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Standards, innovation, and latecomer economic development: Conceptual issues and policy challenges ☆

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ABSTRACT

Little is known about the impact of standards on the economic development of countries which are latecomers to industrial manufacturing and innovation. Standardization is regarded primarily as a technical issue, and hence receives only limited high-level policy support.

However, technical standards contribute at least as much as patents to economic growth. As a key mechanism for the diffusion of technological knowledge and due to the dominant leadership by advanced countries in patenting, technical standards have emerged in latecomer countries as an alternative to patenting. However, latecomer countries and their firms have a set of capabilities and constraints that are fundamentally different from that of advanced countries and firms. This paper argues that latecomer countries should adopt assessment criteria that are more fitted with latecomer contexts which emphasize learning effects and building dynamic capabilities. The paper discusses current issues that are essential in understanding the rise of Asian countries in standardization. We also examine the critical role that patents play for standardization and argue that "strategic patenting" to generate rents from *de facto* industry standards can stifle latecomer economic development.

1. Introduction

There is an abundance of theoretical and econometric studies of how standards shape market competition, but most of these studies have focused on Western economies. And even for Western economies, fundamental public policy issues of standards setting remain grossly under-researched. According to two leading scholars of standards policy, "… [g]eneral

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agreement about appropriate public policy toward government standard setting does not exist. The most basic questions remain unaddressed" (Greenstein & Stango, 2007: pp. 1–2).

We know even less about the impact of standards on the economic development of countries which are latecomers to industrial manufacturing and innovation. Most of these countries are focused on upgrading their economies through innovation, as measured by patents. Standardization is regarded primarily as a technical issue, and hence receives only limited high-level policy support. However, China as well as Korea and Taiwan are now searching for ways to strengthen and upgrade their standardization systems and strategies.

In fact, standards contribute at least as much as patents to economic growth. As a key mechanism for the diffusion of technological knowledge, technical standards contribute to productivity growth. The macroeconomic benefits of standardization thus exceed the benefits to companies alone. For Germany, a widely quoted study conducted for the German Institute for Standardization (DIN) finds that a 1% increase in the stock of standards is positively associated with a 0.7–0.8% change in economic growth (Blind, Jungmittag, & Mangelsdorf, 2011).

But these econometric studies only scratch the surface. Equally important are qualitative impacts, for instance, of environmental, health, food and work safety standards. In fact, broad qualitative impacts of standards are essential for latecomer economic development – a well-functioning standardization system and strategy can work as a catalyst for translating new ideas, inventions and discoveries into productivity-enhancing innovation. Standards are the missing link in a growth strategy which seeks to create quality jobs in higher-value added advanced manufacturing and services (Ernst, 2013, 2011; Wang, 2013; Suttmeier, Kennedy, & Su, 2008). This poses an especially demanding challenge for countries which only recently begun to build up their standards systems and strategies.

Furthermore, rapid and disruptive technical change (such as the transition to the *Internet of Everything*[2]) creates new challenges for standardization. Of critical importance are *interoperability* standards[3] that are necessary to transfer and render useful data and other information across geographically dispersed systems, organizations, applications, or components (Gasser & Palfrey, 2013). Rising complexity and increasing uncertainty are two defining characteristics of the new world of ubiquitous globalization. Technology-based competition is intensifying, and competitive success critically depends on control over intellectual property rights and on "a capacity to control open-but-owned architectural and interface standards" (Ernst, 2002b: p. 330).

This process has increased the economic importance of standardization, but especially so for countries (like China and Korea) which are deeply integrated into international trade and global corporate networks of production and innovation (Ernst, 2009, 1994; Ernst & Kim, 2002). A fundamental driving force is the global fragmentation of production[4] where firms from late-industrializing countries initially at least act as contract manufacturers or, at best, fast followers in innovation. Latecomer firms are naturally disadvantaged in the world of international standards as they have not contributed the 'core technology' on which these standards are based. Their capabilities do not lend themselves to the shaping of system architectures. Latecomer firms are thus forced to accept standards and pay royalties as decided by the dominant economic players. On the other hand, firms which specialize in core technology development and contribute significant resources to ensuring their solutions are codified in standards will have strong market positions.

In short, it is necessary to strengthen our understanding of how standards are created and used in countries with economic institutions that differ from those in Western economies. Particularly, we need to place the current issues of standardization in the larger context of economic development in latecomer countries that seek to catch up with the productivity and income levels of the US, the EU and Japan.

This paper is organized as follows: In the next section, we contemplate why standardization is important in latecomer countries. Next, we raise the challenges faced by latecomer countries in their quest for technology standardization, including standardization tasks, the capabilities and strategies required. In so doing, we demonstrate that the costs of developing and implementing effective standards can be substantial, especially for latecomer countries. We further argue that based on the conditions and the constraints, successful standardization poses a different challenge for latecomer countries than for advanced countries. Developing these arguments, Section 4 explores the role of intellectual property rights for economic development and highlights the tension between standards and innovation. After examining the critical role that patents play for standardization, we also argue that "strategic patenting" to generate rents from *de facto* industry standards can stifle latecomer economic development. The paper concludes with policy implications.

[2] "The Internet of Everything" brings together people, process, data and things to enhance the relevance and productivity of networked connections – turning information into actions that create new capabilities, richer experiences and unprecedented economic opportunity for countries, businesses, communities and individuals.

[3] Standards shape innovation trajectories in all industries. Standards however are of critical importance in information and communications technologies (ICT) industries, particularly in relation to innovation, patents and other IPR issues. Therefore this paper is mainly concerned with standards and standardization in ICT industries.

[4] On the proliferation of global production networks (GPNs) and global innovation networks through fragmentation, see Ernst, D. (1997). *From partial to systemic globalization. International production networks in the electronics industry*. Report prepared for the Sloan Foundation, jointly published as The Data Storage Industry Globalization Project Report 97-02. Graduate School of International Relations and Pacific Studies, University of California at San Diego, and as BRIE Working Paper #98, Berkeley Roundtable on the International Economy, University of California at Berkeley, http://brie.berkeley.edu/publications/WP%2098.pdf; and Ernst, D. (2007). Innovation offshoring: root causes of Asia's rise and policy implications. Chapter 3 in: In Palacios, Juan J. (Ed.), *Multinational corporations and the emerging network economy in the Pacific Rim*. London: Routledge, co-published with the Pacific Trade and Development Conference (PAFTAD), London: Routledge.

2. Why standardization matters for latecomers

There are an almost infinite number of standards that differ in their form and purpose. To shed light on the evolving tasks of standardization, we first need to open the black box of standards and introduce an operational definition. A state-of-the-art definition that serves our purpose well is provided by the National Institute of Standards and Technology (NIST) as part of its Smart Grid Interoperability Standards project (NIST, 2010: pp. 19–20): Standards are

> "…*[s]pecifications that establish the fitness of a product for a particular use or that define the function and performance of a device or system. Standards are key facilitators of compatibility and interoperability.* … Interoperability…[is].. *the capability of two or more networks, systems, devices, applications, or components to exchange and readily use … meaningful, actionable information – securely, effectively, and with little or no inconvenience to the user.* … [Specifically, standards] *define specifications for languages, communication protocols, data formats, linkages within and across systems, interfaces between software applications and between hardware devices, and much more. Standards must be robust so that they can be extended to accommodate future applications and technologies.*"[5]

In the literature, standards are normally categorized as 'proprietary' versus 'open', and as '*de facto*' versus '*de jure*' (Stango, 2004). Proprietary standards are owned by a company that may license them to others, while open standards "are available to all potential users, usually without fee" (Steinfield, Wigand, Markus, & Minton, 2007: p. 163). *De facto* standards achieve adoption through standards competition among rival standards consortia. Finally, *de jure* standards are adopted through consensus, which is sometimes formally expressed through industry committees or formal standards organizations.

At the most fundamental level, standards help to ensure the quality and safety of products, services and production processes, and to prevent negative impacts on health and the environment. Hence, an important function of standards is to reduce "risks for makers of compliant products and users of these products." (Alderman, 2009: p. 2, 3)

In addition, standards enable companies to reap the growth and productivity benefits of increasing specialization, analyzed long ago in chapter III ("That the Division of Labor is Limited by the Extent of the Market") of Adam Smith's "*The Wealth of Nations*" (Smith, 1776/1970, Book One, chap. III). According to economic historian Charles Kindleberger (1983: p. 378, 379), "… [f]or the most part, standardization was originally undertaken by merchants to facilitate a progressive specialization through trade."

Today however, specialization extends well beyond trade into manufacturing and services, including engineering, product development and research. Equally important is the international dimension. As globalization has been extended beyond markets for goods and finance into markets for technology and knowledge workers, standards are no longer restricted to national boundaries. Standards have become a critical enabler of international trade and investment – they facilitate data exchange as well as knowledge sharing among geographically dispersed participants within global corporate networks of production and innovation (Ernst, 2005a, 2005b). As network sociologists emphasize, the "creation and diffusion of standards underlying new technologies is a driving element of contemporary globalization" (Grewal, 2008: p. 194).

In short, standards are the lifeblood of innovation in the global knowledge economy. Today, standards are necessary not only to reap economies of scale and scope, but also to reduce transaction costs and to prevent a duplication of efforts. In addition, standards are required to enable data transfer and knowledge exchange and to facilitate interoperability of components and software within increasingly complex technology systems (e.g., a smart phone or a switching system). Without interoperability standards, it would be impossible to achieve 'network externalities' which shape competition in markets for products and services that use information and communication technologies (Katz & Shapiro, 1985). In these markets, "…[a]s the set of users expands, each user benefits from being able to communicate with more persons (who have become users of the product or service)" (Rohlfs, 2001: p. 8). 'Network externalities' imply that a company succeeds "when customers expect that the installed base of … [the company's] … technology [will] become larger than any other," with the result that the customers "adopt that technology to the virtual exclusion of others" (Sheremata, 2004: p. 359).

Developing these interoperability standards is a moving target. The challenge is to allow for a continuous adjustment to cope with technical progress. Take the example of the rapidly evolving processor technology that drives the world's computers. The central processing units (CPUs) made by Intel and AMD under Intel's "x86" designs are now rivaled in importance by graphic processing units (GPUs) as PCs are used for multimedia tasks. For a computer company to use the GPU technology, it needs at least three things: "a license … [from Intel] … to the "x86" design of the CPU, a clear agreement about interoperability between the GPU and the CPU, and finally a strong enforcement mechanism—with clear standards and a timetable for prompt resolution of disputes."[6]

To cope with these critical challenges, standardization has become a complex and multi-layered activity that involves multiple stakeholders who differ in their objectives, strategies, resources and capabilities. Most importantly, standardization is a highly knowledge-intensive activity that requires well educated and experienced engineers and other professionals.

[5] For a recent analysis of interoperability standards, see Palfrey, J., & Gasser, U. (2012). *Interop. The promise and perils of highly interconnected systems*. New York: Basic Books.

[6] David Balto, a former antitrust attorney at the Federal Trade Commission, quoted in "Intel Nears Settlement in Market Abuse Probe," *Financial Times*, July 21, 2010, 15.

While engineers originally created this discipline, key concepts are now shaped by legal counselors as well as corporate executives and government officials.

A dynamic analysis is required to capture the continuous changes and adjustments in the processes of standardization. A fundamental insight of Schumpeter's "creative destruction" theory is that economic institutions incessantly need to adjust to changes in markets and technology (Schumpeter, 1950). This implies that there is no one best way of organizing standardization. According to the American Engineering Standards Committee Yearbook of 1925, "… [s]tandardization is dynamic, not static. It means, not to stand still, but to move forward together" (Russell, 2005: p. 247).

This fundamental insight still holds today, but unfortunately there is a tendency in current debates about standardization to neglect this dynamic aspect. Standardization systems are in constant flux, and one needs to apply this fundamental insight to the study of contemporary standards systems, and this is true for an advanced economy like the US and a latecomer economy like Korea or China.

In fact, the need for standardization is more visible in latecomer countries where 'institution-voids' are present. Institution-voids are referred to the situation where necessary institutions to facilitate transactions are absent (Khanna & Palepu, 1997). Without standards, a high level of discretion shape business decisions, as firms cannot make a proactive plan for investments. The market in such a situation fails to function due to the lack of interoperability. At the social level, such discretion often leads to corruption, and a clan with greater political connections wins the competition. Standardization thus helps to stabilize the society by manifesting the legitimate and consistent guidelines. By doing so, economic actors benefit from less uncertainty and more transparency and, hence, distortion in domestic income allocation can be mitigated (Blind, 2004).

At the international level, latecomer countries are still a minority group in the standardization community. As for innovation, latecomer countries are way behind advanced countries and, as a result, they have paid out technical royalties to advanced countries (Kwak, Lee, & Fomin, 2011). As technologies become more complex and inter-related, advanced countries have pre-empted fundamental technologies by aggressive patenting. In this situation, standardization can be considered by latecomer countries as a solution to technological dependency caused by the laggard status in innovation (Wang, Wang, & Hill, 2010). By investing in standardization, latecomer countries make their products and services compatible with overseas standards, promoting commodity and service trades. Also, standardization provides latecomer countries with an opportunity of being able to lead global innovation if they successfully integrate local standards into international ones (Kwak, Lee, & Chung, 2012). Then latecomer countries can also participate in creation of a paradigm, which has been dominated by advanced countries.

Yet latecomer countries have capabilities and constraints different from those of advanced countries. Latecomer countries thus need to pursue a different approach to standardization than advanced countries, as discussed in the following section.

3. Tasks for latecomer standardization: corporate and national approaches

As standards created by latecomer countries have only recently begun to play a role in international standardization, we need to examine the specific tasks for latecomer countries. Three aspects are distinguished: tasks of standardization, capability sets and standardization strategies.

Standardization requires a variety of tasks, not necessarily in sequential order. First of all, an organization may need to conduct a cost–benefit analysis of whether to adopt existing international standards or whether to create a new standard. Yet the most costly tasks are the development of relevant technologies to support the standard, and the payment of licensing fees for essential patents (both for the existing standards and for newly created standards). Administration costs for testing, conformity assessment and certification are also huge.

If the country decides to create a standard, it should estimate costs or risks of including one's own patents into a standard. Patent pool management is also necessary. Finally, the organization should offer back-end supports. Other standardization-related administrative tasks include paying for membership fees for formal and informal standard development organizations or logistics costs for administration. Sometimes political activities are required, for example, litigation or lobbying. In case of litigation, legal costs in the United States can easily run into the hundreds of millions of U.S. dollars. In China, however, while costs of patent litigation are rising, they still remain significantly lower than in the United States.[7] As demonstrated by Ernst and Kim (2002), latecomer countries have benefited from varying types of learning including reverse engineering. Similar learning effects need to be realized when latecomers seek to strengthen their standardization capabilities.

In order to undertake the standardization tasks, a set of capabilities are required (Table 1). Yet the capabilities of latecomer countries are fundamentally different from those of advanced countries. For example, advanced countries have a long history of standardization, a proven ability to operate successfully within standardization bodies and to shape international standards, a fairly diversified production and innovation system, and a broad base of accumulated knowledge

[7] Top judgments (or settlements) range from RMB 30 million to RMB 157 million. Top cases include domestic firms litigating against foreign firms, with only one top case of a foreign firm litigating against a domestic one. (Interview with Zhang Yan, IBM senior counsel international property law, April 8, 2010.)

Table 1
Standardization tasks.
Source: Ernst (2013) drawing on interviews with leading standards experts in the US, the EU, and China.

1. Develop the technology to support the standard
2. Cost–benefit analysis of whether to adopt existing international standard or whether to create a new standard
3. Licensing fees for essential patents (both for existing standards and for newly created standards)
4. Pass testing, conformity assessment, and certification
5. Membership fees for formal and informal standard development organizations
6. Logistics (travel etc.)
7. Cost/risk of including one's own patents into a standard
8. Patent pool management
9. Back-end support
10. Legal (litigation)
11. Lobbying

and intellectual property rights (IPR) that helps to generate product and process innovations. They thus are able to "control much of the technological input necessary to meet the standards" (Pai, 2013: p. 5). As a result, a primary concern of law and policies in advanced countries is the protection of IPR, and the "openness" of standards is subordinated to IPR protection.

In contrast, latecomer countries are relatively new to standardization. Most latecomer countries are standard takers, manufacturing products that are developed and standardized by advanced countries. Latecomer countries still have to learn how to operate successfully within standardization bodies. Most importantly, they still have a long way to go to establish a fairly diversified production and innovation system and a broad base of accumulated knowledge and IPR that would allow it to shape or at least co-shape international standards. In latecomer countries, laws and policies are focused on economic development and the diffusion of knowledge inherent in IPR. Standardization is viewed as an enabling platform for innovation and latecomer economic development.

Given the different set of capabilities, countries and companies can choose one of the following standardization strategies, or a combination of them: free rider, fast follower, co-shaper, or leader. Free riders are referred to as those who let others develop standards and save costs; fast followers get existing standards fast so that products with the standard's technology can be deployed quickly; co-shapers adjust existing international standards to suit a country's specific needs, and deploy these adjusted standards in current and future products, and; leaders create new standards and embed own essential patents in the standard. Advanced countries and their leading firms are likely to pursue standards leader or co-shaper strategies, while latecomer countries and firms will initially focus on free rider or fast follower standardization strategies. When latecomers start shifting to leader or co-shaper strategies, a higher level of capabilities is required that the level of capabilities they need to cope with the challenges at the earlier stages.

The diversity of standardization capabilities and strategies explains why there are significant differences in the organization and governance of standardization processes. These differences reflect discrepancies across industrial sectors in technology, demand patterns and competitive dynamics. But standardization processes also differ across countries, reflecting the underlying conditions of population, resources, technological capabilities, products and tastes. Standardization processes reflect peculiar characteristics of a country's economic institutions, its level of development, its economic growth model, as well as its culture and history (Kindleberger, 1983: p. 383). There lies a difficulty with developing a strategy or policy for latecomers' standardization.

Unfortunately, an important weakness of the standardization literature is that we still lack systematic research that compares different national standards systems and their divergent development trajectories.[8] Existing comparative studies are focused on the American, the European and the Japanese standardization systems, neglecting important developments in latecomer countries like Korea, India, Brazil, and, most importantly, China.[9]

4. Latecomer standardization in a new style

Although the success in standardization depends upon country-specific conditions, the goals of standardization can be compared between advanced countries and latecomer countries. For example, it has been generally known that in the US, where standards are developed primarily by private firms, success is typically defined by commercial criteria, like market share, return on investment, and rents that innovators can reap from a particular technology (Ernst, 2013).

In contrast, latecomer countries have sought a definition of success that links standardization to the broader challenges of innovation and economic development.[10] Because latecomer countries have pursued standardization to reduce dependence on advanced countries (a passive goal) and to compete against advanced countries (an aggressive goal), the

[8] There are of course many specialized data bases for engineers that comfffpare technical standards for particular technologies. But very little research exists that compares institutional arrangements and strategies that shape different national standards systems.

[9] An example of this outdated view of the global map of national standards systems can be found in Mattli and Buethe (2003). See however Lee and Huh (2012), and a new project by the *National Academy of Sciences* that seeks to compare different national systems of managing intellectual property in standard development organizations (http://sites.nationalacademies.org/PGA/step/IPManagement/index.htm).

[10] The following definition of success draws on Ernst (2011).

most desired approach for latecomer standardization is through learning. Several latecomer governments have manifested indigenous innovation as a policy guideline for standardization. In essence, therefore, a standards project will be considered a success in latecomer countries if it maximizes learning effects and standardization capabilities. As an extension of this argument, a simple static assessment based on the cost–benefit analysis is not desirable because latecomer countries expect enhancement of innovation capability which requires a longer-term to take effect.

In latecomer countries, learning from best practice standardization approaches may broaden the scope for innovation by avoiding technology lock-in through dominant foreign standards.[11] One characteristic that typically appears in the process of latecomers' capability building is competition with foreign standards and foreign firms frequently discourage the dynamic capability building by latecomer countries. Therefore, constraining strategic patenting by owners of essential patents that could block innovation should be considered in a latecomer context as one of the criteria to assess success in standardization.

This broader definition of success has important *policy implications*. The international community should acknowledge that the challenges faced by latecomers are significant and that one should not always apply the same criteria in judging the performance of latecomers as one would in judging that of the advanced industrial economies. In light of very different political and economic institutions, it is unrealistic to argue that latecomers should converge to a U.S.-style, market-led system of voluntary standards. Countries like Korea and China will need to find their own institutional and legal approaches to develop a standards system that can both foster innovation and cope with the challenges of globalization and rising technological complexity.

Latecomers, in turn, would benefit from studying inherent advantages of the deeply-rooted U.S. tradition of decentralized, market-led approaches to standardization. This may lead to new ways of blending elements of a U.S.-style voluntary system through independent standards development organizations and consortia with a government-led coordination of standards, innovation, and competition policies.

For instance, a hybrid of the best elements of the U.S. and Chinese standards systems could help latecomers to foster indigenous innovation while maintaining open markets. The Chinese model of an integrated government-coordinated innovation and standardization strategy can help to generate the massive investments needed to upgrade a country's innovation system and its standardization capabilities. At the same time, elements of a US-style decentralized market-led standardization system can help to increase the flexibility of policy tools and institutions in order to cope with sometimes disruptive effects of unexpected changes in technology, markets, and business strategies.

In a world of rising complexity and uncertainty, it is always preferable to have built-in redundancy and freedom to choose among alternatives rather than seeking to impose from the top the "one best way" of doing things. First, rising complexity drastically reduces the time available for standards development and implementation, which makes it practically impossible to get solutions right the first time. There may have to be many policy iterations, based on trial and error, and an extended dialog with all stakeholders to find out what works and what does not.

Second, rising complexity makes it difficult to predict possible outcomes of any particular policy measure, especially unexpected negative side effects, of which there is an almost endless variety. In fact, a small change in one policy variable that describes a particular procedure for achieving compliance with a particular standard can have far-reaching and often quite unexpected disruptive effects on many other policy variables and outcomes.

And, third, it is next to impossible to predict the full consequence of interactions among an increasingly diverse population of both domestic and international standardization stakeholders. Given the diversity of competing stakeholders in standardization, the results of a particular national standards policy depend much more on negotiations, gaming, and compromises than on the logical clarity and technical elegance of that policy.

In short, countries like Korea and China today provide an experimentation field for new approaches to standardization that seek to combine the advantages of a bottom-up, market-led approach with a unified strategy designed and implemented in close cooperation between industry and government. Policy makers and corporate executives in the United States, as well as in the European Union and Japan, would be well advised to study these new hybrid institutional approaches to standardization for latecomer economic development, and to learn from them.

5. Intellectual property rights, standardization, and patents in economic development of latecomer countries

To understand the emerging challenges for latecomer economies, lessons can be drawn from recent works on the role of intellectual property rights (IPR) for economic development (An, 2009; Goldstein & Straus, 2009). Learning advanced technologies is critical for successful catching-up. The protection of intellectual property rights is a necessary, but by no means sufficient, condition. Detailed case studies of earlier historical experience in the United States, the Scandinavian countries, Japan, Korea, and Taiwan demonstrate that IPR protection can only contribute to economic development if it takes place as part of a multi-faceted innovation strategy that seeks to strengthen absorptive and innovative capabilities of firms, and to develop a broad-based innovation infrastructure (including standards) (Odagiri, Goto, Sunami, & Nelson, 2010).

[11] Brian Arthur (1989) provides the classic analysis of "technology lock-in." He shows that the economy, over time, can become locked in by "random" historical events to a technological path that is not necessarily efficient, not possible to predict from usual knowledge of supply and demand functions, and not easy to change by usual tax or subsidy policies.

The relationship between intellectual property protection and innovation is complex – "although stronger IPR protection directly increases the incentive to innovate, it also discourages innovation in the long run by suppressing the process of 'learning by doing.' … This implies that both very strong and very weak IPR policies decrease innovation, so a moderate approach is preferable" (Furukawa, 2010).

Of particular interest for the study of standardization is that IPR regimes significantly vary across industries and across countries of different economic size or different technological capacity. Case studies "document again and again the very great differences across industries in the extent to which IPR regimes, indigenous or foreign, affect the catch-up process…. [Hence], it makes no sense to talk about the influence of IP on development in general. One has to specify the sector one is concerned with" (Odagiri et al., 2010: p. 423).

Latecomer countries face a fundamental dilemma' a weak IPR regime may stimulate imitation (without patent holder consent), while discouraging the development of advanced technology through licensing or inward FDI, or through domestic innovation efforts. In a developing country, "utilization of knowledge invented abroad should be given priority over incentive for invention and, hence, a weaker patent regime that targets diffusion … [rather]…than creation should be adopted" (Odagiri et al., 2010: p. 11).

Hence, a country's IPR regime needs to evolve with the development of its domestic innovative capacity. "… [T]he relative merits of different IPR regimes change over the stages of economic development…. [Typically], countries try to alter their IPR regime in response to changing needs. In consequence, a country's IPR regime likely coevolves with its economy" (Odagiri et al., 2010: p. 12). As long as a country's innovative capacity is weak, it benefits from a relatively loose IPR regime. Once the country's innovative capacity begins to improve, its IPR regime needs to be gradually strengthened.

In addition, there is an important international dimension. In-depth research on Asia's export-oriented economies finds that, while their own IPR regimes matter, of at least equal importance for their economic growth have been the IPR regimes of their main export markets in the United States, the European Union and Japan. That research also shows that a sophisticated domestic IPR regime is important, as it forces Asian firms to learn about IPR legal issues and to accumulate capabilities for IPR management.

At the same time, the relationship between standards, patents and innovation is much more complex than acknowledged thus far in innovation theory. Policy-oriented research needs to highlight a fundamental tension that sets standards apart from innovation.

By freezing a given technology, standards are supposed to provide stability for industry and customers, as well as for international trade and investment. Yet, at the same time, innovations continuously upset this stability by introducing new products based on new standards, as Schumpeter argues with his thesis of creative destruction (1950: p. 83, 84). On the positive side, there is no doubt that standards can be a critical enabler of innovation. There is no automatic link, of course, but standards can foster economic growth by reducing transaction costs and achieving economies of scale through interchangeability (Kindleberger, 1983). Economic standardization theory has shown that "… [s]tandards affect the R&D, production, and market penetration stages of economic activity and therefore have a significant collective effect on innovation, productivity, and market structure" (Tassey, 2000: p. 587).

That does not imply that standardization per se is good under all conditions. For instance, standards that fail to address critical societal concerns with regard to climate change, health, or product safety may actually give rise to wasteful and even destructive innovation. Standards may also effectively limit innovation and economic growth when they are used as a weapon to block competition (e.g., Lemley, 2002) such as technical barriers to trade (TBT).

Patents provide the missing link to such anti-competitive conduct. Their role for standards has increased with rising technological complexity. Increasingly, standards include technologies that are protected by IPR. In theory, a neat distinction is possible between standards that are a "public good" (free, collective good) and patents that are a "private good" (for private, exclusive use by patent owners).[12] But in reality, tensions are rising between patents and standards: "… (w)hile technical standardization is meant to transform ideas into a public good, patent protection transforms them into a private good" (European Patent Office, 2007: p. 93).

As globalization has increased technology-based competition, the key to competitive success is a broad portfolio of "essential patents," which are necessary to produce any product that meets the specifications defined in the standard.[13] In fact, each of the major interoperability standards in the IT industry is protected by multiple patent families, giving rise to patent thickets. With increasing complexity of technologies, these patent thickets become denser. For instance, for the GSM standard (for second-generation mobile telecommunications systems), 140 essential patents were claimed by their respective patent holders (Bekkers, Duysters, & Verspagen, 2002).

For the third-generation mobile standards, the number of essential patents has substantially increased. For example, W-CDMA (one of the three competing 3G standards) is protected by more than 2000 patent families comprising more than 6000 individual patents from some 50 companies and consortia (Davey, 2006). At the same time, the number of standards required for a single mobile device has grown exponentially. Today's typical smart phone combines hundreds of standards coming from dozens of standard-setting organizations, for camera, video, web browser, PDA, WiFi, Bluetooth, Linux, USB,

[12] Economists typically define "public goods" by two qualities: "non-rivalry in consumption (i.e. they are not depleted by an additional user) and non-excludability (i.e. it is generally difficult or impossible to exclude people from its benefits, even if they are unwilling to pay for them)" (Baumol and Blinder, 1991: 617).

[13] Patents are "essential" to a standard when it is not possible to comply with the standard without infringing that intellectual property right.

and so on. As a result, smart phones have become the latest patent battleground. In 2010, nearly 8000 patents held by 41 companies apply only to the 3G wireless communications capabilities of a typical smart phone.[14]

The use of "essential patents" as a strategic weapon to prohibit, delay or obstruct standardization processes is well documented in the literature.[15] This is the case when incumbent market leaders pursue so-called 'platform leadership' strategies through allegedly open but de facto proprietary standards.[16] While nominally 'open', these standards are designed to block competitors and to deter new entrants.

Two highly influential studies on the licensing and disclosure of private standard-setting organizations document the difficulties of finding fair and reasonable non-discriminatory (FRAND) compromises in private standard-setting organizations to reduce the negative impact of strategic patenting (Lemley, 2007, 2002).[17]

This poses especially difficult challenges for some industries, like the information and communications technology sector, where interoperability standards are required to make products or services compatible with each other in order to maximize the benefits of network externalities. The emergence of a "winner-takes-all" competition model, described by Intel's Andy Grove, implies that companies need to combine economies of scale and scope with flexibility and speed-to-market (Grove, 1996). Only those companies thrive that succeed in bringing new products to the relevant markets ahead of their competitors. Of critical importance is that a firm can build specialized capabilities quicker and at less cost than its competitors (Kogut & Zander, 1993). Hence, competitive success critically depends on "a capacity to control open-but owned architectural and interface standards" (Ernst, 2002a). It is hardly surprising that, under such conditions, as John Alic puts it, "firms may be tempted to seek profits through collusion rather than technological innovation. And when innovations do result, the costs may be high"(Alic, 2009: p. 3).

According to a recent study by the Federal Reserve Bank of Philadelphia, finding fair and non-discriminatory compromises is made even more difficult by "the potential for opportunistic behavior by participants who own patents on a technology essential to the standard. There is a risk that without sufficient transparency and sufficiently strong mutual interests, network participants could make large investments to implement a standard only to be held up by a firm threatening to withhold a key piece of technology" (Hunt, Simojoki, & Takalo, 2007). The study argues that "… in all likelihood some kind of agreement would be reached, but on terms substantially worse than the participants initially expected. Indeed, the risk of such an outcome may discourage firms from adopting a standard or even participating in the standard-setting process. In other instances, awareness of a key blocking patent might lead to the adoption of a standard that poses less risk to participants but which is also technologically inferior" (Hunt et al., 2007: p. 3).

In short, the use of "strategic patenting" to generate rents from *de facto* industry standards has transformed the dynamics of the international standards system, with potentially very negative implications for latecomer economic development. Within the WTO framework of TRIPS (trade-related aspects of intellectual property rights) and TBT (technical barriers to trade) agreements, only very few remedies are available to address the fundamental tension between patents and technical standards.

This enables patent holders to engage in anti-competitive conduct within national and international standard-development organizations and from outside. The weapons at their disposal include patent hold ups, patent ambush, royalty staking, strategic injunctive reliefs, unilateral refusal to license, and violation of FRAND (Fair, Reasonable and Non-discriminatory) contracts. In short, patent holders can increase their market power "when they demand 'unreasonable' royalties for their patents that are embedded in standards. *Thus, standards generate a market power far beyond the power of exclusion and the freedom of contract granted by patent law* [italics added by the authors]" (Pai, 2013: p. 5).

By stifling innovation and knowledge diffusion, this type of "strategic patenting" is likely to have a quite negative impact on latecomer economic development.

6. Conclusions and policy implications

This paper has explored how standards and innovation interact in countries that are latecomers to industrial manufacturing and innovation. These countries seek to catch up with the productivity and income levels of the US, the EU and Japan, but they have only recently begun to build up their innovation and standards systems and strategies.

A central message in this paper is that latecomer economies like Korea and China face opportunities and challenges in their standards and innovation policies that differ quite considerably from those facing in today's advanced economies. Latecomers typically are standards takers, and have a long way to go in their efforts to shape or at least co-shape

[14] It is from a confidential interview with a smart phone company.

[15] See the seminal article by Lemley and Shapiro (2007). For an analysis of implications for standard development organizations and policy makers, see Weiss and Spring (2000).

[16] The overriding purpose of "platform leadership" strategies is to leverage the existing market power of industry leaders into the control of "systemic architectural innovations" (see Gawer & Cusumano, 2002). For example, Intel has attempted to extend its control over microprocessors by creating widely accepted architectural designs that increase the processing requirements of electronic systems and, hence, the market for Intel's microprocessors (Gawer & Henderson, 2007).

[17] See also the recent systematic study by Jorge Contreras who lays out an alternative approach focused on a reform of standard-setting organizations (Contreras, 2012).

international standards. Latecomers also typically are more vulnerable to the impact of "strategic patenting" strategies that large patent holders use to generate rents from controlling *de facto* industry standards.

Furthermore, latecomers lag behind advanced economies in the sophistication of their standardization capabilities and strategies, and hence are likely to face higher costs of developing and disseminating effective standards. At the same time, ubiquitous globalization and rapid and disruptive technical change (such as the rising complexity of digital networks) create new challenges for standardization. No Korean or Chinese company can succeed in international trade without mastering interoperability standards that are necessary to transfer and render useful data and other information across geographically dispersed systems, organizations, applications, or components. This process has increased the economic importance of standardization, but especially so for latecomer countries which, like China and Korea, are deeply integrated into international trade and global corporate networks of production and innovation.

At the same time, different institutions and weaker standardization capabilities in latecomer countries imply that standards and innovation policies that worked well for advanced economies may not necessarily be the optimal choice for fostering latecomer economic and technological development. A static assessment of the compliance of latecomer standards institutions and strategies with existing approaches to IPR management in standards provides insufficient guidance for policy makers. As technology becomes more complex and inter-related, the gap in innovation capability between latecomer countries and advanced countries has widened. Advanced countries and their firms have led in patenting, which makes it more difficult for latecomers to reduce technical dependence on advanced countries and ultimately to catch up. Hence, standardization has been regarded as an alternative to patenting but latecomers are still new to standardization. This paper has shown that standardization in latecomer countries is fundamentally based on motivation strengthening absorptive capacity through learning. We also suggested ways to measure success or failure of latecomer standardization approaches.

This has important policy implications. Latecomers would benefit from studying inherent advantages of the deeply-rooted U.S. tradition of decentralized, market-led approaches to standardization (Ernst, 2013). The challenge is to develop new ways of blending elements of a U.S.-style voluntary system through independent standards development organizations and consortia with a government-led coordination of standards, innovation, and competition policies.

For instance, a hybrid of the best elements of the U.S. and Chinese standards systems could help latecomers to foster indigenous innovation while maintaining open markets. The Chinese model of an integrated government-coordinated innovation and standardization strategy can help to generate the massive investments needed to upgrade a country's innovation system and its standardization capabilities. At the same time, elements of a US-style decentralized market-led standardization system can help to increase the flexibility of policy tools and institutions in order to cope with sometimes disruptive effects of unexpected changes in technology, markets, and business strategies.

In a world of rising complexity and uncertainty, it is always preferable to have built-in redundancy and freedom to choose among alternatives rather than seeking to impose from the top the "one best way" of doing things (Jordan & Koinis, 2014). First, rising complexity drastically reduces the time available for standards development and implementation, which makes it practically impossible to get solutions right the first time. There may have to be many policy iterations, based on trial and error, and an extended dialogue with all stakeholders to find out what works and what doesn't.

Second, rising complexity makes it difficult to predict possible outcomes of any particular policy measure, especially unexpected negative side effects, of which there is an almost endless variety. In fact, a small change in one policy variable that describes a particular procedure for achieving compliance with a particular standard can have far-reaching and often quite unexpected disruptive effects on many other policy variables and outcomes.

And, third, it is next to impossible to predict the full consequence of interactions among an increasingly diverse population of both domestic and international standardization stakeholders. Given the diversity of competing stakeholders in standardization, the results of a particular national standards policy depends much more on negotiations, gaming, and compromises than on the logical clarity and technical elegance of that policy.

To conclude, countries like Korea and China today provide an experimentation field for new approaches to standardization that seek to combine the advantages of a bottom-up, market-led approach with a unified strategy designed and implemented in close cooperation between industry and government. These new approaches to standardization may also influence debates about international trade agreements. This is true especially for Asia where US-led efforts to create a Trans-Pacific Partnership trade agreement compete with a China-backed Regional Comprehensive Economic Partnership (RCEP) and CJK, i.e. negotiations between China, Japan and Korea to strengthen trade integration between these three Northeast Asian countries.

In short, policy-makers and corporate executives in the United States, as well as in the European Union and Japan, would be well advised to study these new hybrid institutional approaches to standardization for latecomer economic development, and to learn from them.

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