newly competitive markets, government formal standards were intended to ensure compatibility and access for users who adopted one company's solution or another. In telecommunications in particular, government mandated standards were essential for ensuring roaming and compatibility among different operators.[23]

Some states only have a single legal body which makes formal standards – usually those which become formal national standards. China only allows standards developed and adopted by the Standards Administration of China (SAC) to be considered as national standards. Industry standards can be developed under the auspices of different industrial ministries, particularly the Ministry of Industry and Information Technology and the State Administration of Radio, Film and Television, but these must still be submitted through SAC before they can be classified as national standards.[24] As will be detailed in the empirical chapter on China, industry standards, although developed by the state, must still go through the SAC apparatus before they can be considered as Chinese submissions for international standards in ISO or IEC. In France, the French Standards Agency (AFNOR) develops and enforces national standards and coordinates the activities of different sector-based standardization bureaus (AFNOR 2013). AFNOR has been historically quite powerful and it continues to promote French interests – and the French approach to standardization – at the European and international level (Crane 1979). At the European level, however, there are three formal recognized government bodies charged with making standards for different types of technologies or industries: CEN, CENELEC and ETSI (Besen 1990; CENELEC 2010; EC 2012). CEN makes general standards; CENELEC makes standards for electronics and information technology, and ETSI sets standards for telecommunications. Under EU law, only CEN, CENELEC or ETSI standards can be referenced for mandatory compliance or government procurement. Even where industry universally accepts a standard from bodies such as IEEE, the

[23] In mobile telephony, for example, it is important that a phone from one carrier be able to work on the infrastructure of another. While this incurs extra charges, it must also be made technologically feasible. This requires a common standard for the transmission, receiving and handset equipment.

[24] The difference between "industry" and "national" standards is not just academic. In China, a national standard applies to all industries. Industry standards are only applicable in the industry for which they were adopted. Further, for China to make submissions to international standards bodies, an industry standard must first be made a national standard.

standard must first be processed and adopted through the formal apparatus before it can be referenced.[25]

Since the 1980s, there has been a general awareness in industry and academia that the government formal standardization system takes longer to develop standards than does the de facto standardization system (Berg and Schummy 1990). International bodies such as the ITU, ISO and IEC are often criticized for their sluggishness in the face of technological change and the pressing need for more rapid development of standards. In Europe and in the ISO, there have been reforms to enable "fast track" procedures for more rapid standardization. However, the need to ensure consensus before standards can be adopted means rapid standards development and approval remains difficult.

Despite this criticism, formal government standards development organizations remain influential normatively as "legitimate" authorities for standardization. ITU, ISO and IEC standards are also clearly mandatory under the terms of the WTO's Technical Barriers to Trade agreement (WTO 1995). To accelerate development of standards in government formal standardization bodies, some formal bodies, notably ETSI, have modified the consensus-based approach. By adopting different voting structures, usually a form of supermajority, it is possible to accelerate the process of standards creation by preventing small blocks of motivated parties from stopping the entire standards development process.

A second type of formal standard is the organizational formal standard. These are standards developed by an established body outside the purview of government or international organizations with national memberships. The most important of such organizations is the IEEE. These bodies are non-profit organizations without state

[25] Reference in law means that legally binding statutes mention a standard or portion of a standard explicitly. For example, a law on information security could mandate the use of goods minimally compliant with a data security standard. In Europe, however, a data security standard must be adopted by CEN or CENELEC before it can be referenced in law. This added layer of bureaucracy has led to recent reform attempts. These have introduced a fast-track procedure for approval of existing and generally accepted standards which were not developed or adopted through Europe's formal standards structure.

sponsorship or membership. These bodies exist to produce standards for the benefit of industrial clarity and development. These groups are "self-organizing" in the sense that companies or experts perceive the need for standards-based technological coordination and form a group within these bodies to achieve that goal. Standards development by these organizations is often faster than that by government formal standards bodies. Organizational formal standards bodies also produce standards for which there is clear demand as the standards efforts are initiated by industry actors in the first place.[26] Industry groups such as the Moving Pictures Expert Group (MPEG) develop standards to advance the interests of member companies.

Although arguably faster and more "market relevant," organizational formal standards are subject to criticism as being beholden to the interests of incumbent firms or established national powers. Emerging economies in particular see these organizations as biased against newcomers in favor of established powers (Author's Interviews; Ernst 2013). Organizational formal standards also have different levels of "legitimacy" by national standardization bodies. In the United States, standards drafted and published by these bodies can be adopted as voluntary national standards. Industry is free to use such standards as it sees fit; these standards can also be easily adopted as national standards with little or no change by ANSI. In contrast, China's national standards law accords no legal standing to organizational formal standards. While industry may adopt and utilize these standards, the standards cannot become legal national or industry standards unless they have gone through the formal adoption process under SAC or an industrial ministry. A similar situation exists in Europe concerning the need for all standards – with the

[26] Trade groups such as USITO and the American Chamber of Commerce frequently criticize China's government formal standardization system for working on standards for which there is little or no demand by industry. The United States government has also been criticized for pushing standards development or adoption without industry support. The FCC in particular has selected standards for nationwide adoption when industry preferred alternative technologies or the pace of technological development meant standardization was "premature" (Besen and Johnson 1986).

recent exception of ICT – to pass through the formal government standardization apparatus (EC 2012).

The two types of formal standards facilitate different levels and types of political influence. Government formal standards bodies, particularly those with developmental tasks in addition to administrative ones, are vehicles for state policy in standardization. Government formal standards bodies allow a state to push for its technological preferences and to shape market outcomes in accordance with their desired vision for a market – whether open or closed or domestic or international in scope. Even if formal standardization is slower than the market alternative, some states favor the formal process as it affords the state the opportunity to participate and direct standardization to realize strategic goals. For a state like China, dealing with the problems of Gerschenkronian backwardness, the state will see a compelling need for standards everywhere and for a strong state role in developing them. In more established economies, the use of strategic standardization is generally more limited.

Organizational formal standards bodies can become vehicles for strategic action by firms. Dominant enterprises can strongly influence the shape of the standard in order to gain competitive advantages in the market which emerges. Smaller firms or late-comers may have greater difficulty advancing their interests in organizational formal bodies. For this reason, many emerging economies – most notably China – often prefer formal government standards bodies where state power can be utilized to offset the relative weakness of individual firms.

The second broad category of standards is de facto (market) standards. De facto standards are defined by the fact that the standard only becomes a “standard” when competing alternative products have been eliminated or reduced to niche market status. De facto standards are not adopted and codified as national or international standards through formal SDOs. These standards emerge through competition between alternatives. De facto standards can be sponsored or unsponsored and can be difficult to change due to network effects. Research has noted that firms frequently seek to establish their products as de facto standards for their industry but actually prefer less standardization – particularly monopoly-producing de facto standardization – at other stages of production in their industry.[27]

Some strains of the literature argue that market standards most commonly result from monopolistic conditions where a single firm has an overwhelming market share and thus can dictate the standards for its industry (Berg and Schummy 1990). As mentioned above, before the wave of deregulation and privatization in telecommunications in the 1980s and 90s, monopoly operators in each country could effectively dictate standards since they were the only consumer for equipment in that market (Funk 2002). In certain industries, monopoly dictate of standards remains possible. Through the early 2000s, Microsoft's Windows operating system had nearly total dominance in computer operating systems. This control over a de facto standard gave Microsoft the ability to set compatibility standards and demands for software development to other vendors.

With the spread of deregulation in the 1980s and 90s, however, scholars at the IEEE and elsewhere began sounding alarms that de facto standardization would become less common and more difficult due to the breaking up of national monopolies and introduction of competition (Berg 1990; Sherif and Sparrel 1992). These scholars argued that without monopoly, de facto standardization would not work since companies would need some degree of coordination and cooperation in order to ensure broad compatibility. This would require organizational or government formal standardization.

The rise of government formal standardization in the 1980s, however, also gave increased impetus for industry consortia to develop standards (Berg 1990). These consortia sought to compensate for the slow pace of standards development through the formal process and more efficiently produce the standards they wanted for their

[27] Formal and de facto standards processes can both feature in companies' strategies. If a firm is unable to establish its goods or technology as a standard on its own, it may seek to control or influence formal standards processes in order to achieve the same result.

industries. However, there remain fears that self-organized industry standards consortia (organizational formal standards bodies) can violate anti-trust laws.[28] If organizational formal standards bodies are banned, standardization is impeded since neither organizational formal nor de facto standardization by a dominant actor is possible. Only government formal standardization processes would remain but these, as noted above, are frequently slow. The result would be a sub-optimal level of standardization, particularly in fast moving industries where market-creating standards are needed in a timely fashion.

There are two subsets of de facto standards: unsponsored and sponsored. Unsponsored standards have no formal promoters or at least none with proprietary interests in the standard. The QWERTY keyboard standard had no formal sponsor or developing organization but succeeded in the market due to an advantageous combination of manufacturers, typing schools and trained human resources. Since QWERTY has become established, despite having no formal codified rule which requires keyboards to use this layout, few firms would consider utilizing an alternative keyboard layout. This holds true even for mobile device keyboards where – for the sake of typing efficiency and ergonomics – a better layout would be more rational. Although the initial technological reason for QWERTY has long been resolved (as was even in the early days of the typewriter), the standard remains since hundreds of millions of users have grown entirely accustomed to typing in this way. To unlearn it in order to use an alternative standard would be prohibitively difficult (David 1985). Although difficult to dislodge, unsponsored standards are also unpredictable in terms of which, or whether a, standard will emerge as dominant.

Sponsored de facto standards are those developed for the purpose of defining a product or technology to facilitate the dissemination, sale, and adoption of the product or technology. Industry consortia for developing sponsored de facto standards include the

[28] Recent statements from the US Justice Department have confirmed these fears. The emerging position at DoJ appears to be that unless industry is willing to abide by fair and open processes in developing standards in consortia, these groups may be deemed anti-competitive and banned.

DVD alliance and Sony's Blu Ray alliance. Unlike industry consortia which create organizational formal standards, these groups are explicitly for-profit. For-profit industry consortia need not adhere to the consensus and openness principles of formal standards. They also devise their own rules for technology sharing or licensing and develop regimes for the maintenance of the standard, upgrading and promotion of the technology. De facto standards established by firms with proprietary interests can also become the basis for anti-trust action if the dominant firm appears to be using standardization to thwart the rise of competitors or alternatives. For-profit consortia can create monopolies without the openness or fairness principles of formal standards. After de facto standards become established, their sponsors may attempt to use this monopoly position to extract "unfair" rents from licensees or consumers, thus opening them to anti-trust concerns (Langlois 1999).

Formal and de facto standards can also be sorted based on the level at which they are adopted and enforced. Formal (government and organizational) standards can be international, regional or national. International standards arise within government formal bodies with national memberships such as the ISO, IEC and ITU. These bodies formally divide standardization work by specializing in long-range communications (ITU), information technology and short-range wireless (IEC) and most other engineering and health standards (ISO). International standards also arise within organizational bodies with international private or corporate memberships such as IEEE or the Organization for the Advancement of Structured Information Standards. The standards produced and adopted at this level are generally obligatory for WTO members to adopt or conform to. There is disagreement, however, over whether the standards developed in non-governmental bodies such as the IEEE are, or should be, legally binding in the same way that government formal bodies such as the ISO are. European member states in particular value the ISO, IEC, and ITU since their national membership basis gives the European Union a strong voice which benefits standards developed in Europe or containing technologies from European companies. Regional standards are mostly an issue within Europe although the adoption of certain standards as national standards (explained below) can create de facto regional standards blocs. In Europe, three bodies: CEN, CENELEC and ETSI define standards for the entire European Union. These standards supersede national ones, and national governments are required to conform with EU-level standards. Finally, national standards are those adopted by the national standards bodies of different states. These include ANSI, BSI, DNA, AFNOR, and SAC. The exact standards development and adoption processes – as well as strategies and ideologies – of these bodies differ. Some such as AFNOR and SAC are government agencies funded by the national budget. Others such as BSI are government granted monopolies for the development and adoption of standards but are not formally part of the government. National standards bodies are usually the representatives to government formal standardization bodies such as the ISO.

There are other levels for standards as well. In China, for example, there are industry standards. Adoption of these standards is determined by the relevant industrial ministry. There can also be regional standards set by provincial governments. Lastly, there are enterprise standards set by individual firms. The iPhone and Android app development interfaces are examples of enterprise standards. There are no formal agreements or consensus principles used to define these standards, yet vendors must comply with the standards in order to develop applications for Apple or Android products. Given the global popularity of smartphones, application developers are effectively obligated to use these standards. Thus, in industries dominated by major companies, it is still possible to independently set enterprise standards to which vendors must adhere.[29]

[29] Alternative app environments such as Windows Mobile and Blackberry remain limited niche markets. App developers seeking rapid market development are forced to develop for the de facto Apple and Android standards.

Comparison of Different Categories of Standardization

All types of standardization influence the markets which emerge. Formal and de facto standardization practices create different types of standards which build markets with differing features and organizations. First, formal standardization approaches are generally more "open." In the case of standardization, "open" refers to the ability of any actor to participate in standardization, make contributions and review and comment on others' contributions. So long as membership in a formal body is not restricted based on nationality, participation is generally quite open. In Europe, for example, formal standardization procedures frequently undergo review in order to increase the ability of consumer groups and other civil society actors (non-academia and corporate) to participate in standardization. This broader participation has several impacts. Broader participation ideally means formal standardization efforts will have larger pools of technology submissions on which to draw and the final standard will be more broadly representative of different interests. Conversely, in sponsored de facto standards, membership in a developing consortium can be closed or restricted based on any number of criteria.[30] Since formal standards have open participation, all else being equal the market which forms should be the largest possible as more firms have already accepted the standard and agreed to participate. De facto consortia may or may not have a large number of participants. This is partly why de facto standards usually must fight to establish themselves as the dominant standard. The relative size of the developing coalition is a major influence over final market performance. In the case of VHS versus Sony Betamax, the more "open" and participatory nature of VHS meant it was able to develop more quickly and assert market dominance.

[30] Some Chinese standards development industry consortia assign different categories of membership based on payment of dues and technology contribution. Members who contribute more technology have more influence over the development of the standard. Naturally, this practice privileges large established enterprises to the detriment of small ones.

The second area of market influence stems from the means by which protocols are approved and technologies incorporated into the standard. In formal standards bodies, incorporation and approval is done through consensus. Final standards protocols are more likely to incorporate divergent ideas because the members of the organization will have to reach consensus in order for the standard to move forward. This means the standard will ideally have a broad base of participants and wide support, thus facilitating early emergence of a successful market. For de facto standards consortia, decisions on technology incorporation or standards approval can be made by methods other than consensus. While standards consortia do have means for vetting and incorporating technology from non-founding members, there is no need for the group to reach full consensus on technologies. That many sponsored de facto standardization bodies do not use consensus is an area of concern for government bodies which wish to reference and utilize standards in regulations and laws.

Third, whether or not a standards development organization needs to reach consensus determines the speed at which standards can be developed, approved and put into effect. Formal standards often take years to develop, even when the technologies are fairly well defined. Reaching consensus is a difficult process, particularly when firms have strong vested interests in one technology. De facto standards consortia are able to develop their standards faster since opposition can be overridden. Strong actors – usually those with large patent portfolios and extensive R&D resources able to be devoted to standardization – are better able to push for their preferences in consortia while weaker actors have little influence. Both of these features contribute to the speed of de facto standardization. According to the literature, standardization always has a "window of opportunity" in which standardization can take place and serve a useful economic function. This means the greater speed of de facto standardization may be beneficial.

Naturally speed will come at the cost not only of consensus or openness but also at the expense of potential rival technologies. In a formal process, all possible technologies should, in theory, be given a fair hearing and equal opportunity. A working group will run simulations and tests to compare the results on a set of constant metrics, thus determining which technology is superior. The superior technology is then expected to be adopted – perhaps incorporating elements from the alternate proposals. In sponsored de facto standards consortia, there are explicit economic interests in the creation of the group. Consortia are sometimes formed by incumbent firms as vehicles for building ecosystems to support and build demand for their technology. Thus there is no mandated need to consider alternative technologies.

Once the basic technologies of a standard have been adopted, standards can be very difficult to change. This lock-in effectively closes the door on alternative areas of research inquiry. Stated directly – standardization determines the path that future research in an industry sector will take. In mobile telephony, for example, selection of one technology such as frequency division multiplexing necessarily prevents adoption of a rival technology such as time division multiplexing. The incentives to have technology become the basis for a standard become even greater when actors consider long-term consequences. Firms which developed the technologies incorporated into a standard have an advantage in understanding that technology and experience working with it. This tacit knowledge affords a long term advantage both in producing standards-compliant products and in conducting research which builds on the standard. Tacit knowledge and experience with the basic technology makes it more likely that a firm will again lead technology contributions in subsequent standards.

Formal standards processes tend to emphasize established technologies over more novel alternatives. This means that a formal process may succeed in producing a standard with broad appeal and acceptance, but the technology adopted may not be the most cutting-edge. Thus the consumer may be hurt by a relative slowing of the pace of technology upgrading. The preference for established technologies may also privilege incumbent and large scale firms which are better able to develop and test new technologies themselves before bringing them to the table for standardization.

Formal standardization, particularly when led by a government, can also create a circumstance where there is a "blind giant." Standardization is most effective when it defines the parameters of a new technology or industry before many of the specific technological details have been sorted out. This means, a technical committee must act without full knowledge of the implications of their decision. Since poor choices have long term consequences, there is a risk that formal processes will either pick technologies that are outdated or else will choose unproven and potentially unsuccessful technologies. Either outcome is unfavorable. De facto standards tend to avoid the risks of the "blind giant" since the technologies have usually been developed to commercial viability before being released as a prospective standard.

Here it is important to note that while the typology of formal and de facto standardization is useful, it is still an abstraction. By necessity, nearly all standards will be developed through a hybrid process. In some cases the hybrid process is clear: a company or industry consortia develops or even completely drafts a standard which is then adopted by a formal standards body through a fast track procedure. The standard, although developed outside the formal system, has become a formal standard. In other cases, standards are developed in and maintained by formal standards bodies but the standard is represented in the market through an incorporated organ whose role is to promote the use of the standard and to collect royalties on behalf of the actors which contributed to its development. Most standards projects involve such hybrid actions.

Furthermore, all standards unless they are legally binding, are ultimately de facto standards in the sense that success (defined as adoption and use) is arbitrated by consumer selection. Whether a given system is technologically superior (Betamax) or more user and producer friendly (HD-DVD) does not necessarily lead to the broadest adoption of a standard. Formal standards must compete for global market share, at times producing a single global monopoly technology or isolating certain countries which adhere to unique standards.[31] Market competition has limits, however, for formal standards. As government controls the licenses to operate businesses, use broadcast spectrum or build on public lands, the state has ultimate authority over many standards. This makes it difficult for market forces alone to select a single global standard. Where international standards bodies also fail to do so, costs are imposed on industry and final consumers.

Essential Patents and Standards

The protocols defined by technology standards today almost universally involve the use of proprietary technologies, usually protected by patents. For a standard, an "essential" patent is one which necessarily will be violated if the standard is to be implemented by a user. In recent years the number of these "essential" patents has grown rapidly. The only way for a standard to not utilize an essential patent would be to completely redesign the protocols. However, some patents are so broad or basic to the technology in question that it is virtually impossible to perform such a workaround. This means technology standards necessarily require obtaining licensing agreements from essential patent holders. This section explains essentiality and then discusses the different terms on which licenses are usually granted.

Essential patents pose a number of potential risks in standardization. If an IP holder refuses to license their technology during the developmental phase, a standard will have to be redeveloped. As mentioned above, some broad or fundamental patents make such workarounds impossible. If a firm refuses to license, a standard can be blocked.

[31] In the battle over color TV standards in the 1960s, two of the competing standards: SECAM and PAL were government formal standards. With international standards bodies unable to adopt a single international standard (as happened at the ITU for 3G mobile), the standards would have to win support from suppliers and broadcasters, thus turning political into market competition. In the case of color TV, three standards – SECAM, PAL, and NTSC – effectively divided the world between them. Being non-compatible, there were costs imposed in sharing broadcast content and producing TV sets and broadcast equipment.

After a standard is developed and published, an essential IP holder may belatedly emerge to assert their patents and claim the essentiality of their IP. This threat, known as patent holdup, can prevent the implementation of a standard. With the sunk costs in developing the standard having already been made, it is even more difficult to change or redesign the standard. The ex post asserting firm thus has significant leverage to demand high royalties or restrictive licensing terms. A third risk of essentiality comes when firms transfer their patents to other companies. Under current law, there is no provision mandating the licensing agreements for standards be upheld when IP is transferred to a new owner. The new IP holder can then engage in ex post holdup even though terms had already been negotiated and agreed for the IP under its previous owner. This latter category has been the cause of lawsuits in recent years as new IP owners – such as Google after purchasing Motorola Mobility patents – change licensing terms which other firms consider very unfavorable.

The vast majority of standards development bodies adhere to the hard IPR protection norms of the industrial West. As in other debates over the cost of intellectual property, supporters of strong IPR argue that without strong protection of IPR, firms would have no incentive to innovate. Since standards are desirable, they must include and compensate for the existing proprietary technologies of firms. These firms thus have a right to expect fair compensation for the use of their technology. In the US, this norm is broadly held and upheld by ANSI and American companies. In Europe, this norm is similarly supported.

However, there have been attempts by government formal standards bodies to limit the range of options for IPR holders in the interest of getting the widest dissemination of technology possible. In China, IPR protection is not directly challenged formally or informally, but the premise that IPR is an end in itself worthy of protection and monetization is challenged. As IP Takers, Chinese firms do not directly benefit from hard IPR norms. Rather, their interests are in the reduction of all input costs, including those for IPR. Arguably, a low price for IPR would earn more money for all – IPR holders and users – than a high price because of the broader potential adoption of an inexpensive technology. More fundamentally, however, Chinese firms see production and sale of actual products as their goal, not the monetization of technology. Thus, to make and keep their products competitive, they need to control costs. Keeping costs for IPR low is a means to this. For standards, this means that Chinese standardization bodies will strongly encourage – or require – members to offer free or extremely low-priced licensing options.

There are four basic types of licenses for essential intellectual property used in standards. Most standards organizations require that participating members make good faith promises to declare any potentially relevant patents. This declaration is to be made early in the development process and be accompanied by a clear statement of a commitment whether or not to license the technology. Promises to license can take three major forms: (Fair) Reasonable and Non-Discriminatory ((F)RAND), RAND-Royalty Free (RAND-RF) and license without commitment to non-discriminatory principles.

RAND commitments are the most common method for declaring intention to have intellectual property incorporated into technology standards.[32] “Reasonable” refers to the licensing fees that the IP holder will demand from firms which produce goods or services compliant with the standard. Firms are not expected to ask for high rates that would negatively influence adoption of the standard or limit the abilities of firms to successfully produce standards-compliant goods or services. “Non-discriminatory” means that IP holders agree that any firm, regardless of ownership, size, industry or nationality has a right to license and use the technology, so long as the reasonable royalty is paid.

While RAND commits the firm to licensing its technology, the specifications of the terms of that commitment are quite vague. The RAND principle is frequently

[32] The acronym is usually RAND in the United States and FRAND in Europe. This dissertation uses the RAND acronym for simplicity and consistency except in the European Union chapter. The FRAND and RAND commitments are the same.

criticized as “reasonableness” of licensing rates is ill-defined, and the means of determining reasonableness vary from one legal jurisdiction to another. Further, there is no clarity about whether RAND commitments are binding when patents are transferred to other companies. A great fear for standards developers is that protocols will include essential patents and then the ownership of those patents is transferred to a firm which refuses to license or demands unreasonable fees for usage. Such ex post patent holdup significantly increases the power of the firm demanding a new licensing agreement since the sunk costs in the standard make it very difficult to change the protocols so they no longer include those patents.

Royalty Free (RF, RAND-RF) licensing guarantees access to essential technologies without raising the costs for would-be adopters of the new standard. Although the use of intellectual property as a potential source of revenue is increasingly considered a valuable strategy for many firms, in some cases firms find that the RF approach is economically rational. For firms hoping to establish a technology standard for which they have a competitive advantage in design or production, offering their solution on an RF basis makes it more likely to be adopted. Arguably, where two competing technology submissions for a protocol are roughly equal in performance, the RF submission is more likely to be accepted. Indeed, the success of Ericsson’s submission for the GSM standard for mobile communications is often attributed to Ericsson’s RF commitment of its intellectual property for the standard. In contrast, the joint German-French proposal for GSM was heavily proprietary (Funk 1998; Funk 2002). To keep licensing costs down, and encourage adoption of GSM, Ericsson’s proposal was adopted. This gave Ericsson an advantage as it had more understanding and experience working with the technology.

Another reason that firms agree to RF licensing is that not all firms see the monetization of intellectual property as part of their business model. For firms centered on the sale of value-added services or the hardware or software of the standard itself, an

RF offering can increase the chance of having their technology incorporated into the standard and keeping the overall licensing rates low. Over time, an initial RF offering can improve the competitive position and financial opportunities for a firm following this business model. For more pure technology firms, however, an RF license would deny an important source of revenue. This makes many, if not most, R&D-intensive firms hesitant to agree to RF licensing agreements. At times, formal standards bodies have attempted to mandate royalty free licensing for any technologies that will be included in their standards. Companies tend to vociferously oppose these efforts. In recent discussions, even Ericsson has argued that any move toward mandatory RF commitments for essential intellectual property would erode a valuable revenue stream (Author's Interview). Firms may thus agree to RF based on their own strategic calculations but resist potential moves to mandating RF licensing.

Finally, some firms in consortia or formal standards bodies are willing to license their intellectual property but refuse to do so on non-discriminatory terms. Such firms choose to license to different actors on a case by case negotiated basis. The IP-holder in this case seeks to maximize their leverage – either for IP sharing arrangements (cross-licensing) or by maximizing their revenue by negotiating different rates with certain actors. This type of discriminatory licensing can also be used to limit competition by restricting the number of firms actually able to produce for the standard. In the case of GSM, Motorola's refusal to offer a non-discriminatory license for its IP shaped the industry structure for the standard by limiting the production of equipment to major firms which were able to negotiate technology sharing agreements with Motorola. Smaller firms which may have been able to use the standard as a platform for development and market entry were unable to participate as Motorola refused to license its GSM patent portfolio to these firms. Strategic use of limited discriminatory licensing can be an important tool for firms seeking to enhance their competitive position or maximize revenues. In their strategies, however, firms must be careful when making restrictive agreements to license as doing so may result in their technology being rejected by a standards development organization in favor of a less restrictive alternative. Where a firm has absolutely essential basic technology patents it will be able to use this strategy.

There are firms which have potentially relevant IPR but refuse to make an ex ante commitment to license on any terms. Ex ante refusals to license are usually followed by formal procedures by technical committees. The committees seek explanations and ask the firm to reconsider. Refusals to license also lead standards development organizations to halt development of the standard until an agreement is reached. Where a firm refuses to license under any terms, the SDO is forced to either abandon development of the standard or return the standard to lower level working groups to redesign the protocols without reliance on the offending technology.

Ex post refusals to license are the greatest fear for many standards development organizations. In some circumstances, an IP-holder may innocently, or deliberately, fail to declare ownership of relevant intellectual property until after a standard has been drafted, approved and implemented. The IP-holder may then choose to assert a given patent and demand high royalties from any adopters of the standard. This process, known as patent holdup, is fairly rare. However, the fear that it will take place – particularly given the increasing presence of so-called "patent trolls" – is a source of concern to many standards development organizations.[33] Some SDOs have responded by attempting to make a promise to license on RAND terms a prerequisite for participation in standards development. Alternately, some organizations obligate members to ex ante agree to license in some form of their own choosing or else their intellectual property defaults to a RAND-RF license after a certain period of time.

While these licensing principles generally respect the rights of IP holders to dispose of their intellectual property as they see fit, there are limits to their freedom of

[33] While not the subject of this dissertation, patent trolls are companies which acquire intellectual property – specifically patents – through direct purchases with the express purpose of asserting those patent rights through lawsuits or demanding high royalties from companies performing established industry activities.

action. In some countries, particularly those with jurisprudence in the English tradition, there is legal precedent that even a legally acquired monopoly – such as through a patent on a key technology – cannot be used to harm the public welfare. Thus, there is a case to be made that governments could charge firms which refuse to license standards-essential technology (or demand "unreasonable" rates) with anti-competitive behavior. Under anti-trust laws, governments could legally force recalcitrant firms to license their technology. This would, in effect, eliminate the risk of ex-post holdup. However, Langlois (1999) argues that using anti-trust laws to force licensing in standardization is not necessary. Using a Schumpeterian perspective, Langlois argues that even patent holdup is a temporary concern. Standards can and will be changed as the gales of creative destruction bring about new solutions to existing problems. Since innovation will eventually make existing proprietary technologies superfluous, state power should not be used to prevent patent holdup. Nonetheless, for governments and standards development organizations, patent holdup remains a real concern – especially in light of the increasing need for timely development of standards. In brief, the threat of patent holdup remains a real concern in standardization, one that different governments and SDOs seek to address.

Defining a "Successful" Standard and the Role of the State

The literature argues there are different pathways to success for a standard but any successful approach must meet several criteria. For this dissertation, as in the literature, a successful standard is one that is broadly adopted by industry for use in goods and services. A standard that passes through the formal development process but fails to be utilized is not a successful standard.

For a standard to succeed there must be broad participation in the development of the standard. Having both equipment manufacturers and operators involved in the development process speeds implementation of a standard since all of the necessary actors agree upon a standard and are able to act in concert. This coordination can be done under state guidance as it frequently is in Europe but it need not necessarily be state-led. Industry consortia, through self-interest can achieve the same results if the consortia's membership is broad enough.

Second, there must be rapid deployment at scale. As noted above, in standards, the key to success is the "network effect" so would-be standards setters need to achieve scale to realize these benefits. Once a certain scale has been reached, there is a tipping point. After this, there is a bandwagon effect where more and more actors pile in, thus locking in the standard. For an SDO, it is thus important to have a major market player throw its weight behind the standard. This can induce others to jump on board as well. Where market forces will not do this, it is possible for the state to try to compensate by mandating a standard, making policies or regulations that effectively require the use of the standard, or using its procurement power to create early demand and scale. Early achievement of large scale in real or potential adopters is essential for ensuring rapid adoption of a standard.

Third, successful standards should have backwards compatibility with earlier technologies. In some cases, a standard that completely wipes out earlier technologies can be successful if it is a standalone technology that does not need to interface with the earlier devices. For example, DVD players could (and did) replace VHS because the value of one device is not diminished by its incompatibility with the earlier technology. For network technologies, however, backwards compatibility is particularly important since the new system needs to be able to connect and work with the old in order for the value of the new system to immediately have enough users to encourage adoption. In the case of telecommunications, backwards compatibility can also be used as a competitive weapon. Europe and Japan's 3G standard, WCDMA, was not backwards compatible with cdmaOne. This meant there was no incentive for non-committed countries to build 2G networks using cdmaOne since it would afford no benefits when moving to WCDMA which was partially backwards compatible with GSM. Compatibility with GSM would encourage adoption of GSM and limit the spread of the competing cdmaOne.

The ability of standards to succeed is also partly determined by the degree of openness in the development process. Open standards are those which permit many firms to join, contribute technology, and shape the final protocols. All else being equal, the protocols of open standards are completed faster than closed ones and also tend to be more successful in building markets. However, open standards are also problematic insomuch as having many firms involved means there are many potential veto players. This makes it difficult to achieve consensus. Closed standards do not face those problems but may have the problem of limited contribution. Unless the sponsoring actor is particularly well-endowed with human and financial resources, having fewer participants means standard development will take longer. Having a smaller development group also means it is harder for the standard to gain broad acceptance fewer firms have a stake in the standard or its success. More closed standards will need to build broad acceptance through extensive advertising or demonstration.

The potential success of any new standard can be very difficult to determine ex ante. In the 1980s, the ISO-developed OSI standard for computer networking appeared to be the standard which would define computer networking. It was open and developed by formal standards bodies with high degrees of legitimacy and international support. However, in the end, Cisco’s 5 layer approach actually won out over the 7 layer OSI proposal. Cisco’s standard, moreover, was based on proprietary technologies, not the open OSI approach. Thus, even though open standards have real advantages, when a closed competing standard creates a market first or has overwhelming technological advantages, the closed standard may be able to win out over an open one.

Given the advantages of standardization, and the difficulty individual firms – or even consortia – may have in establishing a successful standard, government arguably has a real and substantive role to play in standardization. Although, it would stand to reason that technology standards, being highly useful, would have enough intrinsic value for companies to invest in their development, unless it is a monopoly, a single firm is not able to reap all of the benefits from the market for the standardized good. Since standards are a platform, firms which did not contribute can also benefit from the standard and make use of it. These firms produce goods or services for the market and may thus be considered "free-riders" benefiting from the efforts and investments of others. Even with licensing fees, the creator is unable to appropriate all of the returns from developing a standard.

This discussion is not purely economic. Since the decline of national monopolies in industries such as telecommunications, there has been a gradual decline in corporate investment in standardization. In the late 1980s, this trend became very clear: non-corporate actors would have to become more active in developing, or encouraging the development of, standards for emerging technologies. There is an argument that standards, like R&D, are a social good that under pure market competition will be produced at a socially sub-optimal level. Thus there is a need for approaches to standardization which do not entirely rely upon market forces to ensure standards are developed. In brief, there is a case to be made that governments should be active in encouraging standardization.

In the US, faith in the value of the market means the government does not mandate standardization. The dominant US perspective is that where there is truly demand for a standard and technical rationality demands it, individual firms or coalitions/alliances will form to develop and implement the needed standards. This means government efforts will either be unnecessary or else intrusive and likely to create standards where there is no need. In Europe, there is no such general faith in the power of the market. Government's coordinating and guiding role is considered essential for building and sustaining markets. There is also very conscious awareness of the limited size of European states and their domestic markets. European firms which rely solely on their domestic markets will struggle to become globally competitive. Together, however, European states and companies can be globally successful. Thus, there is a need to encourage coordinated efforts to produce pan-European standards. The European Commission, drawing on the statist heritages of its member states, uses non-market coordination mechanisms to get European firms to work together on common strategic goals, arguing that this way they can be more globally competitive. In China, firms are small and fragmented and generally lack the fiscal and human capital resources to carry out technology standardization activities. That firms are small and weak means they will struggle to set standards by themselves as they are unlikely to be able to start the bandwagon effect. Further, the strong tradition of state leadership in the Chinese political economy means that if the state does not lead, firms will hesitate to take independent action. Thus to ensure provision of the public good of technology standards, the government must lead and intervene.

These different national approaches to standardization all attempt to ensure the success of standards and the firms which produce goods and services compliant with them. Each approach allows for political forces and actors to influence the standard in different ways and to different degrees. In the coming chapters, I explore the standardization systems in the US, Europe and China. The chapters each first outline the formal and de facto standards development systems in each country. This framework shows how standards are developed and where different agents are able to influence the standards development process. Case studies of different standards development efforts in each country show how political influence shaped standardization and the market which emerged.

CHAPTER 3

THE GLOBAL STANDARDS: THE UNITED STATES AND EUROPE

As the first regions of the world to industrialize, the United States and Europe were also the first to create modern technology standards. Although their standardization systems emerged during the same period – mostly the second half of the 19^{th} century – the United States and European countries developed very different standardization institutions which continue to influence their technology markets to the present day. The differences in their institutions of standardization and the market influences these create are the subject of this chapter.

The US and European cases reveal that different roles and degrees of influence for the state in standardization result in very different standardization institutions and technology market structures. In Europe, the statist tradition of many countries – notably France but also corporatist Germany and Sweden – has been elevated to the regional level through the organizations of the European Union and its formal standardization institutions. Indeed, examination of the European-level standardization bodies such as ETSI (telecommunications), CEN (general standards), CENELEC (electronics technology standards), and CECC (Electronic Components) reveals strong support for leadership and control over standardization by government bodies. While German economic orthodoxy dominates EU policy making, in standardization, the French system of coordination and formal standards led by experts in the employment of the state holds sway (Crane 1979; Hall 1986; Ziegler 1995; Borraz 2007). State power allows for interests other than pure profit maximization to be expressed in market structured.

The American approach emphasizes leadership by firms and professional associations. US government action in standardization tends be reactive and serves to ratify the standards which industrial alliances or experts groups have already adopted. For the US, standardization accomplished through formal but non-governmental bodies such as the IEEE is legitimate and should be considered equal to formal standards (Berg and Schummy 1990; Dunlavy 1994; Shapiro and Varian 2003; Hart 2005; Russel 2009; ANSI 2010). The result is technology markets which reflect the interests of firms with little influence from the state or other non-state and non-firm actors. Internationally, the United States supports standards created through groups such as IEEE, arguing that their standards are equally valid as international standards as those from the ISO and IEC.

This chapter explores the operations of the American and European standards systems, discussing how their historical origins and structure determines technology market outcomes. The next section details the history of and most powerful actors in standardization, fitting the countries into the statist/non-statist framework proposed by this dissertation. The third section looks into the current position of European and American economies in the fragmented global economy, emphasizing the technology leadership role enjoyed by both. This discussion is followed by two brief case studies of standardization efforts: television standards and mobile telephony. These cases showcase the role of the state and firms in different standardization efforts over time and the types of technology markets which ensued.

Historical Background

Since standardization has traditionally been one of the first tasks of a sovereign state, the United States and European countries have long had formal standardization bodies. As explored in chapter two, these early bodies played a major role in setting the basic terms of trade and facilitating market creation through reduction of transaction costs. Today, bureaus of weights and measures, while still active and important, have been supplanted by formal and informal organizations devoted to creating technology standards. Technology standardization emerged as a result of the specific political economic conditions in the United States and Europe at the time they industrialized, thus creating deep legacies for the role of the state, firms, and professional societies in setting the terms of technology markets.

In the United States, technology standardization efforts began in the mid-19th century (Dunlavy 1994; Shapiro and Varian 2003). Throughout the 19th century, the central government (sometimes referred to as the federal government) was relatively weak. It was only with the rise of Progressivism and later the New Deal in the first half of the 20th century that government power began to intervene forcefully in the economy. While there had long been calls for stronger government action to encourage economic growth – as early as Hamilton's "Report on Manufactures" in 1791 (Hamilton 1791), the central government largely shied away from playing a major economic role. Firms and industry were thus allowed to self-regulate and perform as they wished.

In this climate, the first major technology standardization effort concerned railroad gauge. During the early years of railroad expansion, firms set their own gauge or else the state governments sought to regulate the gauge in their territories. Without central government supervision, a plethora of different standards spread. By 1860, there were seven different gauges in use, only 50% of which adhered to the "standard" gauge of 4 feet, 8.5 inches (Dunlavy 1994). The second most popular gauge was the five foot wide gauge most popular in the South. Inconsistent railroad gauges made transportation inefficient and more costly, but firms were unwilling to take on the costs of rebuilding their rail lines to meet a new standard. Workers employed loading and unloading trains where tracks shifted gauge even rioted against adopting standard gauge in order to protect their jobs.

For the US, railroad standardization took place in the midst of the Civil War. As rail transport was critical to the Northern war effort, Congress mandated use of standard gauge to make logistics more efficient. Southern states voiced no opposition as they had no representation in Congress at the time. Had all of the states been present in Congress, however, their local interests may yet have been able to block imposition of a national standard.

After the brief expansion of central government power during the Civil War, in the period of rapid industrialization which followed, the United States' central government shied away from intervening in the economy. Firms were free to select standards as they saw fit. The growth of networked industries such as electricity transmission, however, meant a means of common technology standardization would be necessary. Strident competition such as between Edison and Westinghouse over Direct versus Alternating current had shown that some form of coordination would be necessary to prevent incompatible systems. In the case of DC vs AC power, the government played no role in the eventual transition entirely to AC, the switch came as adapters made DC-designed plants and grids compatible with AC, thus reducing resistance from DC technology orphans. Industry settled on its own (Shapiro and Varian 2003).

To prevent incompatibilities like those seen in rail and power generation, industry in the United States settled on a series of standardization institutions later termed "industrial legislatures" (Russel 2009). The American system that emerged in the late 19th century (during the electrification and communication phases of the second industrial revolution) is one of:

> "loosely affiliated networks of institutions, featuring government participation but lacking overarching government control, that helped engineers and executives in a wide range of industries reduce inefficiencies and create platforms for further innovation and production." (Russel 2009)

The system emerged from a conscious choice by electrical engineers in the late 19th century to create professional associations for the purpose of debating and adopting standards. At the time, American electrical engineers observed the trends in Europe toward centralized state-led research and standardization bodies which the engineers feared would place responsibility for standardization in the hands of bureaucrats.

In the early 1900s, industrial associations proliferated for civil, mechanical, electrical, chemical and other engineering fields. These bodies faced some of the same challenges with inter-group coordination that are seen today. Different groups issued their own standards for the same or overlapping functional areas. Reforms in the first half of the 20th century gradually integrated the standardization functions of these bodies, with the IEEE becoming the most powerful – as it remains to this day. By the late 1920s, standardization by voluntary institutions made up of individual experts was so well established that it became the main channel through which American standardization took place. Even in the face of greatly enhanced government power and regulation in the economy throughout the 1935-1975, standardization remained the task of these professional societies. With the coming of deregulation, these standards bodies became even more influential as lower regulations opened up more areas of industry to control by non-state actors.

Although standardization by professional organizations had been allowed throughout the 20th century, federal regulators discouraged alliances created to develop and promote standards since these alliances, which consisted primarily of firms, suggested collusion. With deregulation, however, alliances of firms for the purpose of standardization are again permitted. Since the 1980s, there has also been a conscious effort to allow a more "market-based" standardization mechanism to emerge in the United States. The central government has consciously loosened anti-trust regulations to allow private industry actors to meet and collude on standards. This is an important consideration in the US model for standardization. The state consciously allows firms to collude so long as doing so is limited to standardization activities. The results of standardization, whether from the long-standing professional societies or alliances of firms are generally allowed to stand without intervention from the Department of Commerce or the Department of Justice.

Intensifying global competition in high technology industries, particularly from Asia has led to attempts since 2000 to increase the strategic approach to technology standardization in the United States. In 2010, ANSI released the "United States Standards Strategy". However, rather than being a document detailing a step-by-step plan or targeting strategic technologies, the document affirms the benefits of the current US system and poses only that the central government play a better "coordinating" role in standardization, but denying it the power to lead or direct standardization. In one area, however, the government has attempted to assert leadership. NIST has been active in trying to coordinate development of standards for smart electrical grid technologies as part of broader efforts to upgrade and improve the efficiency of America's power infrastructure. However, the lack of a traditional leadership role for the government has made industry disinclined to follow NIST's direction, making coordination difficult (Ernst 2013). The United States standardization system remains robust and skilled at producing technologically sophisticated standards with strong industry buy-in and interest. However, it is very difficult to coordinate actions under state leadership in areas where excess inertia prevents standardization or industry cannot agree upon a common standard. Further, the domination of the US standardization system by professional associations and alliances of firms runs into international difficulty as European and Chinese authorities do not recognize the legitimacy of standards produced in this way, much to the chagrin of US trade officials (Author's Interview).

Technology standardization in Europe developed in a distinctly different political economic climate. In the mid-19th century, continental Europe was rocked by a series of revolts and aborted revolutions and wars of national unification. Throughout this period, the continental countries became increasingly aware of their relative backwardness compared with the industrialized United Kingdom. In order to ensure political independence, the continental countries needed modern – that is industrial – economies. However, these countries faced problems of insufficient financial capital, lack of inter-personal trust, and low levels of human capital. Nationalistic modernizing central states thus opted to use their power to marshal and apportion capital and push through industrialization. This logic, first outlined by Gerschenkron, argues that the more backward the country, the stronger the state role would have to be (Gerschenkron 1962). In extremis, European states turned to despotism to accomplish their industrialization goals (Moore 1966).

Early efforts at centralized standardization of railroads such as occurred in Prussia revealed the efficacy of strong state leadership and direction. In standardization, the same forces toward centralized, government-pushed industrialization would drive the creation of centralized standardization apparatuses. One of the first centralized successes was the Imperial Physikalisch-Technische Reichsanstalt in Germany, a research institution developing metrology and technology standards for German industry established in 1887 (Hentschel and Hentschel 1996). The success of this approach was such that even non-statist economies like the United Kingdom copied the approach of having a single centralized and powerful standardization authority (Russel 2009). In Britain, the initial standardization body – the British Standards Institution (BSI) – was originally a professional engineering society like those created in the United States. Through the early 20th century its authority over different areas of standardization grew, and BSI was granted a royal charter in 1929. In 1942, under the pressure of issuing "War Emergency Standards", BSI became the sole provider of British national standards, thus allowing this formal organization to become the sole basis of standardization efforts (BSI 2014).

In France, the post-World War II government took an active role in promoting high technology research and industrialization, incorporating technology standards as a key component of this overall strategy (Crane 1979). France built its standardization system around a series of formal government-based institutions including the Union

Technique D’elictricite (a centralized body uniting the professional associations and engineering experts in all electrical industry areas – 1907) and AFNOR (French Association for Standardization - 1926) (AFNOR 2013). In the French standardization system, all standards must pass from these formal bodies up to the government Commissioner for Standardization. With the approval of the Comissioner’s office, draft standards are then distributed among the government ministries. After final approval, all government bodies in France are obligated to abide by the standard. Private industry can be compelled to adhere to specific standards such as the “Controlled Designation of Origin” system. This system mandates strict geographic, processing and quality standards for agricultural products and dates back to the 1919 Law for the Protection of the Place of Origin. As will be explored in the case studies, the French government also uses professional associations, lobbying and promises of resources to get all government branches and private industry to agree to a common set of standards.

The French perspective on standardization plays a major role in determining the terms and balance of trade. The French government argued that technology independence was essential for ensuring political independence. This meant that even at the risk of duplicating research and technology development performed elsewhere, France must invest in its own unique and domestically controlled technologies. Under Charles De Gaulle, France embarked on a series of high profile government-sponsored research and high technology industry projects sometimes referred to as “New Cathedrals.” These included development of a computer industry, the Concorde Supersonic Transport, nuclear reactors, tidal power plants, and electronics. Many of these projects were fully funded by the government and remained reliant on state subsidies to stay solvent. Where uniquely French technologies including those which were world-leading such as Minitel and SECAM were developed and standardized, France often created closed protected markets. Even if not internationally popular or accepted, these protected markets ensured French technology could earn revenues and remain independent of foreign influences.

As the European Economic Community increased its integration and traditional approaches to protectionism became untenable, the French government increasingly turned to technology standards as a means of protecting a dedicated market for French firms. Much of the European standardization system is based on a combination of the German emphasis on scientific basis for standards backed by solid research and the French emphasis on formal organizations and centralized leadership, even using protectionism if necessary to ensure a market for domestic goods.

Major Actors

This section introduces the major actors involved in standardization efforts in the United States and Europe. The history of standardization section above began the process of introducing the standardization systems of the United States and Europe. The United States is primarily a non-state standardization system. While the government is understandably always involved in standardization, it does not usually take a leading role. On the occasions when government bodies in the US have attempted to strategically guide standardization, the result – as explored in the case studies below – often backfired. Thus, in the United States, we find that the leading actors in the standardization system are professional associations and private firms. Unlike many countries, the United States does not have a standardization law. Thus the institutions of standardization are those which have emerged out of traditional practice such as professional associations – and government units involved in industry regulation, and hence responsible for selecting standards even if the unit did not develop the standard itself.

For information technology standardization in the United States, the most important government body is the Federal Communications Commission (FCC). The FCC is responsible for administration of the radio spectrum, issuing of licenses to offer broadcast media services, and regulation of telecommunications (among other tasks as assigned in the 1934 Communications Act and the 1996 Telecommunications Act). The

FCC is an independent regulatory body (FCC 2014). Although created by Congress and officially part of the executive branch of the government – with the five leading commissioners appointed by the President and approved by the Senate for five year terms – the FCC is independently funded through its regulatory fees and is thus independent of budgetary constraints from Congress. In standardization, the FCC has the authority to authorize or prohibit use of certain broadcast technologies and to parcel out the radio spectrum for specific tasks (mobile phones, radio, television, military, etc) (Funk and Methe 2001). These two tasks can mandate or prohibit use of one standard or another. The FCC also has the authority to set national goals such as deadlines for the transition from analog broadcast to digital-only television broadcasting. The deadlines for these transitions can force private firms to adopt whatever technology is currently available – even if the FCC itself choses no standard. Historically, the FCC has taken a direct leading role in standardization on only a handful of occasions – in broadcast color television and AM stereo in particular – but has had generally negative responses from industry when it does so (Besen and Johnson 1986; Shapiro and Varian 2003). The FCC thus tends to allow multiple standards to co-exist or alternately sets general guidelines which industry may use any standard they desire to meet.

As dictated by the historical origins of technology standardization in the United States, industry and professional associations in the United States are powerful and important. Groups such as the IEEE, which has individual membership, allow large firms and research groups to push for adoption or inclusion of their technology. Voting systems in these bodies also allow large organizations like firms to wield significant influence over the decision-making process. Since the 1980s, the US Department of Justice and the Federal Trade Commission have increasingly tolerated collusion among firms to set standards (Besen and Johnson 1986). Although firms walk a delicate line between dividing a market and restricting competition and realizing the public good of standardization, the US government generally takes a tolerant perspective, preferring to let “the market” decide issues of standardization, rather than seeking to use state power (Shapiro and Varian 2003).

The Department of Justice, however, has taken a stronger position against collusive activity in standardization by seeking to strengthen and better enforce RAND norms for standards-essential patents in the interest of preventing patent holdup of standardization by firms threatening injunctions (Microsoft 2012; Kuhn, Morton et al. 2013). Nonetheless, American firms have stridently resisted any attempts by the Department of Justice of the Federal Trade Commission to formally regulate or define the nature of RAND even if they generally support the goals of preventing patent holdup (Qualcomm 2012). The power of the state is constrained in the US system such that firms are often able to set standards and intellectual property policies as they see fit, even if this is to the detriment of consumers and other firms (Apple 2012; Microsoft 2012). Given the weaknesses of the state, suggestions for how to normatively limit firms’ ability to control standards and markets through intellectual property are channeled through standards development organizations, rather than being directed at the state (Contreras 2012).

Because of the traditional influence of the state, there is a much wider array of empowered actors involved in standardization in Europe. Owing to the preference for formal standardization and use of deliberative bodies, European standards must pass through multiple formal bodies before being adopted. The three most powerful pan-European standardization bodies are CEN (European Committee for Standardization), CENELEC (European Committee for Electronics Standardization), and ETSI (the European Telecommunications Standards Institute). CEN and CENELEC operate much like the ISO and IEC. Both are based on national membership and develop technology standards for general use (CEN) and electronics and information technology (CENELEC) (CENELEC 2010). According to the European Commission, standards may only be referenced in laws and regulations by member states once the standards have been approved by CEN or CENELEC (EC 1998; EC 2011). With membership based on the different national standards bodies (Like BSI in Britain and AFNOR in France), these bodies adhere to consensus principles. The goal of both CEN and CENELEC is to harmonize all European standards with the interest of promoting intra-European trade and helping firms acquire large economies of scale through increased potential market size.

ETSI is a significantly different body. ETSI was created in 1990 as the institutionalized version of the various committees which had met to create the GSM mobile telephony standard (Besen 1990; Brenton 1990; Bekkers, Duysters et al. 2002; ETSI 2010). ETSI seeks to ensure telecommunication standards are synchronized across Europe. It also coordinates the development of long-range wireless electronic communication and other broadcast technology standards. Voting on proposed standards in ETSI varies depending on the current level of development for a standard. States have the final approval vote for new or amended standards. However, to prevent holdup, ETSI does not use the traditional consensus approach of most formal SDOs. A proposal needs only 71% of the vote in order to be approved. Voting is also weighted by the size of the member country. There are 423 total votes for member states in ETSI, of which the top six members control 170. Since 300 votes are necessary to pass a proposal, the smaller member states cannot pass a standard without at least two of the larger states. Similarly, the larger states need cooperation from the smaller states in order to reach the 300 vote threshold. At lower levels, firms, universities, research institutes, and national telecommunications regulators can be members of ETSI and participate in the expert groups (working groups) creating and debating ETSI standards. As of 2012, there were 255 member manufacturers (33.8% of the total membership). Manufacturers make up the largest block of lower level and working group votes in ETSI, followed distantly by network operators (Deutsche Telekom, Orange Telecom, etc) with 8.3% of the total membership. Large European companies – the national champions of many states – thus wield great influence over ETSI. However, the European standardization system constrains the abilities of these firms to act independently. They must still seek to create standards through the formal apparatus, not independently or in an alliance operating outside the scope of ETSI. ETSI's voting procedures also constrain the ability of firms to act unilaterally without marshalling the support of governments from both the large and small European states. The necessity of forming a broad coalition – though not necessarily a universal one – ensures a broad representation of interests in ETSI standards.

ETSI's approach to intellectual property is largely internally set (Bekkers, Duysters et al. 2002; Bekkers and West 2009; Bekkers and Updegrove 2012). The European Commission never gave clear instructions on what form the IP policies of ETSI should take even though it clearly outlined its overall strategy for integration and harmonization of telecommunications standards. As a result, the IP policies in ETSI standards such as GSM and UTMS reflected a combination of the interests of firms and states. The initial Memorandum of Understanding on GSM attempted to make all essential patents royalty free. Resistance from Motorola, however not only undermined the RF proposal but even the non-discriminatory licensing promise. European firms' interests over time have gradually come to more resemble those of American firms – that IP should be licensed under whatever terms and conditions the IP holder desires. European states, seeking to influence standards through ETSI and other formal bodies, however, still have managed to shape a norm of lower licensing fees and broad dissemination of technology among European firms (Ericsson 2012). Discrimination against technology from outside of Europe is also central to ETSI standards – again as a result of state pressure to protect the European market and technology.

Position in the Global Economy

Both the United States and Europe are justifiably seen as global leaders in high technology industries. Inventors based in the US and Europe account for the vast majority of global patent filings (WIPO 2012). They account for 72% of global R&D spending (measured as a percent of R&D spending among Organization for Economic Cooperation and Development member states) (OECD 2014). Their companies are brand names in high technology, famous for their sophistication in design and quality engineering. Both the United States and Europe are technology producers and aspire to be standard-setters, both through the formal and de facto approaches to standardization.

In the global economy, both the US and Europe are able to produce their own globally competitive and technologically sophisticated products. They also have strong histories of protection for intellectual property and decades of experience filing and monetizing patents. For these reasons, both the US and Europe can arguably be considered global standard setters rather than takers. This means there are multiple avenues of potential profitability available to US and European firms. They can choose to develop and monetize IP as a major or sole source of revenue – as practiced by firms like Qualcomm. Alternately, they can develop IP but use it strategically at nominal fees while concentrating on the production and sale of goods and services embodying or enabled by that technology as practiced by Nokia, Ericsson and Apple. Of course, many firms such as Microsoft and IBM opt for a hybrid of the two approaches. The main point is that because both the US and Europe have advanced positions in the global economy, there are real choices available to firms and governments for strategies that can yield profits, growth, and international power.

For shaping perspectives of government and firms, however, there are some constraints. While multiple mutually acceptable avenues for business exist, European and American government and firms all support strong norms for intellectual property protection. Firms may opt to license on a free or nominal basis but they do not desire to have their ability to choose how and when to license constrained. Governments thus face resistance from firms should the state attempt to make RAND commitments mandatory. That being said, Europe’s strong state and formal standardizations institutions are better able to enforce the RAND norm through the formal policies of their SDOs.

In the US, many firms quietly believe – or even explicitly state – that RAND is toothless and meaningless (Author's Interview). Intellectual Property is the private property of firms and may be disposed of, or not, on whatever terms they see fit. The US state lacks the authority to force firms to comply with RAND norms although the Justice Department is growing increasingly concerned that the RAND norms are being ignored – or at least the possibility of ignoring those norms.

Taken together, the position of the United States and Europe in the global economy mean that their standards will tend to protect intellectual property, meaning licensing of IP is a viable strategy in the market. However, the differences in the relative power of the state in the two cases mean that the ability to bend or shape firms interests to match those of the state differs significantly. The result is that in Europe, firm interests are constrained by the state, meaning the government has the ability to substantively shape technology markets (Winn 2005).

Technology Market Status in the United States and European Union

The technology markets in the United States and European Union share some common features, particularly as regards intellectual property. However, they differ widely in their degrees of openness and the value of scope. Generally speaking, the weaker state in the United States means technology markets look superficially more like neo-classical markets as economic agents set prices and compete according to the logic of the invisible hand. On the other hand, the stronger European state means the mechanisms of market operation – particularly price are more subject to state control. In the United states, firms decide which technologies to adopt, and they shape standardization by their independent economic heft. Technology markets occasionally fail to emerge as a single standard may remain elusive. The result is two incompatible but monopolistic markets, thus resulting in overall lower levels of innovation and certainly lower consumer welfare.

The European market, in contrast is molded by the fact that government has a strong ability to independently control which technologies are permitted. There is an explicit desire to protect and limit penetration of foreign technologies in the domestic market. Exclusionary standards may be created in order to ensure the emergence of closed markets. European firms' IP interests are also frequently tempered by their emphasis on manufacturing and desire to have a single European market and set of standards.

For IP policies, both the United States and Europe adhere to strong norms of IP protection. In the United States, firms are allowed to set IP policies for standards independent of state pressure. While firms may express a general support for RAND norms, American firms usually reject attempts by the state to intervene in technology markets by forcing changes in licensing and pricing for IP. In extremis, the US technology market allows for the emergence of patent non-practicing entities, so-called "Patent Trolls." (Luman and Dodson 2006; McDonough 2006; NPR 2011; NPR 2013). Not all non-practicing entities qualify as "trolls" but in markets which emphasize the monetization of IP, the incentives encourage the development of firms such as so-called "Patent Trolls." On the contrary, while Europe also protects IP and firms are able to monetize IP as a possible supplementary or even primary revenue stream, there are forces mitigating the possibility of "trolls" emerging. The emphasis by European standards on broadly disseminated standards makes it difficult to assert narrow IP interests which can harm the broader standard and would-be adopters. Further, the emphasis by major European firms on manufacturing means they too have an interest in ensuring access to IP so they can produce, buy and sell technology goods with ease. This somewhat constrains the ability to use patents in a "troll-like" manner.

For the openness of technology markets, the United States is generally quite open. The lack of strong state intervention in standardization or technology selection means foreign firms are free to participate in standards development and contribute their technologies to the pool which will be utilized in the United States. At the same time, however, the reliance on firm- or professional organization-led standardization means it is possible to arbitrarily exclude firms from the market. This tends to be a greater problem in firm-led standardization efforts. Professional organizations have broad enough memberships that a variegated assembly of firms is able to participate and ensure access to a technology standard and its market.

In Europe, formal standardization organizations seek to promote open standards across the whole of Europe. Attempts to develop unique or exclusionary standards are generally crushed by European Commission-level bodies and SDOs. Regional-level bodies seek to harmonize standards across Europe, ensuring all member states and firms have equal and non-discriminatory access to standards and thus the ability to participate in standards markets. This openness does not necessarily extend outside of Europe as European standardization bodies have selected exclusionary standards and made standards incompatible with foreign ones in order to protect the European market. Once a standard is formally adopted in Europe, it may also be referenced in laws and regulations, thus making it possible to develop closed national markets using unique technology standards.

For scope, here the United States and European technology market is very similar. In both cases, firms, states, and SDOs alike seek to build global markets. The ideal is to have one's technology adopted internationally. Europe attempts to create the initial scale necessary to tip markets in favor of their technology by building an integrated common market. For the United States, firms attempt to build international markets through their technology sophistication, alliances or competitive strategies. In the European case, however, it remains possible that when a standard fails to achieve international success, it will be relegated to regional or national status, thus creating a regional or national market with limited scope.

Case Studies

Europe and the United States make excellent side by side comparisons as their standardization systems were actively involved in developing alternative technologies for the same standardization classes. In the following examples, we can clearly see how the two standardization systems stand side by side – showing the differences which spring from their respective statist and non-statist institutions. The following examples compare the development of television standards and mobile telephony – showing both the changes which have taken place over the past half century in both regions but also highlighting the degree of continuity in the midst of European integration and deepening economic globalization.

Color Television Standards: NTSC vs SECAM (and PAL)

Color Television was developed long before it became ubiquitous in American and European homes. The earliest experiments revealed color broadcasting was possible as early as the late 1920s and early 1930s (Baird 1929). Before black and white televisions became widely commercially available, color television technology had proven itself at least technologically feasible. In 1949, the FCC first attempted to select a national color television standard for the United States (Besen and Johnson 1986). As detailed below, the United States and European experiences with color television standards varied widely.

Like black and white television, color broadcasting requires the use of radio spectrum to transmit audio and video data which can be received as analog waves, converted back into images and sound and then played through a vacuum tube display. The analog color transmission technology would hold sway until the 1980s when digital broadcasting became increasingly common – and replaced analog entirely in the United States in the 2000s (Hart 2005). Color television standards are differentiated by their number of “lines” in a broadcast image. More lines yield a sharper image. Incompatible line counts mean broadcasters need expensive converter technology not only to send signals which can be accepted but also to convert video content originally filmed using a different standard. The basic technology for color television worldwide throughout this period was essentially the same – a dominant de facto standard created by RCA. Indeed, the alternative technologies developed in France and Germany were based heavily on RCA's existing technology. However, modifications in the number of lines would make their markets wholly separate from the de facto standard established by RCA.

In the United States, the standard for color television broadcasting reveals the limits of the state in attempting to mandate a technology standard. In the case of black and white television, in 1939 RCA-NBC launched a freely available public monochromatic broadcast in New York. The FCC, however, insisted that the station hold off service until a transmission standard for television could be approved. In response, industry actors with prompting from RCA formed the National Television System Committee (NTSC) which developed standards for monochromatic TV in just nine months (Besen and Johnson 1986). With a standard thus developed, NTSC – an industry body – submitted the standard to the FCC. In April 1941, the FCC accepted the NTSC proposal and permitted monochromatic TV broadcasting in the United States on a certain number of spectrum bands.

Like other United States standardization efforts, NTSC was formed from private industry actions. The impetus for the NTSC came from the Radio Manufacturer's Association. However, the standardization body was open to all "technically qualified" industry members, even if their companies were not part of the Association. This was a private industry association, not a state creation. The NTSC had nine panels, 168 committee and panel members and settled on a compromise number of lines (for monochromatic transmission) of 525. This compromise was a balance between the initial 1936 Radio Manufacturers Association recommended 441 lines and Philco engineers who suggested 800 lines. 525 was a compromise between the two, albeit one worked out in the NTSC – without government interference.

With a single standard agreed-to by American industry, the FCC mandated the 525-line 60 cycle monochromatic transmission standard for all television broadcasting in the United States. Smooth adoption of the standards was possible because the 525-line standard had already been clearly tested by Bell Laboratories from 1936 to 1938. Further, there were no substantial competing technologies. This made it easy to ensure adoption and meant the FCC did not have to choose between competing technologies. In such circumstances, the United States standardization system works well. Once the standard was established, a variety of electronics firms were able to produce compliant sets and components for those television sets, thus producing a competitive market wherein prices could fall sufficiently to make television broadly affordable.[34]

In color television, however, the FCC would attempt to assert its authority over the preferences of industry, believing that the smooth adoption experience with monochromatic broadcasts could be repeated once the FCC had set a common standard. In 1949, CBS petitioned the FCC to launch color broadcasts using a "field-sequential system" of 405 lines, 144 fields per second. Unlike the earlier standardization push led by NTSC, there were competing color technologies available. RCA recommended a "dot sequential system" and Color Television, Inc (CTI) recommended a line-sequential system. The three standards were all incompatible and the RCA and CTI proposals were still highly unreliable and experimental. Given the rapidly growing interest in color TV broadcasting, FCC opened panels for inquiry in 1949 but instead of allowing a private industry body to develop the standards, it opted instead to develop the standard under its own auspices.

[34] The pent-up demand for consumer goods meant a spectacular boom in television sales after World War II. With a single common standard, sets from any manufacturer could be guaranteed to work and could be substituted, thus allowing for an efficient competitive price mechanism.

FCC testimony lasted eight months as engineers offered conflicting claims for the CBS, RCA and CTI standards. Their demonstrations often gave erratic performance. Although CTI dropped out because its technology proved unsatisfactory, RCA and CBS dug in. The CBS standard was incompatible with existing monochromatic receivers and would require either an adapter (costing roughly $25 each) or a redesign of all boxes. RCA's standard was compatible with existing TV sets but expensive and complex. The original RCA submission required three separate receivers (Red, Yellow, and Blue) which were then combined by kinescopes to produce the color image.

The FCC wanted to approve a standard quickly before the installed base of monochromatic TVs grew too large and thus would require major retrofitting. The FCC chose the CBS standard as it had been submitted first and was demonstrably better tested and reliable than the RCA standard. Further, the RCA standard produced dot-like and inferior color and was clumsy and bulky for home use. The CBS standard started broadcast (and manufacture) in 1950.

Despite the FCC's initial ruling on the standard, in January 1950, would-be and current television manufacturers rejected the mandate to use the CBS standard. The NTSC convened a color TV standards body of its own accord. The FCC was hostile to NTSC's efforts, seeing NTSC as needlessly repeating the work the FCC had already completed. Indeed, FCC engineers refused to attend NTSC field tests until 1952. Nonetheless, given the lack of backward compatibility for the CBS standard, NTSC's goal was to make a quality and affordable color standard compatible with existing monochromatic receivers. In 1953, NTSC approved its standard and petitioned for FCC approval. As with the earlier monochromatic standard, the NTSC color standard was heavily based on RCA technology, but the technology had been thoroughly reengineered and researched with input from multiple companies. The FCC approved the new standard to replace the CBS standard in 1953.[35] The final NTSC standard was based on 525 lines and 30 images per second. Backwards compatible with existing television sets, consumers who had purchased monochromatic receivers under the 1939 standard could still view color broadcasts – albeit in black and white. The CBS standard, in contrast, came across as static on monochromatic receivers.

With an industry-developed and adopted standard in place, US color television broadcasting began. However, the relative expense of color sets meant the 1950s and 60s primarily saw expansion of monochromatic TV ownership. Nonetheless, as with monochrome TVs, the US system had produced a technology market. Consumers could freely choose among different styles of televisions and multiple vendors, confident that the sets would be able to pick up television broadcasts. The standards themselves contained protected intellectual property, primarily belonging to RCA. The company, however, was willing to license, albeit for a significant fee. This benefited RCA's position in the market and raised the costs of would-be manufacturers in the US and overseas. The standard was open insomuch as the developer – NTSC – was open to professionals able to understand and contribute to the technology. It was also available for license to anyone willing to pay. In terms of scope, however, the market would have to fight for international recognition. The licensing fees RCA levied on manufacturers meant European countries would try to develop alternative standards.

In France, the battle over color television took place a decade later. As predicted by the theory, the statist nature of France made for a different approach to television standards and created a very different market. As noted above, France has a long tradition of strong state involvement in the economy. In the 1950s and 60s, government promotion of indigenous technological capability was considered an area of primary importance and

[35] In the meantime, the CBS standard had struggled to grow its market. While broadcasts were possible, color broadcasts came across as static on black and white receivers. Users perceived this as a problem with the network, damaging CBS's competitiveness. CBS ended color broadcasts early in the 1950s, only to resume them later using the NTSC standard.

vital for national security. To that end, the state sought to control access to the domestic market in order to ensure a captive market for French products and technologies.

Unfortunately, French membership in the European Community meant that tariffs and other traditional protectionist tools were increasingly banned, especially with the coming of the Common Market in 1968. Standards, however, remained a possible avenue for erecting walls around French technology – creating markets with limited scope but reserved for French firms. Adopting a unique technology standard could afford French television set, recording equipment, and content producers a significant amount of protection as foreign products would need to be converted to match French broadcasting standards, thus raising their costs and reducing their competitiveness against French-made compatible products.

In the 1960s, the French government pushed the Compagnie France de Television (CFT) to develop an alternative color television standard which could be internationally marketed to compete with NTSC, or else be used to protect the French market. Since conforming to a standard is necessary for television broadcasts to be sent and received, a unique French standard would effectively protect French products from foreign (especially German and American) competition. CFT was eager to develop a proprietary standard – with state support – and license the technology in order to recoup some of its massive losses sustained during its efforts to create a French computer industry independent of IBM.

In 1956, Henri De France filed the first patent for the SECAM standard (Sequential Color with Memory). SECAM was in some ways superior to the NTSC standard, particularly as regards color fidelity and image resolution. Unlike NTSC, SECAM used 625 lines and 25 images per second. However, even with its government pedigree and technological sophistication, SECAM was not universally accepted even within France. There was resistance from segments of industry and even parts of the central state apparatus. The three main French electronics manufacturers saw no need for haste in selecting a standard since their monochromatic television set market was not yet saturated. Further, French firms were concerned with how best to compete under conditions of European economic integration. Manufacturers wanted to produce for whatever standard would be adopted across Europe. At the time, France utilized a unique monochromatic standard, thus locking French firms into a closed and isolated French market with limited scope. French electronics manufacturers were thus eager to utilize an international standard – thus increasing their potential market size.

French firms also resisted SECAM based on the licensing prices. Although Henri de France's patents made the standard uniquely French, the basic technology remained 95% American, mostly RCA. Manufacturers would be forced to pay licensing fees for both the American and French patents. As would be expected for an IP Creator-Licenser, CFT sought to use its SECAM patent portfolio to provide a steady source of income.

Intense state effort overcame industry resistance. President Charles De Gaulle sent representatives to meet with the French Electronics Industry Association, hosted banquets and appealed to French patriotism. Prosaically, De Gaulle's representatives promised low royalty rates for French firms and guaranteed that companies would be allowed to test the potential SECAM equipment, thus reducing fears about producing low quality or technologically problematic goods.

The French government was also divided over the standard. The Organisation de Radiodiffusion et Television Francaise (ORTF – the French Broadcasting Organization) opposed adopting a unique standard. ORTF did not support SECAM because acquiescing to it would have taken responsibility for broadcast standardization away from ORTF. ORTF found trying to convert programming from NTSC to SECAM or vice-versa to be costly. ORTF's primary interest was in using whichever standard facilitated export of French programming. Despite ORTF's resistance to SECAM, orders from the highest levels of the French government ordered ORTF to support SECAM. Although this increased antagonism between ORTF and politicians, ORTF complied.

Once adopted within France, the SECAM standard was highly successful. Although the NTSC standard was easily adaptable to the 50 field, 625 line system used by French broadcasters, SECAM managed to keep the French television hardware market protected. French TV manufacturers were thus able to build an industry which by the 1970s was generating 0.5% of French GDP.

As an IP Creator-Licenser, however, France was not content to just push SECAM for the domestic market. The goal of CFT, as well as French manufacturers, was to have their standard adopted as widely as possible across Europe. With looming economic integration and falling tariff barriers, French manufacturers stood to gain if they produced competitive goods for compatible foreign technology markets. However, in seeking to maximize royalties from the technology embedded in the standard, CFT refused to license the SECAM patents to Germany – Europe's leading economy – on low-priced or free terms. Germany's AEG Telefunken tried to enter into a royalty-free arrangement for the SECAM patents through CFT as the two firms had historically strong links and had shared both senior staff and technologies – including on a royalty-free basis – in the past. CFT, however, had set their business model on recouping their sunk costs in SECAM through patent licensing fees. Thus, even the fraternal AEG was unable to get a free license. Without the royalty fee, CFT and other patent holders felt they would gain nothing from Germany because German manufacturers could produce better quality electronics than French firms could. Royalty-free licenses would enable the Germans to make inexpensive equipment and thus take sales away from French firms.

Unable to secure low-cost or free licenses for the French or American technologies, Germany developed its own system, PAL (Phase Alternating Line). The standard was based on SECAM (using 625 lines and 25 frames per second) and was partially compatible. With a converter, PAL-compliant TV sets could receive SECAM broadcasts although only in black and white. With PAL available as a European alternative, the French realized that it would be difficult to ensure the broad or pan-

European adoption of SECAM. This meant the government would need to fight to preserve or gain as much market scope as possible.

By 1966, there was intense global competition between NTSC, PAL and SECAM. The predecessor of the ITU Radiocommunication Sector division, CCIR (Comité consultatif international pour la radio), convened a conference to debate an international color television standard. Unfortunately, the US, French and German proposals all offered similar quality and cost, thus leaving little justification for choosing one standard over others. In the end, voting split three ways between backers of each standard, with none gaining clear support. As a result, CCIR refused to formally adopt any standard, preferring to allow multiple standards to co-exist. As a result, the world divided into three blocs: NTSC, SECAM and PAL. Each standard enjoyed a monopoly in its respective region although there were multiple providers for each standard.

In order to increase the scope for SECAM, the French government took the standard and its affiliated technologies to the Soviet Union. In exchange for promises of Russian support – along with its satellites – in CCIR, the French offered to license SECAM to the Soviet Union on a royalty free basis. The French and Soviets also promised to work jointly on further research, to expand economic and scientific ties and to provide assistance developing production systems for SECAM-compatible equipment. The agreement with the Soviet Union was useful in building the prestige of SECAM. Soviet support helped SECAM build market scope in emerging non-aligned countries in the Middle East. The countries of French West Africa also adopted SECAM. This region, in addition to Metropolitan France and the Eastern Bloc became the full market for SECAM.

The effort to develop SECAM could broadly be considered a success. French producers had captive markets at home and abroad for both TVs and equipment and programming. The industry did earn significant revenues. However, the German PAL system was adopted as the standard throughout Western Europe. The European market would have been far more lucrative for French companies, but the inability to reach an agreement with Germany weakened the French position in Europe.

SECAM resulted in a somewhat confused market. French manufacturers and broadcasters in third-world countries had to pay license fees to CFT. However, the Soviet Union received RF licenses as part of the Franco-Soviet Accord. Thus, the French manufacturers did not receive licensing benefits from the Soviet market. Arguably SECAM was not an open standard or market either. Development had been restricted to French firms and licensing was done on a highly selective and discriminatory basis. The interest of protecting French technology and firms had trumped even the interests of French firms in having an open and integrated market. State power had managed to suppress the interests of firms in order to create the desired protected market. Finally, in terms of scope, while SECAM was able to expand internationally, the standard was less widely – or lucratively – accepted and used than NTSC or PAL. French state power had managed to create a new market, but did not succeed in making it international; hence it chose to protect whatever scope it was able to secure.

Mobile Telephony: From 1G to 3G in the United States and Europe

As economic globalization has deepened, the standardization procedures – and hence technology market formation – in the United States and Europe remain remarkably stable. The United States remains a non-statist IP Creator with strong firms taking the main role in guiding standardization and selecting the de facto standards for the United States. On the other hand, the European case shows that much of the French system as increasingly been expanded to the regional level through various European Union-level standardization bodies – most notably for ICT in the form of ETSI.

Since the introduction of commercial mobile telephony in 1979, there have been four "generations" of technologies governed by different incompatible standards.[36] The generation shift has been defined first by the fundamental shift in technology from analog transmission to digital (1G to 2G), and then two shifts toward ever increasing data capabilities (3G and 4G). The first generation of mobile telephony has its origins in the early car phones designed by Ericsson and research institutes in the Soviet Union in the 1950s and 60s. The first commercial "cellular" technology, however, was developed in the 1970s using analog signals and based on hexagonal "cells" where a moving phone's signal would be connected to one tower and passed to a second as the phone moved from one hexagon into another. The automated handoff of signal made truly mobile telephony possible. This feat, however, could be accomplished in multiple ways, thus allowing for multiple incompatible standards in the first generation of mobile telephony.

The second generation of mobile telephony (2G) saw the exponential growth of mobile telephony use worldwide with markets expanding from single countries to regions and finally encompassing the entire globe. 2G was characterized by a shift from analog to digital signals and a move from frequency division multiplexing toward more efficient code division and time division multiplexing. In the third and fourth generations, standards moved toward reliance on code-division multiplexing and then once again to frequency division (in 4G). These evolutionary standards generations were characterized by significant increases in phone data transmission rates. With an installed global user base and increasing desire for data rich phone connectivity, 3G and 4G standards were designed for international adoption and global scope.

A major challenge for standards developers in moving from one generation to the next was how to ensure backwards and forwards network compatibility. When a system

[36] "Incompatible" here means that equipment or handsets designed to work with one standard cannot work without conversion technology with equipment conforming to a different standard. However, mobile phones are still "compatible" in the sense that calls from phones on one standard can be competed to calls on other standards.

of base stations is upgraded, users still need to be able to connect their existing phones to the upgraded network. Similarly, users with more advanced phones need to be able to still use basic or even advanced functionalities (with appropriate reductions in speed) when connected to base stations of earlier technology generations. Backwards compatibility would become a major area of competition in American and European standards as developing technologies which were not backwards compatible could limit market scope.

European states began developing a series of incompatible analog mobile telephony services in the early 1980s. France, Germany, Scandinavia (mostly Sweden and Finland), and Italy all launched development efforts which resulted in multiple incompatible standards (Funk 1998; Funk and Methe 2001; Funk 2002; Funk 2006). None of the standards had significant technological advantages over the others but their adoption as the standard of choice in different national markets created closed national-scope monopolies. Mobile phones in France could only be operated on the France Telecom network using the RC2000 standard, just as phones in Germany would have to operate on the C-Netz standard. Crossing the border between the two countries would require purchase of a new phone in order to make phone calls as the incompatible technologies could not send or receive signals on the other national network. French phone manufacturers and their analogs in Germany, Sweden, and Italy enjoyed captive markets for their products. With no clear technological advantage, it was difficult, for the standards bearers in these countries to convince other countries to adopt their technology. France and Germany briefly attempted development of a common analog standard in the early 1980s but simultaneously worked to develop their unique proprietary standards. With the promises of greater – and guaranteed – returns from the unique standard, cooperation broke down. Countries without their own standards preferred to adopt the standard with the largest installed base, and thus the greatest availability of products, usually at the lowest price. In the first generation of mobile telephony, this fell to the United States.

In the mid-1970s, AT&T began testing analog mobile radio-based phones using a standard called AMPS (Advanced Mobile Phone System). At the time, no other US firms had developed or proposed an alternative standard. Being first to market AT&T applied for permission from the FCC to launch an AMPS test network in 1975, which was granted to Illinois Bell in 1977 (King and West 2002). With only one technology available, and the compete domination of the US telephony market by AT&T – and its later divested children in the Regional Bell Operating Companies – the FCC chose the existing industry standard. The United States thus became the world's largest single market for mobile telephony.

Foreign telecommunications regulators took notice of the American standard and pushed for adoption. AMPS became the official standard for mobile telephony in Australia, Korea, and elsewhere – quickly becoming the first de facto global standard for mobile telephony. This accords with the position of the United States in the model proposed by this dissertation. The standard was created by industry, developed and implemented and only after the fact approved by the FCC. The state had little role in the development of the standard and simply acknowledged what industry had already chosen. The standard was also intended to have as broad of scope as possible. Through the licensing of Bell Labs, it was possible to expand the number of countries using the standard. However, the standard itself was largely closed, being the product of AT&T research in collaboration with a few other closely related firms – notably Motorola – which conducted research in miniaturizing handsets to make them truly portable.

Although the United States was able to create the first international market for mobile telephony, AT&T would not be able to repeat its success in the second generation of mobile telephony. The 1983 breakup of AT&T into the Regional Bell Operating Companies and divestiture of all firms from mobile telephony weakened the incentive to continue research as well as fragmenting research proposals. The Regional Bell's made excellent profits from their existing landline business and long-distance telephony and did not aggressively pursue or invest in mobile.

At the same time, the FCC deepened its hands-off approach to standardization. As multiple 2G standards became available in the early 1990s (D-AMPS, GSM, cdmaOne), the FCC refused to endorse any particular technology – whether American or foreign. The FCC announced in 1988 that firms would not need regulatory approval in order to introduce new technologies. Firms would thus be responsible for developing and implementing standards in the United States. The market leaders: Motorola and Qualcomm, however, were working on two different approaches – Motorola with GSM and Qualcomm with cdmaOne.

Qualcomm, an R&D-intensive firm, was established in 1985 and conducted research on code division multiplexing for wireless communications. Although Qualcomm designed and produced its own base stations and phones in the early 1990s, these were unreliable. The firm has since exited the product business in general (selling its base station division to Ericsson and handset division to Kyocera). Instead, Qualcomm focusses on the development and licensing of core technologies. Qualcomm's CDMA technology was superior in many aspects to the GSM standard as CDMA made more efficient use of spectrum than the Time Division Multiplexing-based GSM system. However, unlike GSM which could count on political support to coordinate multiple firms to working on a single technology, Qualcomm had to form its own alliances and seek interested manufacturers as well as commercial developers able to carry on the task of turning core technology into usable products. Qualcomm's model is thus based entirely on the licensing of its technologies.

Qualcomm and Motorola devices were incompatible and unable to operate on networks using the other's standard. With the US market thus broken into two monopolies, American standards and technology struggled to gain the attention of foreign markets in order to expand American-based standards worldwide.

Given the massive capital costs in creating mobile telephone networks, firms were hesitant to adopt any standard which was not certain to gain long-term global market acceptance. Without state support, foreign buyers doubted the long term viability of US standards. Market shares for both were thus very low compared with the European standard, GSM.

Here the legacy of America as a non-statist IP Creator shows a possible, if negative, market outcome. As the state lacks sufficient power to strongly coerce industry into cooperating or selecting a given technology, where firms have strong but divergent interests, a common standard will fail to emerge. The result is a fragmented market with a narrower scope.

The fragmented and protected national markets for mobile telephony in the 1980s had heavily constrained the technology markets for mobile telephony in Europe. In response to the fragmentation and weakness, the European Community began pushing for an integrated approach to the next generation in mobile telephony. In 1982, the telecommunications operators of Europe signed a Memorandum of Understanding on creating the Groupe Speciale Mobile (GSM) which would coordinate the research efforts to produce and adopt a common digital signal-based technology standard for the European market. The institution of GSM would later be transformed into a formal European-level standardization organization – ETSI. GSM would then become the acronym for Europe's 2G standard: Global System for Mobile Communications. GSM, and later ETSI, would use formal voting and approval methods using national-level representation to determine intellectual property policies, the openness and scope of telecommunication standards in Europe. Through coordination of all actors in a single developmental effort, GSM and ETSI would ensure that all member states would conform to a common standard. Like the French government, GSM and ETSI are able to override the interests of resistant countries so long as a supermajority of member states agree to the terms of a standard being debated. This ensures a common standard will emerge.

By the early 1990s, European member states were rolling out GSM-based mobile networks. These rapidly expanded. With a common market, prices for equipment and handsets fell. Overseas telecommunications regulators began adopting GSM as their standard – and using European (or Motorola) handsets and base station equipment. By 2005, 75% of global mobile telephony utilized the GSM standard (Bekkers and Updegrove 2012).

In terms of IP, the original MoU for GSM had called for all standards-essential patents submitted for inclusion to be made available on a worldwide royalty-free basis. Both the French and German governments pushed instead for universal RAND licensing rather than royalty-free terms. Both France and Germany sought to maximize the potential returns to their respective telecommunications equipment firms by encouraging pan-European adoption of their standard as well as allowing for broad paid licensing to bring in further revenues. However, GSM voted to support an alternate technology proposal from Ericsson based on non-proprietary technology. Ericsson's non-proprietary proposal used Time Division Multiplexing and was considerably less expensive for manufacturers. In the end, GSM used significantly less standards essential patents than later standards, some 380 in 1998 – many of which were double counted due to filing in multiple countries (Bekkers and Updegrove 2012). The primary inventor, Ericsson had no SEPs to speak of. The largest single patent holder was Motorola. Ericsson was already a world-leading telecommunications equipment manufacturer. Ericsson believed it enjoyed a competitive advantage in production of goods using its technology and thus could still compete with other firms even without the licensing revenues. The RF offer of core technology made Ericsson's technology submission far more attractive than the more expensive and proprietary French and German systems.

Supporting rapid diffusion and inexpensive licensing, GSM voted in support of the Ericsson proposal. Although favoring the non-proprietary Ericsson proposal, GSM still supported IP rights – as one would expect given Europe's status as a region of IP Creator countries. Allowing submission of other technologies for which licensing fees could be charged, GSM encountered a snag from Motorola. Motorola indicated it would not agree to RAND licensing. Rather, Motorola insisted it would retain the freedom to set licensing fees on a bilateral basis and be able to discriminate among firms to whom it would license. European firms unable to secure a cross license were either unable to produce GSM equipment at all or else forced to pay high prices to license Motorola's technology. Licenses for firms without an agreement with Motorola had to pay patent royalties of 10-13% of the wholesale price of their goods (Bekkers and West 2009). This limited their competitiveness. In total, patent license fees accounted for up to 29% of the price for a GSM production license – a major cost obstacle for firms outside the cross-licensing with Motorola and the other leading firms (Bekkers, Duysters et al. 2002). Despite these challenges, the common European standard created the world's largest market for a single technology, one with multiple vendors.

By the mid-1990s, both American and European firms began looking forward the next generation of mobile telephony – 3G. Increasing user density in cities as well as greater demands for data capabilities meant the technology would need to become more efficient. In moving to the 2.5G era, ETSI adopted an intermediate standard known as EDGE. EDGE was a code division multiplexing standard, unlike the early TDD-based GSM. This should have offered an advantage to Qualcomm, the primary developer of CDMA technologies. However, to stymie the development of Qualcomm and ensure a repeat of its global success with GSM, ETSI voted for a 3G standard incompatible with Qualcomm's first generation cdmaOne standard (Grindley, Salant et al. 1999). ETSI's 3G standard, Wideband-CDMA (which used significant amounts of Japanese technology), was backwards compatible with GSM but not cdmaOne (Funk 2002). Accordingly, most countries adopted WCDMA rather than Qualcomm's own 3G standard, CDMA2000. Lack of backward compatibility with GSM limited the appeal of CDMA2000 in many global markets, especially given the massive dominance of GSM networks. WCDMA would repeat the success of GSM in dominating worldwide markets by building on its technology compatibility and the legacy of GSM infrastructure worldwide.

Conclusion

These cases illustrate the means by which differing technology markets have emerged in the United States and Europe. In the United States, companies took the lead in the absence of state leadership. Where the state does take action, it does so reactively, officially confirming whichever standard industry has already approved. In the cases where the state has tried to intervene and set standards, it has failed to do so. The state is not a powerful actor in standardization in the United States. At the same time, the state can also refuse to support any particular standard, preferring to allow all competing technologies and have their respective markets compete for dominance. The goal of American firms remains the building of markets with the largest scope possible, in order to maximize their returns. Firms such as Qualcomm and Motorola seek to preserve the most freedom possible when licensing technology, in order to maximize their revenues and shape the competitive environment. The US market is open to multiple standards but each standard is as closed as desired by the industry group or firm which created it. There is no government or normative effort to create open standards which all may utilize or contribute to.

Europe differs significantly. Here, strong states enforce their vision for markets and seek to promote the particular interests of their national firms. At the country-level, powerful government ministries and standardization bodies enforce conformity on firms within the country through adoption of single standards. At the regional level, these bodies are subordinate to more recently created bodies such as ETSI which seek to harmonize European standards in order to form a truly common market for technology with multiple participants. However, the openness of standards is still restricted by the European-level organizations, just as it was at the country level. Participation by non-European firms is limited and formal rules privilege European-based firms. As Europe legally mandates that all standards pass through formal organizations, not just receive de facto approval by firms or alliances, European technology markets are set up to favor European firms, even at the expense of alternative technologies. Like the US, however, the intended scope in global with the hope of using the common technology market under a single standard as a means of building economies of scale and thus affording an advantage to European firms over their American, Japanese, and (increasingly) Chinese competitors. Europe's technology markets will remain more closed and the role of the state in ensuring they are will continue into the future.

The next chapter looks at the newest entrant into the world of technology standards, China. The chapter explores how China's combination of relative technological innovation weakness with a strong state has produced technology markets which are open and global in scope but also frequently constrained in strategic industry sectors. Furthermore, China's approach to intellectual property differs greatly from the United States and Europe, preferring to support low-cost options even at the expense of licensing revenues for firms in order to promote manufacturing and widespread adoption of Chinese standards.

CHAPTER 4

HISTORY AND POSITION: TECHNOLOGY STANDARDS IN CHINA

Consider China, the world's second largest economy, largest emerging market, and most spectacular economic success story of the last three decades. The hyperbole used in describing China's economic performance, industrialization, and technological upgrading hides a truth – China has indeed emerged on the global economic and technological stage. Yet, China's emergence has clearly revealed that its markets do not operate in the same way as other developed, or even developing, countries. The strong role for the state in the economy and the relative position of weakness – in terms of core technology development and contribution – of Chinese firms means markets in China take on different forms from those in other countries.

This chapter explores the case of standardization and technology market formation in China. China's standardization system is a hybrid of the statist European approach and the non-state model of the United States. China's standardization system by law and tradition places the central state as the leading actor. At the same time, reforms have attempted to increase the role played by companies in the development and initiation of standards. This hybrid system allows for significant variation in developmental processes and outcomes in different standards. Even as this hybrid system has emerged, it is important to note that China's technology standardization system remains highly dynamic and is undergoing continuous transition and transformation. Different standardization efforts – as detailed below – show the tension between a traditionally dominant and leading state and increasingly strong firms seeking their own interests. In some cases, such as TD-SCDMA, the state was able to force firms (in this case China Mobile) to adopt the chosen standard. In other cases, such as WAPI, the state has backed down and allowed industry to have a greater say in which standard will be used. While China is decidedly statist both by law and tradition in standardization, there are limits to the ability of the state to impose its desired standard on industry.

Existing research has shown that China has a highly fragmented political system with intense rivalry among different branches of government and different levels. This competition undermines the image of a highly coordinated strong state able to fully implement its technology development and market-creation preferences. This has strong implications for the future of China's standardization; while the country may aspire to develop a coordinated French-style system, it is more likely to drift increasingly toward an American-style approach where industry leads where it will, albeit strongly checked by the state.

China is an aspiring technology superpower. To achieve its goals such as becoming a world-leading technology innovator by 2020, China's state uses its authority to shape technology markets as best it can to afford advantages to Chinese firms (Suttmeier and Yao 2004; Cao, Suttmeier et al. 2006; Pan 2006; StateCouncil 2006; Kennedy, Suttmeier et al. 2008; NPC 2011). However, given the position of the Chinese economy in the fragmented global economy, the perspectives of firms and state are often at odds, producing standards without demand from industry or defaulting to international standards even where the state has used its authority to push indigenous alternatives. Where the state has been most effective has been in shaping approaches to intellectual property so as to improve the competitive position of Chinese firms. It has also been effective in creating protected markets using mandatory standards, however, not to the exclusive degree seen in Europe or Japan.

For standardization in China, the central state always has a large role. Interviewees considered the preponderance of state influence and the guiding role it takes as the defining feature of Chinese standardization. Even where a standard is primarily developed by enterprises, there is a strong degree of reliance on the state for direction, funding, and approval.

China is also an IP Taker in the global economy. While China has robust and rapidly progressing capabilities in technology innovation, these capabilities are primarily in incremental and second-generation innovation. China's ability to create core technologies which define the architecture for whole systems remains weak. Accordingly, we see that the state uses standards to influence markets, intending to downplay the role for intellectual property and instead emphasize dissemination of technology and low cost. This market shaping comes from direct state intervention as well as from indirect influence of non-corporate actors in standardization – government sponsored development bodies such as CESI and the leading role of research institutions and universities in standardization. The state in China takes it upon itself to determine market outcomes, and uses standards to attempt to create the markets characteristics it feels are most beneficial for Chinese firms. At the same time, increasingly independent and capable Chinese firms push back against state-led standardization efforts they feel are not in their interests. Examination of the Chinese standardization system reveals the extent to which the different actors involved in standardization determine the structure of the markets and how benefits will be distributed within those markets.

In this chapter, I first outline the history and current status of China's national standardization system as it has emerged and evolved over the last thirty years, with particular emphasis on the legally mandated leadership role for the state and the lack of clarity on the roles and responsibilities for non-state actors in standardization. This section looks at the formal and informal organization, institutions and channels of influence in Chinese standardization. Of particular emphasis in the role of the 1989 Standardization Law of China and the ongoing evolution of China's patent laws. These laws form the basic framework for standardization within which different actors seek to maximize their advantages and shape markets to suit their desired vision. The next section explores the position of China within the fragmented global production system. It defines China as primarily an IP Taker but notes that the country aspires to a greater IP creation capability and role in the global economy. The section briefly notes how China's position shapes the perspectives on standardization and technology markets for both state actors and firms. After this background, the chapter turns to a series of case studies of standardization in China. These case studies look at four standardization efforts in China: TD-SCDMA, WAPI, IGRS, and AVS – showing how China has developed different standards while adhering to principles for standards based on its position in the fragmented global economy.

China's Statist Institutions of Standardization

Scholars of Chinese political economy differ on their interpretations of her government policies and the efficacy of those policies, yet all agree that the Chinese state is heavily involved in the management and even day-to-day operation of the economy. Predictably, China has strongly statist institutions of standardization which cement the government as a leading actor in creating and molding markets for technology. State interests – as shaped by China's position in the fragmented global production system – are expressed in the market structures which have emerged in China.

This historical section considers the history of standardization in China and the development of the formal organizations and institutions through which standardization takes place. I emphasize the centrality of the state, not so much as a regulator but as a strategic actor in standardization. The second portion looks in detail at the various state and non-state organizations involved in standardization in China and how these relate to each other and to the central state. With the leading actors thus defined, the chapter then turns to the position of China in the fragmented global production system and how this determines the perspectives on key standardization and market features.

History of Standardization in China and the Role of the State

While China was among the world's first civilizations to emphasize standardization and to realize the benefits of common standards for market formation and sustenance, technology standardization – as in the West – only became important with the advent of industrialization. Accordingly, China's technology standardization system emerged only in the last seventy years. The formal structure of China's technology standardization system today took shape through a series of revolutions, reforms, and re-reforms since 1949. Key developments in the development of the technology standardization system took place in the early 1950s, 1980s, and again in the late 1990s.

For 2000 years, imperial governments sought to establish and enforce uniform standards as part of their nation-building and economic policies. Standards were set and maintained for weights and measures, metallurgy, and coinage. However, as China never experienced mass-production-based industrialization, it had little experience with technology standards as they were emerging in the 19th century. It was in the West that the concept and different models – formal and de facto – for standardization emerged. After the 1911 Xinhai Revolution, China began tentatively integrating itself into the Western-centric international technological order. China's halting attempts at modernization and industrialization from the 1910s through the 1940s led it to integrate itself at least officially into the Western-led global technology standardization system.

In 1920, China joined the ITU. China was also one of the 25 founding members of the modern ISO in 1946. Despite these efforts, China's internal and external conflicts as well as general technological and industrial backwardness meant the country had little if any influence in the global standardization system. China's participation gave it an insight into the operation of the international standardization system but China had little to contribute, especially in cutting edge technologies.

As argued in research studying industrialization and modernization during the late Qing and Republican periods, China had begun developing scientific and technological capabilities oriented toward the West. However, whatever institutional development managed to take place during this period was undone by the 1949 revolution and establishment of the People's Republic of China. That year, the Republican government of the Kuomintang collapsed and fled to Taiwan and the Communist Party – which soon firmly aligned itself with the Soviet Union – took power. Historical institutionalists argue that historical legacies are most easily broken in the context of war, revolution or other crisis. China in the late 1940s and early 1950s experienced all three. Such standardization institutions and expertise as had been developed since 1911 were thoroughly destroyed. Indeed, many of the experts fled with the defeated KMT government to Taiwan. China thus had to completely rebuild its standardization system.

As part of the process of "Building Socialism" under Soviet tutelage and "leaning to one side", that is toward the Communist Bloc, in the early 1950s, China's new government established wholly new institutions and organizations for standardization. From 1950 to 1955, China's government was restructured along Soviet lines. This meant creating industrial ministries to govern the economy and a central planning agency to set economic targets in a series of five year plans.

For standardization, one of the most important reorganizations was the division of government administration into industrial ministries. Modeled on the Soviet system, China established a standardization department under the National Technology Commission in 1955. In keeping with the functional division based on type of economic activity, a separate standardization body for agricultural standards was established in 1964 under the National Science and Technology Commission.

During this period, which might loosely be considered "the Soviet period", or planned economy period, standardization was strictly utilitarian. As markets played virtually no role in the Chinese economy, standards were to support the plan. Standards mandated the shape, quality and characteristics of different industrial goods so as to ensure their ability to work and be utilized by other agents in the planned economy. For example, during this time, a standard might classify the depth of threading on screws. Adherence to this standard – both for screws and for screw holes – was essential to ensuring plan targets could be filled. Throughout the planned economy period, standardization in China was effectively mandatory regulation. Where standards for different goods were set, industrial enterprises were obligated to follow the standard.

The growing inefficiencies of the Chinese planned economy during the 1960s and 70s have been explored elsewhere (see, for example: Naughton, Shirk, Garver, Ernst). After Mao Zedong's death and the purge of the Gang of Four in 1976, a more pragmatic leadership sought to realize the "Four Modernizations" of agriculture, industry, science and technology, and national defense. Modernization in part would be facilitated through opening to the West and the rest of the world. Accordingly, China rejoined the ISO effective on September 1, 1978.

During the "Reform and Opening" period beginning in 1978, China's central and provincial leadership began increasing the scope for markets in China's economy. Administrative reforms during this time sought to both increase the efficiency of planning and to grasp the vitality of markets for fostering economic growth, increased incomes and technological innovation. In the 1980s, reform came to standardization as well. In 1982, the National Standards Association was created to administer standardization. In 1984, China passed its first Patent Law, creating the first concept of a system of protected intellectual property. Most importantly, the National People's Congress passed the Standardization Law in 1989, creating the legal basis for standardization in China, cementing the centrality of the state in standardization.

As mentioned above, under the planned economy, technology standards were indistinguishable from compulsory regulations. Industrial firms were required to comply with such standards; indeed compliance was essential to the smooth operation of a planned economy. Only if components adhered to rigid standards could they be guaranteed to be usable by other factories as allocated by the plan. The Western concept of voluntary standards which define a product, service or technology but are open to amendment and are free to be ignored by enterprises was completely alien to the system. Interviewees noted that it was not until the late 1990s that general awareness of voluntary technology standards and their economic influence became widespread.

It is important to remember that while the 1980s was a decade of reform and the introduction of market forces into the economy, the broader industrial economy at that time remained almost entirely planned and state controlled. Small businesses, workshops and even small private enterprises began to proliferate – particularly in the countryside – but the urban economy remained largely unchanged. Throughout the 1980s, state-owned (and then planning-based) enterprises contributed over 70% of industrial output (Naughton 2007). Such market forces as had begun to take effect in the state industrial sector were primarily limited to administrative reforms – typically restricting the power of the Party Secretary and empowering professional managers – or permission to sell surplus output on open markets, so long as it was produced using market-sourced inputs. This was the era of Chen Yun's "Bird in a Cage" economy. The state-owned and planned economy was to remain dominant. Market forces, like the songbird, could provide vitality but needed to be constrained. The economic primacy of the state remained unchallenged, as did the importance of government direction. This system changed by the 1990s as the private and collective (non-state-owned) segment of the economy outgrew the planned economy (Shirk 1993; Naughton 1995).

In the climate of the still state-dominated 1980s, China drafted and adopted the Standardization Law (NPC 1988). The National People's Congress adopted the law in 1988 (effective January 1, 1989) after several years of development and debate. As the plan and state overwhelmingly dominated the economy throughout the years the law was developed, it enshrined planning and state leadership in the standardization system. It remains the sole legal basis for China's standardization system – even though the institutions have developed beyond the basic requirements of the law over the last twenty-five years. As one interviewee put it, when describing the sometimes arbitrary actions of a state-led SDO in China:

> "If (the SDO) feels they cannot give MNCs a logical reason for their decisions, they will use the old 1989 Law as an excuse. This happens in top down cases where high-level government strategy has tied the organization's hands. When this happens, they can simply cite the law – arguing that there is nothing they can do to help MNCs since the law makes no provision for them" (Author's Interview).

Since the Standardization Law remains the legal basis for the standardization system in China, it is important to understand the context in which it was developed and hence the types of perspectives and powers it fosters.

During the 1980s, market reforms posed an ideological challenge for China's leadership. While still members of the Communist Party and officially dedicated to the goal of building and preserving "socialism" Deng Xiaoping's reforms explicitly rejected some of the basic tenets of socialist economics: comprehensive planning and collective ownership of farming.

Communist Party leaders agonized over how to justify these changes without undermining the justification for rule by the Communist Party. The ideological solution was the "Socialist Commodity Economy" (Liu 1991). This school of thought argued that the "Commodity Economy" was indeed essentially a market-based system of exchange where there is profit motive and prices set by supply and demand as opposed to a traditionally socialist system of fixed prices and planning. However, great pains were taken to differentiate the "Socialist Commodity Economy" from a "Capitalist Commodity Economy." The latter involves blind pursuit of profit for personal, not firm or national, gain. It involves the fetishism of capital and worship of money that destroys social and familial relations. The "Socialist Commodity Economy" on the other hand, is run with a healthy appreciation of the needs of the whole – individual, enterprise, and state. Profits are to benefit all, not just the entrepreneur. A major feature of the “Socialist Commodity Economy” is also the prevalence of state ownership but the clear end to planning and quotas and subjecting enterprises to market forces to make them more efficient.

This somewhat confused ideological position meant that while enterprises were to be encouraged to pursue profit, this goal had to be tempered. Attempts at controlling “Spiritual Pollution” throughout the 1980s had limited success (Baum 1994). However, while losing control over the daily lives of the people, the continued dominance of State enterprise meant the government would continue to wield disproportionate power over the economy, particularly in key sectors. The government would continue to control key areas of the economy, including technology standardization. By law, since 1989, the State remains the only source for authority in standardization. The private sector has no legal standing in standardization. Since 1989, China has developed more standards development organizations, both state-controlled and nominally independent, but all in the context of a legally dominant government. China’s economy has also grown far larger and far more sophisticated. The next section details the current institutions and organizations in China, accounting for their historical antecedents and influences as well as the mandated and institutionally established roles they play in standardization today.

State and Non-State Institutions of Standardization

The legal mandate that China’s state lead the standardization process is based on the Standardization Law, drafted and debated from 1985 to 1988. Given the time in which it was developed and adopted, the law reflects views on standards embedded in the then-extant reality of a planned economy and official economic philosophy still trying to differentiate China’s system from Western capitalism. The law formally enshrines a strong leadership role for the government. One interviewee effectively summed up the importance of the law by remarking on the difference between standardization institutions in China and the United States: “What makes standardization special in China is the leadership of the state” (Author’s Interview).

Like the WTO TBT agreement with its emphasis on the market creating and trade enhancing aspects of standards, China’s Standardization Law was intended to encourage international trade, technology interoperability, adoption of international standards and development of standards for the protection of health, safety and the environment. The law created the legal basis for China’s institutions and formal organizations of standardization. Figure 3 offers a brief summary of those articles in the law which interviewees noted are most influential in China’s standardization institutions. Any discussion of China’s institutions and how these act to determine standards, and markets for technology, must therefore begin with this law. Most importantly, the law requires the state take responsibility for standardization. There is no provision in the law for non-state leadership or independent standardization organizations such as IEEE or W3PP. All standards development must begin and end with government action.

Under the aegis of the Standardization Law, China’s SAC has formulated a series of standardization policies. In 2004, for example, SAC issued a draft policy which formally declared that the state should guide national standards which: “grant bearing on industrial development and competitiveness.” Further, state guidance should address IPR and standard issues “so as to improve the proportion of self-proprietary technologies in Chinese standards” (Slater 2009). A draft regulation from SAC the same year would have forbidden the use of proprietary technology in mandatory national standards or else require royalty-free or RAND licensing, regardless of the patent holder’s wishes (SAC 2009; Willingmyre 2010). While this policy was not adopted, it remains under consideration in various forms. The policy points to the importance and power of government involvement in standardization with the intent of shaping technology markets to the benefit of Chinese firms – by lowering the costs for intellectual property and encouraging the use of indigenous alternatives to foreign technologies.

Article	Implication for Standardization in China
3	This article defines the formulation and supervision of implementation for China's standards. Standardization is to be included as an integral part of the national economic development plan.
5	Responsibility for unified administration of standardization is assigned to a body under the State Council.
	The State Council body is officially responsible for the administration of standardization activities across the country.
	Article 5 also permits relevant bodies under different ministries and regional governments to take responsibility for standardization within their industrial or geographic jurisdictions.
	As the chief administrator for standardization activities, the State Council body is empowered to direct standardization.
6	This article delineates the four legal types of technology standards in China: National, Industry, Regional, and Enterprise.
	National standards must be "formulated" by SAC, which means international standards being adopted must also go through the formal approval process
	The next level for standardization is at the nationwide industry level. Different industrial ministries may promote, set and adopt standards for their different responsible areas.
	Where a regional government sees the necessity of a standard for improving the coordination and functioning of local industry, it may adopt a regional standard.
	Where no standards exist, enterprises may define their own enterprise standards. Enterprise standards should be registered with the local authorities, thus making them quasi-official.
7	The article officially defines two classes of Chinese standards, dividing standards into compulsory and voluntary ones
	Compulsory standards have the force of law even without being separately referenced in laws or regulations.
	The ability to make compulsory standards presents the possibility of using standards as a protectionist tool or to promote a given technology or enterprise through a mandated market
12	Trade associations, scientific research institutions and academia should be involved in the formulation of standards.
	The article stipulates, however, that "a department engaged in the formulation of standard shall organize (the) committee on standardization technology".
	Industry or academia cannot independently form working groups or consortia to develop standards.
	All standards developed in China must be formal standards developed within the apparatus of government or government-controlled SDOs.
13	Standards should be developed and amended in accordance with developments in science and technology, hence the need for trade associations, research institutions and academia to get involved in standardization.

Figure 3: Standardization Law of China

The role of intellectual property in China’s technology standards and markets stems from the laws and policies enacted to govern patents in general and standards-essential patents in particular. The National People’s Congress passed China’s first patent law in 1984. The law has since been revised three times to shape the role of IP in China’s industry with the most recent changes have been proposed in 2008. The 2008 reforms attempted to balance private and public interests and national innovation strategy while strengthening protections for IPR holders. Essentially, the reforms sought to enable the state to realize goals of broad dissemination of technology at low prices will also encouraging China’s innovators through improved protection of their IP.

A fourth revision is currently undergoing review. When initially made available for comment, the fourth revision included provisions making it possible to demand compulsory licensing of essential patents for Chinese standards (SIPO 2012). After receiving 400 comments, this proposal was again returned for further revision. Commenters strongly rejected the proposals regarding mandatory licensing which was seen by many, particularly large foreign enterprises, as an attempt at forcing technology transfer. Nonetheless, within China’s SDOs there are policies designed to effectively mandate licensing, albeit on a RAND basis, not RF.

In 2010, the China National Standards Institute (CNIS), a research body under SAC, proposed the *Disposal Rules for the Inclusion of Patents in National Standards* (Willingmyre, 2010).[37] The initial January 2010 draft contained language broadly considered inimical to the interests of IPR holders. After receiving comments, a subsequent revision was produced in April 2010. However, this draft still contained

[37] CNIS is a research institute under AQSIQ. Like SAC, CNIS has a .gov.cn Internet address. Established in 1990, CNIS is a research and education think tank responsible for developing standardization theory, strategy and education for China. CNIS makes standards for service industries and serves as a consulting body for groups seeking to develop or propose recommendations for standard development projects to SAC. CNIS’s relationship with SAC is not direct although many CNIS workers have also spent portions of their career in SAC. As evidence of the somewhat confused relationship, when asked when CNIS was established, an interviewee answered “In the 1950s, under Soviet guidance.”

ambiguities with regards to granting licenses. For example, the April 2010 revision stated that "For purpose of patent licensing, the licenser should fill out the Patent Licensing Declaration Form" but it does not clarify whether this language means a declaration of intent to negotiate licensing terms, or if it firmly commits the IPR holder to a license simply by filing the paperwork. Further, there is uncertainty over the language governing "essential patents" which makes it appear that commercial necessity, as opposed to purely technical, can obligate a firm to license their technology to would-be adopters conforming to a standard. The proposal remains under revision.

The State Council body responsible for standardization in China is the Standards Administration of China (SAC). SAC (established in 2001) is the successor administrative body to China's various standards administrative bodies going back to 1955. While still directly under the State Council, unlike earlier departments, SAC itself is not officially part of the government. SAC is an officially a non-governmental organization under the State Administration of Quarantine and Inspection (AQSIQ). AQSIQ, in turn, is a sub-ministerial commission directly responsible to the State Council but not under any specific ministry. In this way, AQSIQ is much like the State Intellectual Property Office (SIPO) which is also a commission which answers to the State Council but does not have direct ministerial representation.[38]

Interviewees varied on their perspectives over whether or not SAC should be considered a government office. Officially, it is considered an "Institutional Organization" (事业单位) under the control and direction of AQSIQ.[39] Like ANSI, this means it is not actually a government office even though it represents China at the

[38] Sub-ministerial commissions like AQSIQ and SIPO do not have their own representative ministers on the State Council. Their leaders do not attend State Council meetings unless specifically called – usually by the Vice Premier. They are not responsible to other ministries but can be influenced by the policies or preferences of ministries and commissions with State Council representation.

[39] Institutional Organizations are non-profit bodies offering a social service to satisfy a cultural, scientific, health or other demand. They are considered part of state institutions and some are part of the official civil service and employ career bureaucrats. Dating back to the time of the planned economy, Institutional Organizations are initiated by the government but are not explicitly part of the state structure.

international level in the ISO and IEC. This distinction, however, is academic as SAC is funded directly through the central government. SAC's website is listed as a .gov.cn domain, the same domain used for state ministries and commissions. Further, SAC employees receive the same benefits and career stability as other government officials. Government interviewees tended to emphasize that SAC was not formally part of the government. Nonetheless, most interviewees in industry and standards development work said that the "Institutional Organization" status was meaningless. In their interactions with SAC, interviewees said they treated SAC officials the same as they would representatives of any other extension of the Chinese bureaucracy.[40]

SAC is the ultimate arbiter of standardization in China. Only SAC may issue the identification numbers used to designate a standardization effort as a prospective national standard. National standards are identified by use of a GB (国标, short for 国家标准) standards number. To date, SAC has approved, published and implemented approximately 27,000 national standards. Of these, approximately sixty percent are "internationally comparable" whether to ISO/IEC or foreign country standards. This means roughly 40% of China's national standards – not including industry or regional standards – are different from international standards in the same sector, or else are standards for sectors for which no international standard yet exists (Author's Interview).

As the final approver and publisher of national standards, standards submitted from industrial ministries or regional governments must be approved by SAC before becoming national standards. When adopting foreign or international standards, SAC must perform the analysis and approval. Like European standardization, only formal standards have legal standing in China – and these all must pass through the government standardization apparatus – SAC.

[40] This is similar to many state-industry relations in China's political economy. Any group with state affiliation is generally treated as a formal extension of the state meaning it has significant power over industry, and firms seek connections and favor with such bodies. At the same time, however, like all state bodies, it is subject to influence from industry and firms increasingly lobby the state to support their interests, not just accept state pronouncements.

The day to day work of standardization falls to an array of mostly government-run or affiliated standards development organizations. Most of these SDOs were established under the various industrial ministries. Once provided a GB number by SAC, these standardization efforts are fast tracked for approval as national standards. Otherwise, standards are first developed as industrial standards, approved by their ministries, and then submitted for approval as national ones although not all industrial standards become national standards.

Industry standards apply only to firms or other agents in a specific industry, not to the entirety of the national economy. Although industry standards can be made for any industry, the majority of these that make headlines – and controversy – are in electronics and ICT. Such industry standards are administered by MIIT.[41]

MIIT directs two standards development organizations which handle the work of developing specific industry technology standards: the China Electronics Standards Institute (CESI) and the China Communication Standards Association (CCSA). CESI, first established in 1963 under the Ministry of Electronics Industry (one of MIIT's predecessors), is responsible for electronics and near-field wireless communication standards. With its focus on near-field communications, CESI has direct representation in the IEC through its representatives who sit on JTC1 (the Joint Technical Committee between ISO and IEC for consumer and business ICT standards). Although created by MIIT's predecessor, CESI is administratively under SAC – insomuch as CESI's industry standards are submitted up to SAC for consideration as national standards. CESI still receives its funding from MIIT, however. Rather than be financially independent, MIIT's official position is that CESI needs guaranteed funding in order to act as an independent third party standards developer. Hence, state funding is always guaranteed. In addition to

[41] Before the creation of MIIT in 2008, standards for the electronics and IT industries were created by the Ministry of Information Industry (MII). MII was formed in 1998 by merging the Ministry of Posts and Telecommunications (MPT) and the Ministry of Electronics Industry (MEI). The two ministries had been in charge of long-range communication and electronics industry standards, respectively.

its state budgetary allowance, CESI also receives fees for performance standards compliance testing of products and selling testing equipment.

CESI has adopted a pragmatic view of intellectual property. According to its 2007 IP Policy, CESI acknowledges that intellectual property is important in standards but preference is given to actors which submit patents for consideration in the most open manner possible – meaning RAND or RAND-RF. CESI's IP policy is used as a template for the various technical committees working on industry standards in ICT – such as AVS and IGRS as detailed below. CESI IP policy offers four types of IP declarations to firms: RF, RAND, Patent Pool, and No License. The Patent Pool option is becoming increasingly popular and widely promoted by CESI whose members are interested more in disseminating their technology and winning brand attention than they are in direct monetization. Low cost patent pools are intended to foster quick and widespread adoption. One interviewee explained CESI's perspective on embedded IP in standards:

> "We never believed that adopting or using international standards is damaging for industry, but if we adopt standards with barriers like patents which cannot be licensed, then that would be damaging. Similarly, if a patent was licensed under unfair terms – since we should get special consideration as a developing country – that would be to our disadvantage. Although we make a lot of products in China, we are still comparatively underdeveloped. The question is how to balance the legitimate interests of both the IP holders and the licensees who must pay. In CESI, as a standards maker, when a firm joins a working group, the group must be balanced for mutual benefit. So IP holders and licensees must be willing to negotiate. To facilitate negotiations, CESI sets rules for disclosure, when firms must submit contributions, or at any other point. Furthermore, whether or not a firm offers a license, if it is a member, it is obligated to disclose" (Author's Interview).

The second MIIT-directed standardization body is the China Communication Standards Association (CCSA), responsible for long-range communications, particularly mobile telephony and wireless data. CCSA was established in 2002 by merging the administration and activities of six telecommunications and long-range network communication standards working groups that had been established by MIIT's predecessor ministries – the Ministry of Posts and Telecommunications and the Ministry of Information Industry. As a testament to enduring historical legacies, CESI and CCSA roughly correspond to the earlier division of responsibility between the Ministry of Electronic Industry and the Ministry of Posts and Telecommunications before their merger in 1998. This division of labor is not without precedent, however, as Europe similarly divides near-field and long-range network and communication standards between CENELEC and ETSI. Creation of CCSA was a pragmatic decision to streamline the administration of working groups in this functional area. CCSA provides experts to China's delegations to the ITU for international-level standards negotiations.

In both CCSA- and CESI-sponsored technical committees and working groups, there is a similar structure. In their working groups, there is always a government representative, sometimes sent directly by the SDO or else sent from MIIT. The government representatives sit on the secretariat of the working group. Officials are only responsible for administrative matters to ensure the development process follows the Standardization Law concerning deliberation, consensus, public comment and revisions. Nonetheless, the government remains both the source of funding for standards development organizations and the developer of long-term strategy. As stated by one interviewee:

> "As for the government, they are one step behind but one step higher. They can see further and plan for the future. But the actual work in standards is left to the experts. In our committees, there is a CESI representative in each group. Sometimes there are also representatives from MIIT. Fortunately, 80% of MIIT officials have a technology background so they at least understand science. The government, however, does not have a strong day to day influence apart from provision of funds and setting the overall direction." (Author's Interview)

China's technology standards system formally follows a combined bottom up and top-down approach to standardization. While the state remains the primary initiator of standardization activities and the final approver and implementer, there is a role for non-state actors as well. The system created by the Standards Law allows for the creation of enterprise standards.[42] While some interviewees scoffed at the idea of non-state standards: "How can there be an enterprise standard? There is no such thing" (Authors' Interview), it is legally possible for firms to establish standards through their internal policies and then register the standard with local authorities. The conception is that the firm will make standards for quality, safety or technological sophistication above and beyond those demanded by industrial or national standards.

In practice, some of China's large firms are able to dictate standards by fiat. This occurs when the company enjoys a preponderance of economic influence in the national or regional market. Hence, any standard it adopts internally will become the de facto standard for the region by virtue of the firm's economic weight. To illustrate, some interviewees noted that China's power generation companies enjoy regional semi-monopolies. In such circumstances, a firm such as Southern Grid can mandate transmission standards which become effectively binding. Supplier firms and subcontractors are obligated to conform to the standard since there is no alternative to working with the monopolist. As explained by one interviewee:

> "A standard can become a standard even without going through the SAC. When an extremely powerful company like National Grid or Southern Grid adopts an enterprise standard, the firm forces the hand of other companies. To supply to these companies – which are the only game in town – you must conform to the standard." (Author's Interview)

[42] As noted in the main description of the Standards Law, there is a category for sub-national regional standards as well such as would be set by local or provincial governments. Although China's highly fragmented political system would seem to encourage further fragmentation and market confusion through expansion of incompatible local standards, none of the interviewees in government, academia, or industry mentioned regional standards as posing any threat to commerce or technology development. Indeed, regional standards were only mentioned in a handful of interviews, and then only in passing.

Although able to set standards as they see fit – so long as they also conform with established national and industry standards – China's large enterprises are generally also state-owned – in part or in full (Thun 2006; Huang 2008; Breznitz and Murphree 2011). This means that they are also subject to state pressures to set their internal standards in accordance with national policy. In heavily regulated and oligopolistic industries such as telecommunications and power generation in China, firm standards effectively become national standards. This actually affords the Chinese state with a further avenue for mandating standards. While WTO rules do not permit the adoption of exclusive national standards when international alternatives exist, firms are free to adopt internal standards as they see fit. Since they completely dominate their industries in China, their internal standards effectively become mandatory national standards. This can effectively get around WTO restrictions on protectionism by the state while accomplishing the same goals in practice. As noted by one interviewee:

> "It actually wasn't the Chinese government which forced foreign mobile phone makers like Apple and Microsoft to conform to the WAPI security standard. China's phone network operators like China Mobile and China Unicom set their own security requirements for WiFi security, which meant the phone makers had to conform to the WAPI standard since only WAPI met these requirements." (Author's Interview)

Apart from their independent standardization capabilities, large firms are also active in China's formal standards development organizations. The government strongly encourages such participation, but unlike France where large enterprises can be controlled by strong state leadership, large Chinese enterprises resist mandated technology sharing or low-priced licensing of technology to their competitors. In the IGRS home networking standard, one interviewee described the difficulty of getting multiple large technology companies to actively contribute their intellectual property:

> "The IGRS working group was formed in July 2003 back when the entire project was still completely under Lenovo, under the supervision of the then Ministry of Information Industry. However, the legal documents that prospective working group members had to sign mandated full technology disclosure for all members. This was problematic since Lenovo led the group. Companies such as Great Wall balked at disclosing their technology to their competitor. This discouraged potential members and contributors." (Author's Interview)

The fact that one large firm or another tends to dominate a given standards development effort also makes it difficult for large firms to cooperate due to their intrinsic lack of trust. The result is that standardization often becomes the responsibility of a single firm. In the cases below, this was a challenge for standardization in the TD-SCDMA and IGRS cases. China's state is strong but unable to force companies to completely cooperate, thus complicating efforts at technology upgrading.

Apart from large firms, the major contributors to China's technology standards, and hence actors of major importance in market formation, are research institutes and universities. China's technology innovation system differs greatly from the ideal innovator as proposed by Schumpeter. Rather than large enterprises leading technological development, much of the most basic research that leads to potential breakthroughs occurs in China's universities and research institutes. These labs now work in close cooperation with one another and the state – which is the primary source of their funding – to produce technologies which may serve as the basis for technology standards. Research institutes' greater levels of experience with R&D and technology for standards means university labs tend to have a much greater role in standardization in China. In particular, university researchers are heavily represented in working groups and technical committees. Interviewees estimated that most working groups were approximately fifty percent university researchers and fifty percent company representatives. In some cases, interviewees noted that university representatives accounted for virtually the entire working group, often implying that industry had no interest in the standard.

One of the institutional reasons for the importance of university labs and research institutes is the emphasis government funding now places on standardization. University professors are rewarded with greater opportunities for travel and research funding if their technologies are incorporated into standards. Further, many national funding projects explicitly mandate the development of technologies relevant for establishing new technology standards. Accordingly, professors dedicate their R&D teams and efforts to producing standards-relevant technologies. They also actively participate in the formal processes of standardization (working groups, technical committees, lobbying) to ensure their technologies are included.

Small firms in China have a weak role in standardization. Although now encouraged to participate in formal standards bodies, small firms tend to lack the R&D capabilities to contribute significantly to standards protocols. Similarly, many lack to resources to sustain long-term involvement in standards development. At the same time, however, many small firms have been eager participants, sending representatives to working group and technical committee meetings in China's various standards development organizations. According to interviewees, these firms are not promoting their own technology. Instead they are seeking the good publicity as technologically sophisticated firms that they receive by participating in standardization. There are some direct subsidies such as government grants for standards participation but the amounts are generally small and insignificant for even small firms. Small firms' involvement provides access to highly ranked engineers and managers in major Chinese firms and government ministries. These connections are highly valuable for increasing the sales and business opportunities of small firms. Firms that otherwise would be unable to speak to influential managers at large firms can use standardization meetings to network and draw attention to their capabilities as well as conformance with the standards promoted by larger firms. In this way, standardization also facilitates market activity by helping lower transaction costs and communication barriers between agents.

With the major actors in China's standardization system thus defined, with an emphasis on the leading role for the state, the next section details China's position in the global economy.

China's Position in the Global Economy: IP Taker/Aspiring IP Creator

Before the Industrial Revolution, China was arguably the center of the global economy. In the midst of this economic plenty, China was a world-leading innovator. Joseph Needham's research on Chinese science and technology notes the hundreds of firsts in science and engineering accomplished by pre-modern Chinese dynasties.

Despite the significant economic and scientific achievements of early China, the country did not experience an industrial revolution. By the beginning of the 19th century, the incredible productivity of industrialization and mechanization in Europe and the United States left the traditional Chinese economy far behind. At its nadir, China accounted for less than 4% of the global economy in the 1970s. In 1978, China's per capita GDP was $165 (in constant 2000 dollars). Its industry was heavily reliant on Soviet technology imported in the 1950s, simplified and spread throughout the economy (Garver 1993). China's most powerful computers were transistor-based mainframes designed and built in the 1960s and only capable of 110,000 calculations per second (Ling 2005). In contrast, the CDC 6600 designed by Cray in 1964 was capable of 3 million calculations per second. China also faced high levels of un- and under-employment, intense rural poverty, rising discontent and cynicism among urban residents and general dissatisfaction with the state of China and the communist party (Baum 1994).

To tackle the growing crisis of faith, the leadership of the communist party initiated economic reforms (Shirk 1993; Naughton 1995). These differed greatly from the economic modernization programs popularized by the East Asian Developmental States. Economic reforms, development plans and programs in Japan, South Korea and Taiwan were methodical and based on progressive strategic visions for industrial restructuring, foreign investment and technology upgrading (Johnson 1982; Amsden 1989; Cheng 1990; Berger and Lester 2005). Disciplined state bureaucracies carried out the economic development plans as dictated by responsible pilot agencies (Japan), a government planning agency (Korea) or the ruling party (Taiwan). The state tightly controlled access to foreign exchange, aggressively promoted exports and sought foreign investment under specific conditions. Foreign firms' access to domestic markets was constrained and contingent upon technology sharing. Where technology was acquired, developmental agencies spent up to ten times the amount spent to acquire the technology to pay for indigenization, learning and dissemination. While not universally successful, this approach controlled the pace and means by which these countries entered the global economy, facilitating steady firm upgrading.

China's reforms were more experimental and ad hoc. This approach meant that certain areas of the economy would be reformed and opened before others. Furthermore, opening different sectors of the economy would be conducted in a fragmented manner. Further complicating the process was the "play to the provinces" (Shirk 1993). In order to get around resistance to reform from the central government's industrial ministries, Deng Xiaoping encouraged policy innovation by and fiscal liberation for provincial authorities. By the early 1990s, the result was a patchwork of reformed and unreformed sectors of the economy, regions with widely varying degrees of policy independence, and regions with sharply divergent levels of market-led economic activity and entrepreneurship.

Indeed, one of the main features of reform was the lack of a vision for the endpoint (Segal 2003; Breznitz and Murphree 2011). At the outset, the primary goals of economic reform were summarized in the slogan of the "Four Modernizations" of agriculture, industry, science and technology and national defense. First mentioned by Premier Zhou Enlai in 1964 as the goals for socialist construction in China, the Four Modernizations gained prominence after Mao's death in 1976 (Shirk 1993; Baum 1994). In practical terms, the goal was to increase the food supply and achieve self-sufficiency in grain, create urban jobs, modernize the education system and earn foreign exchange which could be used to then purchase technology for further the entire modernization project in a virtuous circle.

To accomplish the practical goals of the Four Modernizations, China's leadership was highly pragmatic. In order to avoid resistance to reform that had bedeviled attempts at reform in Hungary and other planned economies, the planning apparatus was left largely untouched until the early 1990s (Naughton 1995; Weingast 1995). Five-year plans continued to be drafted which mandated production quotas for factories, set prices and determined where and how resource inputs and human capital would be allocated. Factories which wished to continue producing in the old ways were welcome to do so. The central state remained committed to stability and ensuring that reform would not be blocked. This meant placating established interests and going around them until they no longer mattered (Naughton 1994).

Rather than attempting to use the instruments of planning to direct investment in strategic directions – as done in the other East Asian Developmental States. The market economy was permitted to grow up and around the Plan. To foster rapid development, local governments were permitted to experiment with different policies. Firms and would-be entrepreneurs were allowed managerial freedom to experiment with new product lines, human resource relations and work incentives.

Throughout this period, however, there was no emergence of a clear mandate on reforms or the long-term direction of reforms. Indeed, the very goal of the "Four Modernizations" was a vague prescription at best. The objectives or end game of reform were never explicitly defined. Throughout the 1980s, there was also a constant battle within the central government leadership over the pace and extent of reform.

In this context, the rational course of action for both would-be entrepreneurs and ambitious local officials was to pursue short-time horizons in business. Knowing that economic growth was always rewarded – both with formal promotions and opportunities for graft – local officials were strongly incentivized to maximize levels of foreign direct investment and job creation. The fastest means of doing so was to encourage export processing or other forms of labor-intensive manufacturing.

The rational response of China's new class of entrepreneurs was to insert their enterprises into the fragmented global economy at whatever level was available. With no long-term strategy emanating from the center to shape the industrial economy toward some normative goal, entrepreneurs were free to make money as best as possible without concerns for mandates to upgrade, transfer technology or strong-arm foreign partners. Firms thus developed niche capabilities in component supply or final assembly within global production chains. While not yielding major technology upgrading, this was able to build China into the workshop of the world, albeit without concerted and coordinated efforts to secure upgrading by firms. Innovation and IP development capabilities thus remained limited.

China's position within the fragmented global economy is thus not the same as for other East Asian developmental states. While all engaged in low value-added assembly and light industry, Japan, Korea and Taiwan used state influence to push for rapid upgrading. China's large underemployed population also meant that low-value added activities could remain profitable for longer, enabling firms to remain focused on production and scale rather than innovation. China's firms developed innovation capabilities and competitive advantages in the application of technology and the organization of production but much less in the conduct of long-term research to invent or wholly redefine products and industries.

Thus China developed into an IP Taker in the global economy, with a manufacturing economy based on the import and use of foreign technology and conforming to foreign standards. Use of foreign standards meant the Chinese economy became part of global markets, massively increasing potential customer volumes for

Chinese firms. At the same time, China's government is not content with this position in the global economy.

China's 2006-2020 Medium to Long Range Plan for Science and Technology is cognizant of China's enterprises' degree of reliance on foreign technology (StateCouncil 2006; Serger and Breidne 2007). Accordingly, there are goal metrics in the plan for reducing the percent of foreign technology in China's products, ideally by making equally competitive or better Chinese alternatives. That the plan felt the need to call for decreasing foreign IP in the Chinese economy is evidence of the weakness of China's indigenous IP creation system. While still an IP Taker, China pays increasing attention to the importance of IP creation and is seeking to build its capabilities toward that end.

General Condition of Technology Markets in China

Technology markets in China accord with the predictions of this dissertation's theory as a Statist IP Taker country. The Statist IP Taker will have active government involvement to promote the success of indigenous firms whether through promoting and protecting their technology or using its influence to lower the costs of intellectual property for firms. China's government has indeed followed both of these tracks – encouraging development of indigenous alternative technologies and attempting to lower the prices for technology licenses so as to improve the competitive position of Chinese firms.

For China's IP policies, the government strongly promotes the development of what is termed "indigenous innovation" and "core technology" or "self-owned intellectual property." The government sets targets for reducing the use of foreign technology and its replacement with indigenous alternative – most notably in the target of only 30% dependence on foreign technology by 2020. China's government promotes indigenous alternative technologies through provision of funding for R&D projects. Interviewees in research institutes, particularly in universities, noted the importance of government funding for sustaining their standards-relevant R&D projects. These projects come with mandates that technology development be done with an eye toward inclusion of the technology results in indigenous or international standards. One interviewee summed up the overall government perspective:

> "Some government bodies in China feel that China should develop its own standard for every area where there is a foreign standard on principle, even if the Chinese technology is inferior. This is done to protect China's own industry. Others feel that China's technology is actually better in some ways that foreign technology but the firms and standard have a lack of market maturity so there is a need for protection against foreign bias and prejudice against a Chinese standard. More and more China is getting better at technology or at least being able to produce comparable and cheaper alternatives so China's standards should be getting better. Also, the government my just want leverage over foreigners or to lower royalties but eventually all of this spending is going to pay off in technology capability building." (Author's Interview)

As suggested by the interviewee's comments, the Chinese state is actively involved in lobbying foreign standards alliances and dominant IP holders to lower the IP licensing fees charged to Chinese companies. As manufacturers, China's firms are frequently squeezed by the licensing rates they must pay just conform to international standards – effectively a pay to compete requirement. The state intervenes to benefit Chinese firms. As stated by a representative of a Chinese SDO:

> "Lowering royalty rates, both for foreign standards and by having our own cheaper standards, is a major goal in developing standards in China. It has always been the goal. It is the goal for associations like ours to keep royalty rates as low as possible to encourage adoption." (Authors' Interview)

Finally, in the domestic sphere, Chinese firms are increasingly adopting more open and inexpensive IP licensing policies. Domestic firms realize their weak position in the global economy – a factor of their position as low-end manufacturers in global production chains – and seek to compensate through lower priced technologies. If the licensing rates for Chinese technology standards are lower than foreign alternatives, there should be greater adoption and utilization of the Chinese standard. The government strongly supports these efforts at lowering the prices for IP. MIIT in particular through CESI is looking to implement nominal-priced patent pools for a variety of Chinese information technology standards.

The theory predicts that standards development and hence technology markets will generally be closed in a statist country like China in order to benefit domestic firms. This is generally the case. Chinese standards are often explicitly or implicitly Chinese-only in their participation. Foreign firms do not have the same rights and participation experiences. Standards development efforts within China are state supported and protected. In key sectors such as information security, the state bars foreign participation at all. In other cases, interviewees noted that foreign firms are welcome to participate insomuch as they are requested to contribute their intellectual property at low or free rates but are otherwise discouraged from participation. Foreign firms are also discouraged from being observers in standardization bodies through ambiguous policies which appear to mandate licensing of technology merely for participating in any capacity in a standards development organization or working group.

Apart from indigenous technology development efforts and support, however, China's technology markets are generally very open. Because of the need to have access to international technologies and produce goods compliant with international standards, China maintains a policy of broadly accepting international standards and permitting their use within China. Chinese firms usually prefer international standards to domestic ones due to the better reputation of foreign technologies and the greater degree of sophistication of standards development and testing by large foreign SDOs.

Finally, the scope of China's technology markets is, as suggested by the general openness principle, usually international. China's firms prefer to utilize standards which plug them in to international markets. The exception is in sectors deemed critical by the state. Here, China will create explicitly domestic standards with limited range, even at the risk of setting China apart from the rest of the global economy. As will be discussed in the WAPI case, attempts to mandate a narrow scope standard also meet with domestic resistance from enterprises geared toward selling into foreign markets. To protect itself from accusations of using technical barriers to trade, China also widely submits technologies for consideration as international standards. The goal is ultimately to create global-scale markets for Chinese technologies or at least to permit the restrictive use of a Chinese standard since it has also been approved as an international option.

The following section offers four case studies of standardization in China. Each shows how the combination of strong state influence and the position of China in the global economy determined the market outcomes of the standardization effort.

Case Studies

This section considers four standardization efforts in China. Each effort shows adherence to the logic of this dissertation. The strong role of the state and the position of China in global production chains determine the content of the standards and the markets which ensued. This section considers a variety of standards: TD-SCDMA, an internationally accepted and certified third generation mobile telephony standard, WAPI, a highly controversial wireless internet security standard, IGRS, an emerging standard for home inter-device networking, and AVS, China's alternative to MPEG-4 audio and video encoding. Each standard successfully shaped a new market, mostly with the strong assistance of the state as well as new approaches to intellectual property.

Time Division-Synchronous Code Division Multiple Access (TD-SCDMA)

TD-SCDMA is China's first major successful international standard and has been widely considered as a sign of the increasing technological sophistication of Chinese enterprises and the increasing innovative capabilities of China more broadly (Marukawa 2010). The technology behind TD-SCDMA is a combination of both the European and American technological approaches to multiplexing (the use of a single transmission band to transmit multiple signals more or less simultaneously – and thus make more efficient use of limited spectrum). The CDMA portion is based on Qualcomm technology while the TD portion comes primarily from Siemens of Germany. The “Synchronous” aspect was developed by a firm in Austin, Texas (Cwill) established by Chinese students residing in the United States. TD-SCDMA, by combining multiple approaches to multiplexing promised to allow for high upload and download rates while also allowing for efficient use of spectrum in crowded areas where many users place high data demands on a small number of base stations.

TD-SCDMA, by virtue of its technologies, was developed with significant input from many actors. However, the final developmental stages and the implementation of the standard – and hence market creation, fell to a narrow range of actors. In 1995, the Ministry of Science and Technology (MOST), the Ministry of Posts and Telecommunications (today part of 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). Seeing the success of European firms with the globally popular GSM standard and the royalties earned by Qualcomm’s CDMA standard in the United States and Korea, China’s leadership sought to repeat these technological and economic successes through development of an indigenous standard that would showcase independent Chinese technology (freeing Chinese firms from reliance on expensive foreign standards and their embedded patents) and potentially earn overseas revenues as a globally competitive standard.

Developmental work fell primarily to the Chinese Academy of Telecommunication Technology (CATT), a research institute under the Ministry of Posts and Telecommunications. To continue commercial development of the standard and compatible transmission equipment, CATT created a commercial entity – Datang Telecom. Overall supervision of the standardization effort was the responsibility of CCSA. Siemens of Germany contributed its TD-CDMA technology, developed as a possible 3G standard to replace GSM in Europe. When Europe went with Nokia and Ericsson's WCDMA, Siemens went to Datang who agreed to collaborate on an alternative 3G standard. Firms such as Motorola also contributed proprietary technology and assisted in performing simulations before the standard was submitted for ITU consideration. In simulations, TD-SCDMA actually performed better than WCDMA (Authors' Interviews). In the Siemens-Datang collaboration, Siemens provided the "egg" or "seed" technology and Datang completed the technology integration process. However, although the kernel of the technology existed, there was no complete production chain including chips for TD-SCDMA. Therefore Datang went to Samsung and Philips and Texas Instruments. The idea was to license TD-SCDMA to them for chip development but they did not express strong interest in the standard. In the end, TD-SCDMA was jointly developed by the Chinese Academy of Telecommunication Technology and Siemens and commercialized by Datang Telecom. After being successfully approved as an international standard by the ITU in 1999, the standard took another eight years of development and testing before being formally launched on December 31, 2008.

Although there was frequent speculation that China would only allow its telecommunications operators to use TD-SCDMA, China did not create an entirely closed market. Instead, at the end of 2008, MIIT licensed all three international standards – one for each telecommunications operator. The standards were thus allowed to compete but in effect each operator enjoyed a monopoly of compatible phones. For China Unicom – licensed to build a network using the WCDMA standard – this was a boom as only it could offer a 3G capable iPhone.

The IP policies of TD-SCDMA accord well with the predictions of this dissertation. Development of indigenous technology was given strong state support as noted above, but foreign technology was also permitted and licensed, albeit with strong efforts to license the technology on favorable terms. The Chinese state used its financial resources – over $700 million by some estimates – to support the development of TD-SCDMA technology, primarily through Datang Telecom. State support for IP development for TD-SCDMA was justified by a variety of interviewees – not only those affiliated with the companies involved in developing TD-SCDMA or receiving state largesse. One interviewee noted the primary reason why the state needed to support IP development for standards like TD-SCDMA:

> "In a given technology, there are dominant foreign technologies which China must overcome. The state is necessary to give the time and space to develop a technology sufficiently and get it into the market. If a technology can be given the space and the time to develop, Chinese technology has at times been even more advanced than technologies overseas. However, foreign firms have the advantage of name recognition, brand and technology trajectory in their favor. Hence the state must lead the local market to even given Chinese technology a chance." (Author's Interview)

Other firms such as Huawei and Zhongxing Telecom – China's leading telecommunications equipment manufacturers – were strongly encouraged to join in the technology development efforts. Interviewees noted, however, that as both firms were already active in research for the WCDMA standard, they showed little interest in TD-SCDMA.

Most importantly, TD-SCDMA proved very beneficial to China's telecommunication equipment industry as the ultimate tool with which to reduce royalty payments on the other two international 3G 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). In a similar fashion Huawei used the threat of TD-SCDMA to negotiate lower royalty payments for domestic and international CDMA products with Qualcomm (Sinocast 2006). These reductions in royalties accord with the predictions that an IP Taker will seek to build markets with the lowest IP prices possible – using state power where possible to accomplish this goal.

For openness, TD-SCDMA was generally an open standard – and hence an open market. Foreign and domestic firms were all encouraged to participate in development of the standard. Indeed, the majority of the core standards-essential patents in the final standard were foreign. Of the 148 Time Division Duplex patents filed with China's State Intellectual Property Office, over seventy percent are held by foreign companies (most notably Siemens and Qualcomm) (Ernst 2011).[43] Nokia, Ericsson, and Siemens provided thirty-two, twenty-three and eleven percent, respectively, of the total patents for TD-SCDMA. Datang only contributed roughly 9% of the core SEPs. Thus, it is clear that foreign participation in the standard was generally encouraged.

Further openness could be seen in the initial development of TD-SCDMA. In the 1990s, the central government and research institutes leading the project invited MNCs to add their technology to the pool and help educate researchers on the detailed steps involved in standardization. Over time, however, the development of TD-SCDMA fell increasingly just to Datang Telecom. CCSA increasingly restricted direct foreign participation in development, forcing would-be foreign enterprises to partner with local

[43] As a standard based on time division multiplexing, as opposed to code or frequency division, the TDD patents are essential to the standard and among the most critical.

vendors. This was intended to upgrade Chinese firms' capabilities. However, it had the general effect of cooling foreign enthusiasm for the standard, again reducing participation primarily to Datang.

The market was also not fully open. Once completed, the decision to offer 3G licenses to China's mobile telephony companies required a direct push from MIIT. For years, China's leading mobile phone company – China Mobile – had pushed to receive a license to offer 3G services. China Mobile favored WCDMA, the global standard compatible with its existing GSM network. Instead, MIIT offered the WCDMA license to China Unicom, a CDMA2000 license to China Telecom and forced China Mobile to adopt TD-SCDMA. This was designed to create demand for TD-SCDMA equipment and to create a dedicated market for those products – one led by China's largest and most powerful telecommunications firm. Had MIIT not forced China Mobile to develop a TD-SCDMA-based 3G network, China Mobile would not have done so. While the market was open or any firms seeking to produce goods compliant with the standard, the demand side was constrained due to the issuing of only a single TD-SCDMA license.

Finally, in terms of scope, TD-SCDMA was intended to be a global standard. In 1999, Datang Telecom, with CATT and Siemens, submitted TD-SCDMA to the ITU as a prospective international 3G standard. Upon review of the application, the ITU approved TD-SCDMA as one of the three international 3G standards. However, despite being available for international licensing, TD-SCDMA found little interest outside of China. As an IP-taker in the global economy, China's technology was generally perceived as less developed, or certainly less reliable than the already tested and proven European and American 3G standards. Further, as mentioned above, even China's own mobile operators were disinclined to offer services using the technology. Indeed, in the years following the 2008 introduction of 3G services, China Mobile's overall share of the telecommunications market – and 3G services in particular – fell as China's users preferred the more reliable and established China Unicom WCDMA network. Despite its international certification, TD-SCDMA ended up restricted to China – and really to a single operator. Had the Chinese state not acted, it is likely that TD-SCDMA would not have been adopted or utilized at all. It took state power to create the standard, and state power to force enterprises into adopting the standard and hence creating a market, albeit one with limited scope, for TD-SCDMA goods.

Wireless Authentication and Privacy Infrastructure (WAPI)

One of the most famous cases of state-led technology standardization in China was the Wireless Local Area Network Application and Privacy Infrastructure (WAPI) networking encryption standard. In the late 1990s, Western and Japanese electronics engineers submitted the protocols for wireless local area networking (WLAN). Submitted and approved through the IEEE apparatus, the WLAN standard received the number designation 802.11. Better known by its brand name, WiFi, 802.11 rapidly became the global de facto WLAN standard to which electronics manufacturers all conformed. This created a single global market in WLAN equipment, with parts and systems interchangeable across borders and device platforms.

However, researchers noted early on that the initial versions of 802.11 contained a security flaw. It was possible for a relatively sophisticated hacker to tap into a user's WiFi uploads, downloads, and traffic by using software to mimic the identity of the user's computer, thus enabling the hacker to monitor all traffic. Chinese researchers in a small startup firm called IWNComm developed a suite of encryption and user authentication algorithms which fixed the security flaw, making it much more difficult to eavesdrop on a user's WiFi signal. WAPI, as the standard came to be known, was not a complete WLAN suite. It was only a set of security protocols designed to increase the trustworthiness and security of standard 802.11 use. One interviewee explained the justification for WAPI:

> "802.11 was like selling pants with a hole in them. I will not buy pants with a hole. The WiFi alliance said they had fixed the security hole with the different upgrades to WiFi, including 802.11i in 2004, but the old security flaw was still there. WAPI alone can fix this problem" (Author's Interview).

IWNComm was established in 2000. Most of the founders had worked as university researchers. In keeping with the statist origins of much of China's technology, much of the technology which later became the core of IWNComm's patent portfolio in WAPI traces its roots to university research dating back to 1992. The initial 7 million RMB (roughly $825,000 at the time) in startup capital for the firm was self-raised although subsequent research was sponsored through government grants. Beginning in 2002, IWNComm established an independent revenue stream based at least 50% on licensing its wireless security patents. Although IWNComm supplied most of the core patents and the basic security algorithm, the entirety of the WAPI standard was, like TD-SCDMA, officially the product of dozens of firms and universities working in concert.

Foreign enterprises were not involved in the development of WAPI, although they were aware of the research project. Intel Capital even proposed to invest in IWNComm in 2001-2002 but IWNComm refused the capital injection because, according to interviewees, "they felt that Intel did not respect them." Aside from provision of some early research funding, the government was less overtly active in development of WAPI. However, the standard was sponsored by CESI.

Once IWNComm and its partners had completed the WAPI standard, the working group passed the standard to CESI and on to MIIT to begin the legal process to become a standard at the industry, national and international level. In 2003, MIIT announced that all WLAN products in China would have to be WAPI compliant and use its encryption method. WAPI was to become a national mandatory standard for information security. However, the standard itself remained largely closed. Only eleven – all Chinese – firms had access to the encryption algorithms. Other firms which sought to make their technologies compliant would be forced to partner with these companies and, they argued, open their core technology to potential competitors. Intel and other foreign companies saw the WAPI initiative as a thinly veiled attempt at industrial espionage. Since the algorithm was closed, companies seeking compliance would need to share their proprietary technology architecture and algorithms with the eleven WAPI firms and allow the WAPI firms to make the necessary patches to integrate WAPI.

Domestic and foreign firms strongly opposed the compulsory use of WAPI. MIIT shortly backtracked on its initial plans to require all WLANs to use the WAPI encryption method. The plans to impose the WAPI requirement were postponed indefinitely in late 2003. Foreign firms argued that IEEE's 802.11 was the international standard and that as a WTO member, China could not refuse to use the established standard.

In response, MIIT passed the WAPI standard to SAC for submission to the ISO as a potential formal international standard. The entire effort largely fell apart. Chinese delegates were unable to secure visas to ISO meetings in the United States. The 802.11 standard announced the 802.11i version which corrected the security flaw. ISO argued that there was no need for a supplementary standard since the flaw had already been corrected. ISO technical committee members voted to reject WAPI.

WAPI, however, has since been adopted, implemented and enforced for certain devices in China such as smart phones. This was done without direct state requirements. As an interviewee explained:

> "It actually wasn't the Chinese government which forced the foreign mobile phone makers to conform to WAPI; it was the requirements of the three Chinese phone network operators which required foreign mobile phone makers to make their phones WAPI capable" (Author's Interview).

However, China's three telecommunications operators all demanded that their WiFi capable phones also include the WAPI security features. Since China only has three operators, this demand made WAPI compliance mandatory for mobile phones being sold in China. Despite the failure of the attempt to make a market by legal state fiat, the WAPI requirement by China's operators created the demand necessary for a market to emerge.

In this market, IWNComm is the primary beneficiary of licensing fees. However, in order to promote adoption, IWNComm set its license rate for its roughly 600 patents at a nominal amount. Further, IWNComm tried to encourage adoption of WAPI by entering patent sharing agreements with over 300 firms. These agreements are to make it easier for manufacturers and brands to make their technology WAPI compliant – and to do so in a cost-effective manner. Describing the IP policy for WAPI, an interviewee said:

> "We never really optimized the royalty rates or returns from our patent portfolio. In WAPI, we have embedded patents but with our partners like LG, Nokia and Samsung, we signed an agreement and made the royalty rate very low – 80000 RMB up front and then a 1 RMB per unit ongoing license. This nominal fee helped secure a market for WAPI by getting partners on board but it means our revenues are low." (Author's Interview)

While the IP policy was designed to encourage adoption and increase the size of the potential demand for WAPI technology, the standard itself and hence the core of the market was and remains closed. The development process was opaque, conducted largely by IWNComm and a few partnering universities and research institutes with limited outside input. The core encryption algorithm was closed. Only eleven firms had access to the algorithm. They thus enjoyed a protected market in consulting and development work making products compatible with the standard. Other firms could not independently make their goods WAPI-compliant. This closed structure necessarily constrained the market. It also made many firms wary of participating in the WLAN market in China at all due to fears of IP theft.

After failing at the ISO in 2004, WAPI was limited in scope to China. Initially, the only scope for the market was among government offices which were ordered to procure WAPI-compliant products. However, many government units ignored this requirement and simply purchased general 802.11-compliant goods throughout the 2000s. With the adoption of WAPI as the basis for enterprise security by China's three mobile telephone companies, however, the scope of WAPI's market expanded to all WLAN capable smart phones sold in China. This created demand for WAPI-compliant signal encryption chips, helping stir production of WAPI-compliant components as well.

As a statist IP-taker, the WAPI case in an illustration of the limits of China's push for indigenous technology development and upgrading. While state support and resources can create a new technology, this is not sufficient to produce the market. Indeed, mandating the use of a standard is not allowed under WTO rules, thus making it difficult to create markets by state fiat. At the same time, however, China's state is able to act through its major state owned enterprises, thus created mandatory compliance without having to pass regulations which will not stand up to WTO scrutiny. WAPI also illustrates the low importance attached to monetization of intellectual property in China's technology markets. Adoption in products and widespread use are considered more important that making solid short-term returns through licensing fees. This perspective will become even clearer in the next standard – the IGRS home networking standard.

Intelligent Grouping and Resource Sharing (IGRS)

IGRS is one of the firs attempts to develop a standardized set of technologies for goods which may constitute a home-based Internet of Things. In its early form, IGRS mostly concentrates on resource sharing among information processing devices such as mobile handsets, computers, televisions, cable receivers. The technology thus concentrates on resource management and communication to enable networking and information sharing across short range – household or office size – space between information technology goods, electronics and information devices. IGRS version 2.0, currently under development, aims to expand capabilities from the WLAN level to wide-area networks and eventual ubiquitous access at the metropolitan level or larger. IGRS-based systems are designed to be effectively automatic, eliminating the need for complex system managers and IT departments. Fully operational, an IGRS-based system should be self-constructing. New devices, if compatible, will integrate themselves automatically into the system, contributing their resources and connecting to those of the other devices in range. Hence, when IGRS capable devices are within range of one another, they will automatically synch and begin resource and data sharing. Devices will also be able to work in tandem with one another, enabling capabilities or processes that would be impossible for one device working alone. IGRS became the basis for the first international standard for 3C Convergence (Content, Computers and Communications), adopted in 2012 by ISO/IEC JTC1 – some nine years after the IGRS Working Group was established.

Unlike other standardization efforts in China, IGRS did not begin with research institute or university researchers. Instead, large firms were the leading actors. The research underlying IGRS technology was initially an initiative within Lenovo, China's largest PC manufacturer. On July 17, 2003, the Ministry of Information Industry created a formal Working Group for IGRS. Although development had begun "outside" the state apparatus (although Lenovo is a partially state-owned firm with strong research ties to the

Chinese Academy of Sciences and is considered a national champion), for a standard to be created, there legally had to be a government authorization and formal working group (IGRS 2012). Designation as a working group by MIIT made it possible for Lenovo's research on a suite of 3C integration protocols to be considered for adoption as an industry or national standard.

For the next 18 months, Lenovo and a small group of cooperating companies and laboratories tested the protocols and presented their research results to MIIT. In June 2005, MIIT formally approved IGRS as China's recommended industry standard for device interconnection and resource sharing. Testing and improvements by the IGRS Working Group through the MIIT Electronic Standardization Institute Information Product Standard Compliance Certification Test Center were completed on August 30, 2005 with MIIT experts approving of the new standard. IGRS's protocols were then passed to SAC for submission to the ISO/IEC Joint Technical Committee (JTC1). In meetings with JTC1, MIIT sent representatives from CESI – the MIIT SDO formally responsible for the IGRS working group in China. MIIT thus offered strong support for developing and promoting the standard internationally.

Leadership by firms instead of universities or labs proved problematic for IGRS. The working group was explicitly led by Lenovo led until 2006. The IGRS working group thus experienced difficulties attracting members due to the conflict between MIIT's legal requirements regarding IP sharing and de facto Lenovo leadership (Author's Interview). As a formal working group under MIIT auspices, members were obligated to full technology disclosure. However, Chinese firms involved in IGRS such as Great Wall, Konka, TCL, Hisense and TCL balked at sharing their technology with Lenovo, fearing that they would be giving away secrets to a major competitor.

In the debate over standards as public, private or semi-public goods (Kindleberge 1983), the IGRS case shows that the Chinese state was necessary to push through the public goods benefit of standardization. As Ferrell and Saloner (1985, 1986, 1988) note, even where all firms would benefit from standardization, there may be hesitancy to join a standards effort or choose one competiting standard versus another. So long as standardization does not take place, the public good benefit of a universal platform remains unrealized. In China, state power was able to push through the IGRS standard and realize the benefit of a broad platform.

In 2006, IGRS was formally split away from Lenovo – relieving the firm of any commercialization and conformity testing responsibilities. Under the new arrangement, the government working group would be responsible for engineering and protocol development and a new incorporated IGRS corporate entity would handle royalties and certification of compliance (Author's Interview).

While it may seem counterproductive to involve the state in an industry-initiated standardization effort, in the context of China's political economy, it actually increased the efficacy of the standard development project. In the years after the group was given state recognition and split away from formal control by Lenovo, membership increased from 59 to 170 members (April 2006 to June 2012). Despite being formally separated, Lenovo remains the leading company, serving as corporate chair for the IGRS Working Group and Core Members Committee (Hu 2008). Thus, as a "semi-public" good, Lenovo as the leading contributor and most influential working group member, stands to benefit the most from development and implementation of IGRS, even as all participants benefit from a common platform on which all can develop goods and services.

The constitution of IGRS also formally grants different types of memberships which give members greater or lesser influence over the path of the standard (IGRS 2005). There are five categories of membership ranging from core member to observer. Core membership consists of the original five founding members of IGRS and the next top eight technology contributors. Core members have significantly more influence over the direction of the standard, including technology adoption, IP policy, and approval or rejection of protocols than other categories of membership (Author's Interview).

Interviewees stated that the major difference in membership categories came down to having to pay different levels of membership dues – higher categories of membership pay higher dues – and being required to participate more actively in the life and operation of the standard and its working group. Members which do not "actively promote" the standard in their products, submit technologies, evaluate proposals and work to build the brand awareness of IGRS will not be eligible to become "promoting" or "core" members. To date, no foreign firms have become core members, although there are several now at the promoting member level including Korea's LG and Cisco. The stability of the core membership committee makes it clear that the group is unlikely to change in composition. Interviewees also noted that a representative from CESI sits on the core members committee as well, serving in his capacity as the state representative. While membership is open to any companies, the core membership committee – with significant influence over the strategic direction of the standard is effectively closed. This limits the number of firms able to strongly shape the standard and means certain actors have greater ability to push their interests in the standard, and the market for goods which ensues.

IGRS's approach to intellectual property is designed with the interests of China's major electronics manufacturers in mind. Having historically been subject to expensive licensing fees from foreign enterprises and experienced difficulties securing non-discriminatory licenses in the past, IGRS's constitution mandates that members allow non-discriminatory licensing of any technology they contribute to the standard (IGRS 2005). Further, "contribution" means full disclosure of potentially relevant patents, all of which will be available for license. In order to facilitate non-discriminatory licensing and make it easier to spread IGRS, the working group and its incorporated entity are also trying to develop a patent pool. Again based on the negative experiences of China's manufacturers, the IGRS patent pool will publish all relevant licensing fees early and clearly, making it possible for would-be adopters to know in advance the exact costs of making standards-compliant products.

As further evidence of the influence of China's position in the global economy, IGRS sets low rates for licenses. While there is no official policy in the IGRS constitution mandating low license fees, the members seek to disseminate their technology as widely as possible. It is therefore seen to be in members' self-interest to keep rates low. As the member firms, particularly the top contributors have invested significant resources – and received significant state support – in developing their technologies for IGRS, all see it as in their interest to have the electronics industry worldwide adopt the standard. In order to overcome resistance, firms thus demand low costs in order to encourage adoption within China and elsewhere.

IGRS is not a closed standard but its leadership group – the 14 member Core Members Committee is stable and exclusively Chinese (IGRS 2012).[44] Any actors, however, whether a member (at any level) or not may contribute technology and proposals to the standard. Furthermore, many small firms have joined IGRS as regular members or observers without any technology or expertise to contribute at all. They use the standard as a networking opportunity to meet with high level managers in China's leading electronics companies, thus increasing the opportunity to get noticed and form partnerships. In interviews, it appeared that this coordinating function was one of the greatest contributions of IGRS to China's electronics industry. The market which is emerging for IGRS products will ideally be highly competitive and open due to low licensing fees and mandatory non-discriminatory licensing of technology. At the same time, however, the Chinese state will continue to shape the standard through its representation on the Core Members Committee and by lobbying with the dominant large firms to ensure the standard promotes China's broader interests both in the electronics industry and in international standards forums.

[44] One of the core members, ASTRI, the Hong Kong Applied Science and Technology Research Institute, is not incorporated in the Mainland but has a wholly owned Shenzhen subsidiary established in 2008 to cultivate its research consulting and contract business with Mainland China.

After being approved as a joint ISO/IEC standard suite in 2012, the scope for IGRS is global. Firms anywhere in the world are permitted to utilize the standard and produce goods compliant with the terms of the protocols – so long as the necessary licensing fees are paid. To date, however, the standard has not yet found a large market. One of the major problems, as with all “network of things” technologies, is lack of understanding of what it is, and what value IGRS adds on top of existing basic home or office wireless networks or Internet-based sharing and backup tools. Just as with TD-SCDMA, international approval of the standard has drawn increased attention to China’s growing technological innovation capabilities, but this has not translated into increased demand for the products. Indeed, ISO/IEC has opted to approve multiple standards for the same types of technology, thus limiting the market-creating power once wielded when only a single standard would be created. Interviewees stated that resistance to IGRS stems mostly, as it has for many of the standards discussed here, from China’s position as an IP taker without a reputation for innovation or quality technology creation. Even within China, there has been limited acceptance of IGRS. Building a market will require greater state push to stimulate demand or else greater action by China’s leading firms to create an environment attractive enough for other firms to begin producing for and consuming IGRS.

Audio-Video Standard (AVS)

AVS is the Chinese standard for sound and video encoding, decoding and compression. The standard competes with the dominant international market for MPEG-4 devices in the optical storage media such as Blu-Ray Discs or disc-based game systems such as the Microsoft X-Box, digital downloadable media including online embedded sound and video as well as digital broadcast media for television and mobile applications industries. Standards like AVS and MPEG translate the analog sound and light waves of audio and video recordings into digital format (1s and 0s) which can be easily compressed and stored on media such as CDs and DVDs. Compressed data in digital format can also be broadcast much more efficiently than analog signals. Both AVS and MPEG-4 (sometimes referred to as AVC) are successors to the long-standing MPEG-2 standard which dominated digital media formats through the 1990s and into the 2000s. The MPEG standards are the product of the Moving Picture Experts Group, a joint committee under ISO and IEC, established in 1988 to coordinate standards for video compression and transmission (MPEG 2010).

Compared with MPEG-2, both AVS and MPEG-4 have much greater compression capabilities (so more data can be stored per unit space on a disc). This enables not only smaller discs but also greater sound and video quality as more information can be stored in the same amount of space. The AVS standard is comparable to the international MPEG-4 standard. MPEG-4 is officially known as H.264 and was developed jointly by the ITU-T Video Coding Experts Group and the ISO/IEC JTC1 Moving Picture Experts Group. Both AVS and H.24 have similar compression and image quality characteristics. Test results showed that AVS technology was twice as efficient in data compression as the MPEG-2 standard, thus making it comparable to H.264 (AVS 2012).

AVS was developed using contributions from multiple sources in a collaborative working group. However, unlike H.264 which is dominated by representatives of major electronics firms, roughly half of the intellectual property contributed to AVS has come from Chinese universities and government research institutions. H.264 was initiated by the existing joint ISO-IEC technical committee as part of its ongoing standardization work. In contrast, when the AVS development effort was initiated in 2002, the major contributing members were all university labs or research institutes, all of whom had existing projects in audio and video encoding technologies. Chinese firms, while active in the production of equipment using similar encoding technologies such as those in AVS, had only weak research capabilities. As a result, they did not contribute much technology to the standard.[45] AVS was a state-initiated standards development effort led by government actors in the form of university labs. Participation by firms was highly limited.

AVS began through the separate efforts of researchers in different universities and government research institutes. Throughout the 1990s, different research groups had conducted work on compression, encoding and decoding technologies for audio and video. In the early 2000s, Chinese manufacturers came to dominate production of electronics, especially digital video players. Despite dominating world output – some seventy-five percent of world DVD player production by 2003 – Chinese manufacturers faced a severe profit squeeze from licensing fees charged by MPEG-2 and the international DVD alliance (Kanellos 2004; Linden 2004). Each MPEG-2 capable device had to pay a $2.50 license. The DVD alliance (including its encoding and compression technologies) charged an initial license fee of $21.00 per player. Licensing fees became the most expensive part of the wholesale price of a DVD player.

In light of these difficulties, the Ministry of Information Industry launched an initiative under its Department of Science and Technology to create an inexpensive Chinese alternative to the established compression technologies. The Department of Science and Technology provided funding, set up the initial working group, and coordinated related industrial activity. The Ministry's goal was to sponsor creation of a technology comparable to the next generation MPEG standard and significantly better than the MPEG-2 standard while charging less than either of the international standards for licenses. Building on the existing research from different institutes, the first version of AVS was submitted to MIIT in January 2005. The draft was approved as an industry standard in April that year.

[45] Although not the major initial contributors of technology, companies have joined the AVS working group and industry alliance. Today, the AVS group has 91 members of which 20% are universities.

How has AVS shaped the market for digital compression technologies and digital electronics in general? For IP, AVS takes an approach unique even within China. While the official policies of the AVS alliance only call for a standard RAND commitment from firms which list relevant technologies, the group in practice favors RAND-RF or listing standards essential patents in its newly created patent pool (AVS 2004; Author's Interviews). Since the 1990s, MPEG has also used a patent pool managed by the MPEG-Licensing Authority to handle licensing payments and set the terms of a license. While the H.264 patent pool contains nearly 1000 patents in over 100 patent families, AVS has only 50 patents in its patent pool. Some of the difference in number may be attributed to the age of the respective standards. JTC-1 (the MPEG development group shared by ISO and IEC) has been in existence since the 1980s. Over 20 years, the group has accumulated significant intellectual property. However, AVS participants claim that a significant portion of the so-called essential patents in the H.264 patent pool is actually unnecessary. Many of the technologies in the pool – which licensees must pay for – are only incrementally different from existing embedded IP or are actually not essential to the standard. This means the patent pool, managed by MPEG-LA forces licensees to pay for large number of unnecessary patents.

In contrast, the AVS working group claims to have far more stringent requirements for the inclusion of technology in the patent pool. Only truly unique and essential patents are included in the pool. Further, the price for licenses of all patents in the pool was announced even before the AVS standard had been completely developed. This meant that would-be adopters could know ex ante the real price for using the standard. In contrast, the hard IP norms of H.264 and its contributors meant the MPEG standards would be developed with only a RAND promise without detailing the actual or potential costs involved.

In the case of the AVS standard, Chinese enterprises have utilized two strategies to shape IP in the market for compression technologies. The AVS working group policy is to include essential technologies in a patent pool which will charge a low flat rate (initially about $0.12 per device) for adopters. In response to the low rate charged by AVS, MPEG-LA set a new, significantly lower rate for Chinese manufacturers using the MPEG-4 standard. While MPEG-2 charged $2.50 per device, AVC's rate was $0.15. Interviewees agreed this was in response to the competitive challenge from the Chinese standard. By setting a low royalty rate, the Chinese were able to force a foreign competitor to lower their rates as well. Thus, whether a manufacturer uses AVS or AVC, they will pay significantly less than they would have otherwise. Further, AVS licenses are free for content providers and broadcasters whereas MPEG requires payment up to $6.5 million for licenses to broadcast content using the AVC standard.

AVS, as an attempt to create an alternative to an established international standard and technology was largely closed to foreign participation. Officially, the AVS alliance and its associated working groups are relatively open, with the only stipulation being that members must be in China. The constitution of the AVS working group states: "Any unit or organization that is registered in Mainland China and is an independent legal entity under Chinese law may apply to be Official Member at will, provided it agrees to abide by this Constitution" (AVS 2004).[46] Entities not registered in Mainland China may only seek observer membership. Furthermore, the status of "registered in Mainland China" is somewhat ambiguous. Interviewees noted that it was not clear whether this meant an enterprise had to simply have sales or representative offices in China or if this meant having a locally incorporated subsidiary, preferably engaged in R&D which was being patented in China (Author's Interviews). In terms of membership in AVS, the constitution notes that there is a difference between being a "full" and "observer" member: the right to vote. Observers may attend meetings and even contribute to the

[46] In contrast, voting membership in standards bodies such as IEEE's 802.11 local wireless networking working group is awarded to individuals, not enterprises. Gaining voting membership is simply a matter of attending 2 out of four consecutive plenary meetings and paying the meeting fees. At the next meeting, an individual can vote IEEE. (2012). "About IEEE P802.11 and How to Participate.".

development of the standard but do not have a vote in the incorporation or rejection of a given technology submission or draft protocol.

Having begun as research in universities and government research institutes, AVS remains close to the state. It is thus in some ways considered a strategic project designed to break the control foreign IP holders hold over standardized technologies in digital electronics. In the early years of AVS, representatives from MPEG visited China to discuss incorporating AVS technology and the entire working group into the broad MPEG working group structure. AVS refused, insisting on keeping the technology and standard distinct.

While development of AVS is largely closed and restricted to outsiders, the licensing of the standard is truly non-discriminatory. Any actor willing to pay the license rate may utilize the technology. This has been instrumental in building domestic support for the standard and its technology. Today, the market, while still utilizing only Chinese technology and led by Chinese developers, is open to all comers. It has since found increasingly wide market acceptance, including by China's local and provincial television broadcasters, for whom the free licenses are highly appealing. Although H.264 has much lower fees than the previous generation, for broadcasters, the costs can still be onerous, thus making AVS appealing. A limit to the acceptance of AVS is among very large Chinese firms. In particular, China's three mobile telephony operators have all opted to use H.264 as the basis for their IPTV transmission. For these firms – the most profitable SOEs in China – the license fees required by MPEG-LA are not considered a problem (Author's Interview).

The scope of AVS is limited by the same problems plaguing most countries in the IP Taker category of the global economy. Chinese manufacturers are recognized as sophisticated, inexpensive and able to produce high quality goods. However, Chinese technology is generally seen as backward, especially when compared with existing internationally developed standards. That IEEE cannot legally make standards in China's system also limits the ability to cooperate with the international standardization apparatus in this industrial area. The result collectively is that AVS has found a welcome market within China but a weaker one overseas. China's market for compression technologies remains open, however. Most compression chips now support both the H.264 suite and AVS. This means AVS must solely compete on price with the better established international standard. So long as China remains seen primarily as a manufacturer, it will be difficult for Chinese technologies to take root outside of China or supplant established technologies – especially those made through no long-standard and established permanent working groups.

Conclusion

As a latecomer to the world of technology standards, China presents a case quite different from those of the United States and Europe. China is not yet a developed IP-Creator able to set international standards by virtue of its early movement in technology or single market unity. At the same time, however, China exhibits similarities to Europe in the power and influence of the state over the standardization process. Like France in the 1960s and ETSI in the 1990s, China's government attempts to build markets for technology in order to advance the interests of Chinese firms. At times such as with TD-SCDMA and WAPI, this involves creating a protected market with a dedicated source of demand. In other cases, the state acts on behalf of IP Taker enterprises to pressure IP holders – both foreign and domestic – to offer low licensing fees. This helps improve the competitiveness of Chinese firms, even without their taking control over or creating entirely new markets of their own accord.

China's institutions of standardization place the state at the center, making it the initiator, financer, and leader of most standardization projects. Accordingly, the state is able to wield great influence over technology markets – especially as regards shaping IP norms to encourage low priced licenses and creating protected markets when desired or necessary. China's position in the global economy is such that its firms emphasize manufacturing and treat intellectual property as just one among many industrial inputs. The state acts on their behalf to encourage inexpensive domestic licensing and to pressure foreign IP holders, even in standards to which China contributed no technology of its own, to lower their rates for Chinese firms. China's position in the global economy also means that it has a strong desire to create its own internationally competitive technologies – a project whose responsibility falls upon China's powerful state.

CHAPTER 5

CONCLUSION

Technology standards at first seem unglamorous. They are derived through complex processes of negotiation, testing, examination and debate by engineers speaking an obscure tongue. Else, they are the product of dynamics specific to firms or small groups of firms – often as a black box. Standards themselves are collections of protocols, hundreds or thousands of pages in length, which few but engineers can hope to understand or appreciate. So why study them?

Simply stated, standards matter since they build markets. They do so through reducing transaction costs, increasing the size of potential customer bases and reducing uncertainty over future trends in the market. Scholars have long looked at other institutions and policies believed relevant for the creation, operation, and sustaining of markets. Hence, it is only logical to look at standards as well.

What makes standards so interesting is that they are explicitly politically created. Standards are the product of negotiations among actors with very different perspectives and preferences. These negotiations are political insomuch as not all actors have the same level of influence in the standardization process. Some have no seat at the table at all. Others are prominently at the head of the table and direct the discussions. Since standards are politically created, this means that markets for technologies, influenced as they are by the defining characteristics of standards, are politically determined as well. The process of standardization sets the terms for competition in the market, arranges the distribution of gains, and the scope of the market. By setting these terms, in a way technology standards actually rig markets to the advantage of some and the detriment of others.

To recap where we have been, the link between standards and markets for technologies involves three steps. At the far left are the ultimate causal independent variables: historical institutions and a country's position within the global economy. It is these variables that determine outcomes in standardization. Historical institutions determine which actors are involved in technology standardization and their relative level of influence over the process. Specifically, historical institutions determine the level of influence that the state wields over standardization. Strong states are able to build markets by mandating standards or coercing firms into following one technology or other. Weaker states must allow firms to decide for themselves which technologies to standardize. Position in the global economy determines the perspectives of these actors – whether government or firms – concerning the proper role for intellectual property in markets and the balance between monetization of IP and production in seeking profits.

Specifically, these independent variables determine the values of our intervening standardization variables: intellectual property policies, openness and scope. These then dictate the values of the same variables in technology markets – the dependent variable in this dissertation.

To test this model, this dissertation examined case studies in the United States, Europe and China, exploring how their different standardization systems and positions within the global economy determine their approaches to standardization and hence the characteristics of their markets for specific technologies. The case studies do not suggest that there is an ultimate golden standard for standardization. Each of the national approaches is able to produce standards which then shape markets for those standardized technologies. However, the nature of those markets varies widely.

Bringing it Together: the Cases of Japan and Korea

This model and approach is not limited to the case studies from whence it was derived. It also can shed light on the performance of other states which produce their own standards. Naturally, this is a somewhat limited set of cases on which to draw as most countries in the world are neither active participants in standardization nor even involved in the process in more than a peripheral manner. There are a handful of other countries which have taken an interest in technology standardization as a means of shaping and building markets for technologies with the intent of security sustained competitive advantages or growth for their economies: India, Brazil, Russia, and Taiwan to name a few (NationalAcademies 2012).

This dissertation often mentioned the case of Japan in its discussions of the political economy of standardization, particularly as regards the impetus for created global norms of volunteer and open standards under the WTO. Japan provides an interesting case of a technologically sophisticated country that owing to its predilection for protection, developed closed standards which limited their scope to the domestic market, thus building highly sophisticated but limited markets within Japan (Funk 1998; Funk and Methe 2001; Funk 2002; Funk 2006; Kushida 2008; Kushida 2011). As foreign participation was discouraged and institutionally difficult – the technology sharing agreements among Japanese firms largely barred foreign firms from participating – there were few parties interested in spreading Japanese standards worldwide. The markets thus remained restricted to Japan. In the long run, Japan's emphasis on closed and limited standards isolated the country, cutting it off from developments in global ICT – based on different standards – and severely harming the competitiveness and position of Japanese firms. Similar problems took place in France in the 1980s and 90s as emphasis on indigenous standards such as Minitel isolated the country and its firms from developments in the emerging Internet.

In mobile telephony, Japan's loss of status has been particularly egregious. Japan was the first country to deploy commercial mobile telephony using an analog standard called NTT, doing so in 1979. It was also able to develop two versions of second generation mobile telephony, both ideally suited to Asian market conditions of dense cities with high concentrations of would-be simultaneous users. It also developed a core portion of the third generation technology which would be incorporated with European technology as WCDMA. Throughout this time, however, Japan's approach to standardization was based on its history of forming cooperative bodies of Japanese firms to conduct research, share technology, and commercialize new products. The sharing of technology was limited to Japanese firms with comparably-sized patent pools. This approach to standardization privileged Japanese firms to the near total exclusion of foreigners. The result was foreign firms developing their own alternative standards, often in large consortia and promoting these worldwide. By the 4th generation of mobile telephony, Japan's technology contribution had become insignificant. Of the major patent contributors to the 4G LTE standard, Japan only had one major firm, NEC, which only contributed approximately 0.5% of the patents by value. In comparison, China's firms Zhongxing Telecom and Huawei contributed a total of 6.6% of the patents by value (LG 2012).

The same data set reveals how careful attention to and participation in standards has greatly facilitated the economic upgrading and growth of a country. When compared with the other major participants in technology standardization, Korea is a major late-comer. Indeed, Korea's emergence as a high-technology innovator has largely taken place since the 1990s. In the case of mobile telephony, Korea went from having almost no industry or R&D capability in the 1970s and 80s to becoming the second largest contributor of patents by value to the 4G LTE standard – some 33.5%, second only to the US's 42.3% (LG 2012).

Broadly speaking, Korea can be considered a developmental state (Amsden 1989). It has a strong government with a dedicated focus on promoting industrial development and sustained economic growth. However, unlike Japan – the archetypical developmental state (Johnson 1982) – Korea's science and technology policies and institutions have been externally oriented. Korea's government has been highly strategic in pursuing avenues for technology upgrading and raising the capabilities of Korean industry. An interesting illustration is the success of Korea in mobile telephony.

In the early 1990s, Korea's government began to consider issuing mobile telephony licenses to Korea's telecommunications operators. However, the government, in keeping with its developmental focus, wanted any such adoption to not only create a market for mobile telephony but also to facilitate the development of Korea's technological capabilities in this sector. Early negotiations with the GSM alliance – including Motorola, the leading patent holder unwilling to license or share technology with non-established firms – showed that while it would be possible to license GSM patents and so deploy a GSM system, it would not involve any technology transfer. On the other hand, Qualcomm was actively seeking partners for testing and development of its cdmaOne standard – particularly how it could integrate with existing wireline telephone systems (Yoo, Lyytinen et al. 2004). The decision to adopt cdmaOne within Korea was intended to create a single market for mobile telephony, as well as a platform with opportunities for innovation. The standard was relatively open insomuch as Korean firms were welcome to participate. The standard also had global reach as Qualcomm was aggressively marketing the standard in the US, China and elsewhere, thus meaning conforming to the standard would have a large market and many potential customers. Within Korea, as Qualcomm is not an equipment firm, Korean firms would have market dominance due to their position as standards developers, thus ensuring a solid revenue stream with which future investments could be made. The result was an integrated mobile telephony market in Korea, rapid penetration of mobile telephony and expansion of services at low prices.

By the 2000s, however, there was increasing fragmentation. As Korea and the rest of the world moved into the 3G and 4G era, mobile Internet became the new technology. However, there were no global standards for mobile Internet. Within Korea there were three separate incompatible standards in use. The result was, as the existing literature shows, a fragmented and inefficient market for mobile Internet in Korea. In keeping with Korea's state-guided but firm-led and externally oriented approach to standardization, the government created the Korea Wireless Internet Standardization Forum to coordinate efforts and develop a single standard for mobile Internet. With broad participation by Korean firms – operators and manufactures as well as research institutions like the Electronics Technology Research Institute – a single standard emerged – WIPI (Yoo, Lyytinen et al. 2004; Lee and Oh 2008). Korean firms, due to their broad participation all had a stake in the new market and ensured its success. At the same time, Korea's openness to the rest of the world meant the standard was compatible with both the WCDMA and CDMA2000 3G mobile standards then in use worldwide. By keeping open, Korea's potential market scope remained global.

Markets for mobile telephony goods in Korea have blossomed. Samsung and LG are globally competitive brands as well as producers of network technologies. The markets stemming from Korean standards in mobile telephony have facilitated strong revenue streams which have been plowed back into research and development, allowing Korea to rapidly emerge as a global force in telecommunications. Careful and strategic use of standards to create competitive and innovation-spurring national markets facilitated this accomplishment.

"The Wealth of Nations": Why We Should Concern Ourselves with Standards

Adam Smith's magnum opus – *The Wealth of Nations* concerned itself with the same question that mercantilists had addressed over the preceding centuries: how does a country secure national wealth, and accordingly, power. Unlike the mercantilists who saw the route to wealth through protection of markets, national monopolies and other uncompetitive approaches, Smith argued that openness and competition would bring wealth. It was the role of the state, Smith argued, to ensure that competition took place. Once this regulatory role was accomplished, the market would do the rest and secure prosperity for a country. Smith's insights remain relevant today. The question is how can and should states best ensure competition and market performance?

These questions are more relevant than ever in light of the current global economic climate. Growth and social well-being in the post 2008 Financial Crisis World seems to be increasingly elusive. While certain economic metrics (like stock market valuations) continue to show sustained success, the whole of the economy appears to remain weak – and is broadly perceived as such. Europe, despite its potential in good governance, strong human resources, and long-term familiarity with technology and innovation, has been underperforming in terms of setting and or leading international standards for the last decade. Many Europeans fear that their countries have lost their traditional areas of competitiveness in artisanal goods or heavy industry but have not managed to replace these industries with sustained competitiveness in high technology innovation. Europe as a whole seems to stumble from one debt crisis to the next while facing a growing wave of discontentment over the entire integration process. China is desperately seeking an alternative source of economic power to continue its growth and modernization. Part of this is the prosaic concerns of an economy that is outgrowing its old low-wage, capital-intensive model and needing to become far more efficient and knowledge-intensive. A second portion, however, is the question of national power.

This final point bears repeating as it is significant for all of the cases and indeed every country in the world. From a political science perspective, the goal of economics is to yield the wealth necessary for national power. American and European concerns over their lagging economies are based on fears of domestic social instability if the economy falters as well as concerns of losing their leading positions in the world, especially to rising countries in East Asia. Going back to the days of the Meiji Restoration in Japan, there has been a concept, repeated in China, Korea, and elsewhere that economic wealth and national security are inseparable. In the case of Japan and China, this was pithily summed up in the 4-character phrase: "富国强兵" – Rich Country, Strong Army (Samuels 1994). There is a healthy literature exploring the link between economic wealth and national power. For the purposes of this conclusion, however, suffice to say, countries have a profound and necessary interest in the health, sophistication, and relative position of their economies in the global economy. A country that is poor and peripheral, no matter the determination of its arms, will only be a bit player in global politics. Conversely, rich, sophisticated economies at the center of global industries wield enormous power and influence. From a realist perspective, it only makes sense to seek economic power since this is the root of security in an anarchic world. For mercantilists, it is simply about looking out for one's own and glorifying the motherland, even – or perhaps expressly – at the expense of others. Even for liberals who believe in a mutually beneficial global economy where all can benefit, there is an understanding that the "blessings of liberty" are only meaningful if the people are content – which is a function of wealth.

This dissertation has shown that standards determine the way that markets for certain technologies will form and the characteristics of those markets. Depending on the national vision for how to best acquire wealth and power – domestically and internationally – governments and industry will do well then to carefully consider their national approaches to standardization. While all approaches – formal and de facto, state-led and firm-led, closed and open – can produce standards, the markets they produce have very different patterns of distribution, degrees of technological sophistication and long-term viability.

This dissertation does not argue that there is a single ideal form for standardization. The literature is replete with scholars who argue for the merits of one system over another, typically arguing that there is a single "standard" to which all countries should conform if they wish to produce standards (Blind, Steen et al. 2009; da Silva 2010; Ernst 2011; Ernst 2013). Nonetheless, all methods of standardization are able to produce markets. However, countries are constrained by their history and position in terms of the types of technology markets they will produce.

To illustrate, in the United States, the attempt by NIST to set national standards for the smart grid in order to improve energy efficiency have proven highly problematic. While in the end, NIST may be able to create a standard, the difficulty will have shown through in the time it took to develop and implement the standard. This suggests that for technologies which require significant coordination across many actors or industries, the US non-state system of standardization has a difficulty creating markets.

In Europe, historical institutions have created a highly dirigiste system of standardization reliant on governmental bodies and EU-level formal organizations. However, there is evidence of efforts by the EU to reform its reliance on formal organizations and allow for greater industry leadership. Recent reforms to CEN and CENELEC permit the fast tracking of certain ICT standards which have already been approved by industry bodies – whether IEEE or an industry consortium. These reforms seek to gradually change the institutions of standardization in Europe, making them less reliant upon and beholden to state interests and the voices of multiple veto-wielding interest groups. By giving industry a more direct pathway to creating standards – while maintaining the overall standardization system with its emphasis on formal standards – Europe may be able to gradually shift norms more toward the leadership of industry and away from often cumbersome bureaucracies. Nonetheless, Europe will continue to emphasis balancing interests through formal standardization (Winn 2005).

China often struggles to balance its legally mandated state leadership over standardization and the traditional interventionist role for the government with a desire to promote independent technological initiative by firms. Efforts by groups such as CESI, however, reveal that there are approaches trying to increase the role played by non-state and non-academic actors in standardization. Through encouragement of firm participation – often facilitated by access to resources – China may be able to gradually shift away from state control toward a more firm- and industry-based technology standardization system. However, by law and tradition, China will remain highly statist in its approach to technology standardization. Markets will also reflect the position of China as an IP Taker meaning there will still be emphasis on inexpensive intellectual property, thus differentiating Chinese technology markets from those in the West.

Contribution to the Literature

For too long, standards have been viewed as a background condition which simply exist for markets, rather than as an active force for the creation of those markets. This dissertation has shown that not only are standards the basis of markets for technologies but that the politics of standardization helps determine the structure of those markets.

Since the 1980s, there has been economic interest in standardization as an end in itself – studying the conditions under which standardization can be expected to occur. It has been acknowledged that once there is general standardization of a technology, the nature of competition changes from one based on features and technological sophistication to one based on price. Standardization has been modeled mathematically, showing how different variables determine the likelihood of success – that is establishing a standard.

Unfortunately, the two literatures have never taken the next step, showing that standardization is an intervening variable between national institutions and the structure of the global economy and specific market features and structures for given technologies. This dissertation has drawn this connection, showing the salient aspects of standards which in turn shape the values of different market features.

In future research, this basic model and proposed theory needs to have hypotheses generated and tested. Do the predicted relationships hold true in all cases? Does the mechanism accurately show the relationship between institutions, standards and markets? Greater in-depth study of standardization in other industries such as automobiles, chemicals, and perhaps metals should further help to test this theory, based as it is on the

ICT industry. In less networked industries, do technology standards build markets in the same way? Are the same variables salient or are there other causal variables which determine the structure and performance of markets? Like all research, this dissertation leaves open many questions for future research. It has, however, shown the way into an entire new stream of quantitative and qualitative studies. This research will be particularly policy relevant as it concerns the institutions of standardization and how these work – and may thus be reformed – to shape markets. Better understanding and control over the process of standardization in different political economies will open new avenues for policy makers seeking to alter market outcomes and build national power and influence.

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